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# Analysis of the relationship of the input parameters in an independent way and their effect on the efficiency of the treatment of wastewater with activated sludge technology

# Análisis de la relación de los parámetros de entrada de forma independiente y su efecto en la eficiencia del tratamiento de aguas residuales con tecnología de lodos activados

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**Abstract**

The research analyzes the possible effects of three design parameters: flow, biochemical oxygen demand and suspended solids in mixed liquor in the operation of a domestic wastewater treatment plant with activated sludge technology from a conventional process. Applying the elementary calculations equations for this type of treatment, each of the three design parameters was varied, keeping the others constant, it was observed and analyzed how the dependent variables respond: hydraulic retention time, mass load, volumetric load, needs oxygen, sludge recirculation, excess sludge and treatment efficiency. Observing the results of each of these behaviors, it is verified that the most important factors to achieve high efficiency are the reactor volume, the regulation of Suspended Solids in Mixed Liquor (SSLM) through the operation of the recirculation flow and the regulation of the oxygen entering the reactor. This work is an alternative analysis to understand the operation of the reactor in a treatment with activated sludge.

**Treatment water, Sludge activated, Suspend Solids in the Mixture Liqueur, Reactor volume**

**Resumen**

La investigación analiza los posibles efectos de tres parámetros de diseño: caudal, demanda bioquímica de oxígeno y sólidos suspendidos en licor mezcla en el funcionamiento de una planta de tratamiento de aguas residuales domesticas con tecnología de lodos activados de proceso convencional. Aplicando las ecuaciones elementales de cálculo para este tipo de tratamiento, se hizo variar cada uno de los tres parámetros de diseño manteniendo constante las otras, se observó y analizo como responden las variables dependientes: tiempo de retención hidráulico, carga másica, carga volumétrica, necesidades de oxígeno, recirculación de lodos, exceso de lodos y eficiencia del tratamiento. Observando los resultados de cada uno de estos comportamientos se comprueba que los factores más importantes para lograr una alta eficiencia son el volumen del reactor, la regulación de los Sólidos Suspendidos en Licor Mezcla (SSLM) mediante la operación del caudal de recirculación y la regulación del oxígeno que ingresa al reactor. Este trabajo es una alternativa de análisis para comprender el funcionamiento del reactor en un tratamiento con lodos activados.

**Aguas residuales, Lodos activados, Solidos suspendidos en licor mezcla, Volumen de reactor**

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## Introduction

The population of the city of Tarija with respect to the last census of 2012 has grown at a rate of 3%, it currently has 222,116 inhabitants, the coverage of the sanitary sewer service is 81%. The wastewater flow is approximately 416 L/s, only 200 L/s are those that are treated by a lagoon system. To cover part of the water treatment deficit, a new plant with conventional activated sludge technology is being put into operation, it will have a capacity to treat an average flow of 210 L/s (756 $m^3$ / hr) projected for a future population of 98,000 inhabitants with a design period of 30 years [1].

**Figure 1** Photograph of the San Blas treatment plant

The treatment of wastewater with activated sludge is an alternative for the purification of wastewater [2]. The water that comes out of the primary treatment (sedimentation) enters a biological reactor with aeration, followed by a clarifier where the sludge settles, from which the water comes out with a very acceptable quality of treatment, with the possibility of being reused for example in irrigation systems [3-7]. It consists of putting the residual water in contact with a culture of microorganisms (biological treatment) under aerobic conditions inside a reactor [4] as shown in Figure 2.

