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Tesis

Design of a Rushton Turbine for the Improvement of the Bioreactor in the Wastewater Treatment Plant in the City of Morococha (Carhuacoto)-Peru

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Para optar el Título Profesional de
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Design of a Rushton Turbine for the Improvement of the Bioreactor in the Wastewater Treatment Plant in the City of Morococha (Carhuacoto)-Peru.

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Abstract. The study is carried out in a domestic wastewater treatment plant (DWWTP) in the city of Morococha in Peru, with a population of 9 thousand inhabitants, at an altitude of 4200 m.a.s.l., has a processing capacity of 1620 m3 /day with a flow that is not constant, focuses on secondary treatment consisting of a sequential biological reactor (SBR) of aerobic technology. The problem is the excess flow in certain periods of time and the incoming wastewater was not processed in an optimal way, as an objective a redesign of the bioreactor was proposed, incorporating a Rushton Turbine of 6 horsepower (H.P.) of power with 6 propellers and dimensioned according to mathematical models, the results were the improvement of effluent quality for turbidity, dissolved oxygen, pH and residual chlorine, improving the reaction speed, and controlling the treatment flow, providing a better quality effluent to the receiving body which is a nearby river in this way the negative environmental impacts are reduced for the population.

Keywords: PTARD, Bioreactor, Aerobic, settler, SBR, biological, turbine.

1. Introduction

Currently, one of the greatest global challenges is to ensure water quality. [1]According to the World Health Organization (WHO), water quality is directly related to poverty, as municipal industrial wastes, as well as human products, are released daily into aquatic ecosystems. [2] since municipal industrial wastes, as well as human products, are released daily into aquatic ecosystems due to severe effects on microorganisms in low concentrations through wastewater. [1]-[2]. The activities carried out by the population generate an increase of heavy salts[3], organic matter and various toxic elements that affect and cause the degradation of water resources worldwide. [4]. One of the challenges in the wastewater treatment plants are the biosolids waste, trying to find an alternative solution worldwide, focusing on the transformation processes, an adequate treatment and finally its final disposal, to obtain or convert it into important and mainly useful material to improve its productive chain. [5]. 54% of Mexico's wastewater is not treated correctly. [4]25% of the population of Costa Rica only covers the sewage system. [5]. Therefore, it is very convenient to study different wastewater treatment technologies for the development of the countries. [6]On the other hand, Colombia is facing the problem of water resources in order to be able to save water to avoid overexploitation of groundwater, which is mostly generated by groundwater pollution. [7] The main part is generated by pollution in the rivers, which is 90% of its population generating the discharge of wastewater without any treatment. [8].

In Peru, the major problem is that 7 to 8 million Peruvians do not have access to drinking water supply or access to safe drinking water. [9]and the absence