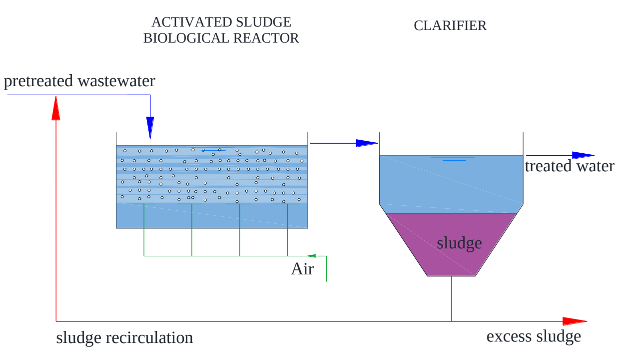


**Figure 2** Reactor and clarifier scheme
*Source: Own elaboration*

The treatment of wastewater with activated sludge is a continuous flow process with suspended biomass, and the adequate concentration within the reactor must be kept constant, through recirculation of sludge, purging and control of the retention time. The activated sludge is produced by the sedimentation of flocs where bacteria, fungi and protozoa abound [2,8]. This sludge contains microorganisms in charge of oxidizing the organic matter and thus purifying the residual water. There are variants such as: High load, medium load, prolonged aeration, nutrient reduction and others [2].

This work was carried out for the (referential) design parameters of the domestic wastewater treatment plant in the department of Tarija in Bolivia. It is a new plant with conventional activated sludge technology that has: Grates, grit remover, degreaser, consists of four lines with primary settler, biological reactor, clarifier, disinfection, sludge recirculation and sludge treatment process. The proposal is that the treated water can be used in agricultural irrigation complying with adequate quality standards. Bolivia does not have an approved regulation for reuse, but it does have guide values such as those described in the following table:

| Parameter | Unit | Limit values for use in irrigation |
|---|---|---|
| DQO | mg/L | < 100 |
| DBO5 | mg/L | <30 |
| SST | mg/L | < 50 |
| pH | - | 6.5 - 8.4 |
| CE | mS/cm | 0.7 - 3.0 |
| Temp. | °C | - |
| N-NH3 | mg/L | < 30 - NT |
| P | mg/L | - |

**Table 1** Guide Values used in Bolivia
*Source: Technical Magazine: Bolivia water and environment - Number 4 - August 2019*

The contribution of this research is to try to explain how the following variables affect efficiency; the flow rate, volume of the reactors, Biochemical Oxygen Demand, Suspended Solids in Mixture Liquor and dissolved oxygen. Considering as a hypothesis that it is possible to determine the efficiency in a Wastewater Treatment Plant from the reactor volume, BOD, SSLM, dissolved oxygen and recirculation flow.

The objective was to analyze the relationship of the input parameters independently and their effect on the efficiency of wastewater treatment with activated sludge technology in one of the 4 lines that make up this treatment plant.

**Methodology**

The variation of the parameters was analyzed: inlet flow, inlet BOD, SSML and oxygen needs. Applying the activated sludge equations (kinetic model for the design of this treatment system), the behavior of the variables was calculated: reactor volume, hydraulic retention time, recirculation flow, oxygen needs, excess sludge and treatment efficiency.

Graphs were made where the behaviors of the most important variables were described and they were analyzed, issuing criteria of effects of input parameters on the operation and treatment efficiency based on Guide values used in Bolivia, and conclusions were also issued.

The input variables considered were:

a) Design flow (Q), is the amount of water to be treated ($m^3/h$).

b) Biochemical oxygen demand ($BOD_5$), indicates the amount of dissolved oxygen (mg/L) that is required for the biological degradation of organic substances contained in wastewater [1,2]. This variable is simulated at the reactor inlet. According to historical records in the sanitary sewer system of the city of Tarija for wastewater for domestic use, the values can vary from 150 to 350 mg/L (raw water without treatment).

c) Suspended solids in mixed liquor (SSLM), it is the key factor in the treatment with activated sludge, it is the concentration of suspended solids in the aeration tank, it is mainly composed of microorganisms and non-biodegradable suspended matter [7-8]. The typical variation range is 2000 to 4000 mg/L. [2.8].

d) Suspended volatile solids in mixed liquor (SSVLM), (mg/L) in a sample of mixed liquor will consist mainly of microorganisms and organic matter [4-5]

e) Sludge age (days), is the average residence time of the microorganisms in the reactor [1-8], for a conventional system and without nutrient removal it is between 3 to 15 days.

f) Biocinetic coefficients, characterize the life of the essential microbial mass for the treatment by activated sludge, there are average values that can be used, (Growth coefficient: Y = 0.65 mg SSV / mg BOD; Mortality coefficient: Kd = 0.06 1 / day) but, it is best to define them in the laboratory [6] for each specific project in order to optimize energy costs due to the use of electromechanical equipment. Regarding the electrical energy consumption associated with the artificial aeration of aerobic reactors, this represents the main cost in wastewater treatment. It is estimated that it can reach up to 75% of the operating costs of waste water treatment plant [9].

From the input data, the output variables are simulated:

a) Volume of the reactor ($m^3$); it is where biological purification processes take place.

b) Hydraulic retention time, the water in the reactor with aeration must remain for a certain time to achieve a high degree of purification [5-8], this value is between 4 and 8 hours according to design recommendations [8-2].

c) Mass load, is the mass flow of substrate, either BOD or COD that is applied to the reactor, this value can be between 0.2 and 0.5 kg BOD 5 / kg MLSS • day.

d) Volumetric load, called organic load, is the mass flow of BOD or QOD per unit of effective volume of the reactor, this value is between 0.5 and 1.5 kg $BOD_5$ / $m^3$ • day;

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e) Oxygen needs (kg $O_2$ / day or in mg / L), oxygen is needed in the reactor for the proliferation of microorganisms, it is supplied by fine bubble diffusers [7], this value must be between 1 and 3 mg/L, higher values do not provide benefit, rather there is an unnecessary consumption of electrical energy especially when the flow decreases and the hydraulic retention time increases.

f) Recirculation Flow (L/s), to maintain a relatively constant quantity of microorganisms (MLSS) in the reactor, it is necessary to recirculate a certain quantity of sludge from the clarifier to the reactor [5-7].

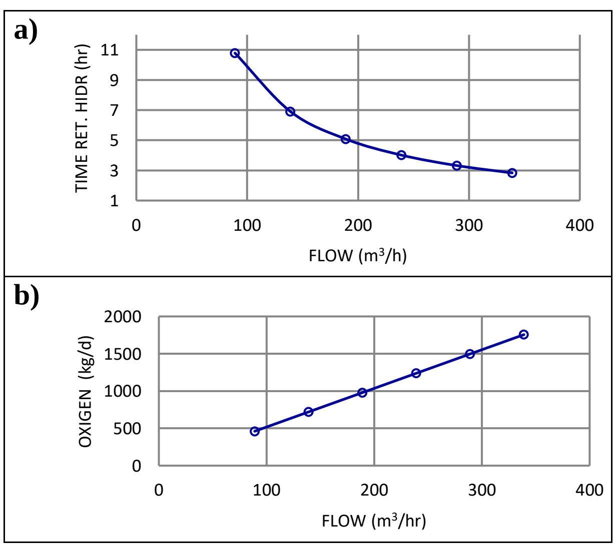
g) Excess sludge. The sludge that is not required to be recirculated is purged to the sludge treatment process in an average amount of 1.68 kg SST / day.

h) Efficiency, measures in percentage the degree of purification of the water that leaves the clarifier with respect to the entrance.

**Results**

The effects of the input variables foresee analyzing the situation when the reactor is already built, that is, at constant volume. There are other parameters that must be regulated to achieve adequate yields.

**Flow effects**



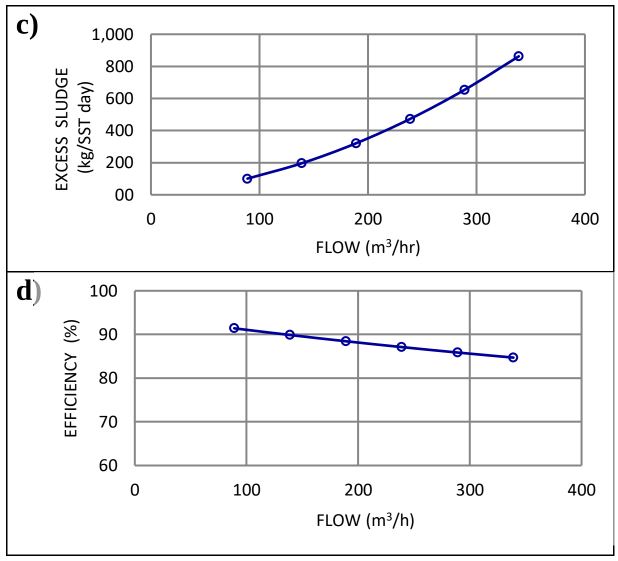




**Figure 3** Flow effects: a) Hydraulic retention time; b) Oxygen requirements; c) Excess of sludge; d) Efficiency
*Source: Own elaboration*

The higher the flow rate (Figure 3a), the retention time decreases in a very sensitive way and affects all other processes, because the water with the organic matter will remain in the reactor for less time and the microorganisms will have less retention time to degrade the organic material. Not all organic matter will be removed, and the effluent will have high $BOD_5$ values. If the flow rate increases, more oxygen will be needed (Figure 3b), to compensate for the increased volumetric load. The recirculation flow rate increases because more microorganisms are needed, this to maintain a suitable microorganism concentration in the reactor. The amount of excess sludge increases (Figure 3c), this because the volumetric load has also increased. Efficiency decreases (Figure 3d), because if the flow increases for the same volume it causes the hydraulic retention time to decrease, therefore the efficiency decreases. If the volume cannot be expanded, one solution is to increase the recirculation flow and more oxygen injection.

That is why it is important to control the flow that enters the reactor, for this automatic flow meters are used, as necessary, the water is stored in the inlet collector to the plant for times less than the day and the water input is regulated in one or more of the treatment lines.

### Effects of BOD

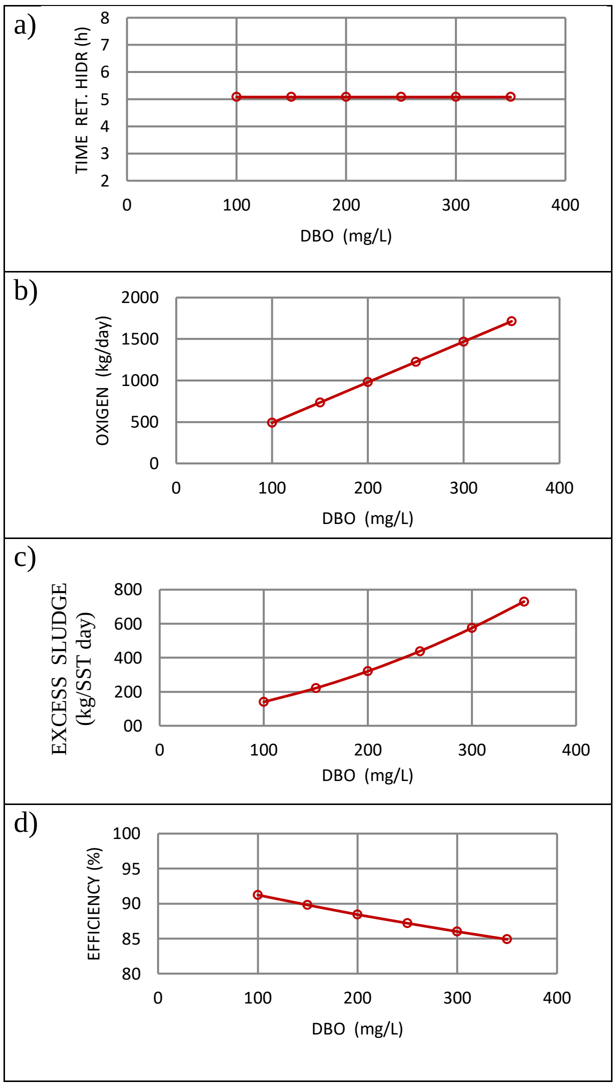



**Figure 4** Effects of BOD: a) Hydraulic retention time; b) Oxygen requirements; c) Excess of sludge; d) Efficiency
*Source: Own elaboration*

The increase in BOD does not affect the hydraulic retention time (Figure 4a) because it only depends on the flow and volume. Given the increase in BOD, and keeping the volume and flow constant, there is a considerable increase in the mass load and the volumetric load. The increase in BOD means more food for the microorganisms, causing an increase in the need for oxygen in a sensible way (Figure 4c), having constant volume and retention time, more work is needed, more energy consumption. It increases the excess sludge (Figure 4c), because a greater amount of organic matter has entered and because the recirculation flow has not changed. There is a drop in efficiency (Figure 4d) due to the increase in the pollutant load and because the retention time cannot be increased. This situation could be improved with an increase in recirculation and an increase in oxygen in the reactor.

### Effects of SSLM

The hydraulic retention time only depends on the flow and volume, being these constants, there will be no change in this parameter (Figure 5a). If the reactor volume is constant then the increase in the SSLM does not affect the volumetric load. At a constant volume with an increase in SSLM, an increase in oxygen is not required (Figure 5b) because the mass load is lower, therefore the microorganisms make less effort to degrade organic matter because there is little food. This is an indication that the recirculation flow rate can be lowered. The increase in SSLM produces more excess sludge (Figure 3c) in less time because there are more microorganisms that accelerate the process. The increase in SSML means an increase in the microorganisms in charge of purifying the water, if the volume and flow are constant, there will be a smooth increase in efficiency (Figure 5d).

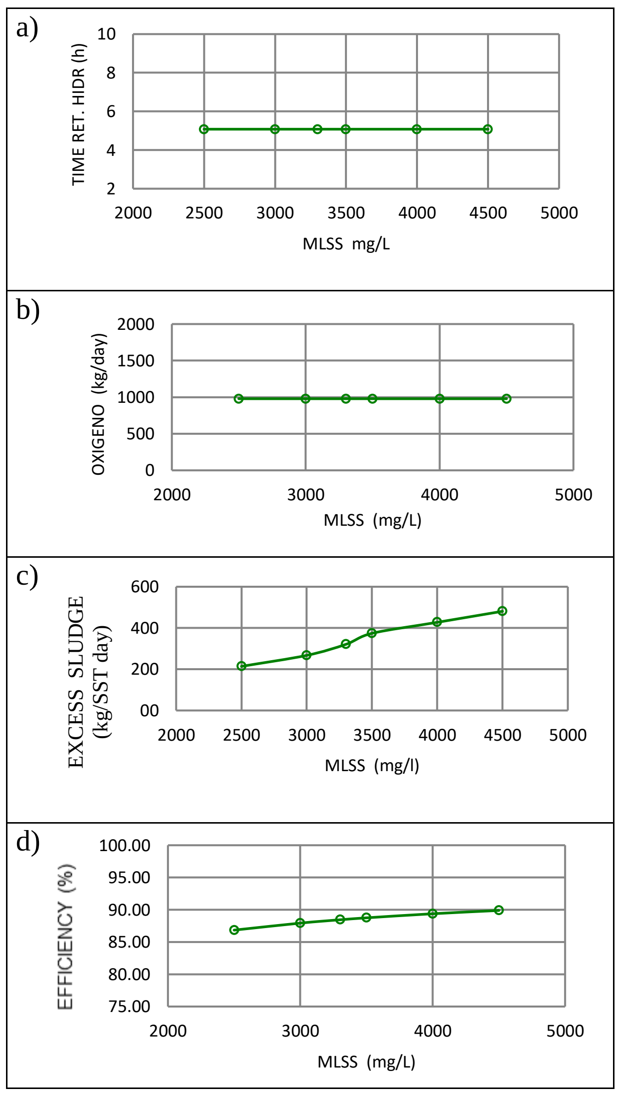



**Figure 5** Effects of SSLM: a) Hydraulic retention time; b) Oxygen requirements; c) Excess of sludge; d). Efficiency
*Source: Own elaboration*

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## Conclusions

In the analysis of the graphs, it was possible to predict the moments in which the system can present low and high efficiencies.

When the reactor volume is immovable, (in operation) the most important variables according to the analysis of the graphs and bibliographic review are the SSLM that can be regulated with the recirculation flow and the injection of oxygen into the reactor. Efficiency drops with increasing flow rate and increasing BOD; Given the increase in flow and BOD5, the SSML and oxygen are increased in order to maintain efficiencies greater than 90%. For this reason, there must be a balance between the organic load (Q, BOD) with the microorganisms (SSVLM) and oxygen injection.

The BOD arriving at the plant is not controllable; the flow rate can be controlled to some extent by storage in the inlet manifolds and a battery of reactors which come into operation as the flow rate increases; SSLMs are controllable by recirculation flow. To regulate the inflow, it is recommended to implement storage and regulation basins.

The monitoring or measurement of the flow, BOD5 and SSLM at constant volume, in an activated sludge plant in operation is very important because it could be verified that it produces variations in the efficiency of the system and it must be prepared to take the most appropriate actions such as regulation of the inlet flow, regulation of the recirculation flow and regulation of oxygen entering the reactor.

The oxygen that is injected into the reactor through the diffusers must be regulated according to the oxygen needs calculated based on the organic load that enters the reactor. If there is oxygen deficiency, the efficiency will decline and if there is excess oxygen, it does not improve the efficiency, it is maintained and can even decrease since it can impair the good formation of flocs, in addition there is unnecessary electrical energy expenditure. From the analysis of the set of graphs, it can be seen that activated sludge technology has the advantage that it can withstand variations in pollutant load by monitoring the parameters of dissolved oxygen, SSLM, BOD5 and others in order to take the regulatory measures described. in the previous paragraphs.

As future work, it is recommended to carry out simulations in software such as LINX ASM1, AQUASIM and others [3,5,10] making combinations of variation of the input parameters, for example if the flow rate increases and the BOD decreases or vice versa; Simulations of the effect of the presence of nutrients such as nitrogen phosphorus can be carried out, which in adequate quantities are necessary for the proper functioning of the system.

## References

[1] Echeverría Ivette, Saavedra Oliver, Escalera Ramiro, Heredia Gustavo, Montoya Renato. (2019) Potential for reuse of wastewater treated by anaerobic systems combined with biofilters. Bolivian Private University.

[2] La Iglesia Gandarillas, J. (2016). Active sludge fundamentals and types of reactors. Wastewater Management and Reuse Module. Master in Water Engineering and Management. EOI.

[3] Loaiza Navía, J. L. (2007). Modeling of the Activated Sludge Process in the Northeast Wastewater Treatment Plant of the Monterrey Metropolitan Area, NL.

[4] Espinosa Rodríguez, M. Á. (2010). Modeling and simulation of the activated sludge process of the wastewater treatment plant “Dulces Nombres de Monterrey.

[5] Orta Zambrano, I. T. (2013). Calibration of mathematical model for the design of activated sludge treatment systems in the city of Guayaquil (Bachelor's thesis).

[6] Rogel Dorantes, J. A. (2013). Determination of the kinetic parameters of a Sludge-Model to study the minimization of solids in a biological wastewater treatment process. Master's Thesis. Autonomous Mexico State University.

[7] Altamiranno Abraham, J. R. (2020). Determination of the kinetic parameters of a Sludge-Model to study the minimization of solids in a biological wastewater treatment process. Master's Thesis. Autonomous Mexico State University(Doctoral dissertation, Universidad Autónoma de Nuevo León).

ISSN: 2410-3993

[8] Metcalf & Eddy. 2000 Wastewater engineering, treatment, discharge and reuse. Lathe 1. Mc Graw Hill. Third edition. Mexico.

[9] Altamirano, José R. (2020) Development of a Mathematical Model for the Proposal and Evaluation of Scenarios for Reducing Electricity Consumption in an Activated Sludge Treatment System. Master of Science with Orientation in Environmental Engineering. Autonomous University of Nuevo León - Mexico.

[10] Vilanova Ramon, Sant´ın Ignacio, Pedret Carles. (2017) Control and Operation of Wastewater Treatment Plants: Modeling and Simulation. Ibero-American Journal of Automation and Industrial Informatics 14 (2017) 217–233.

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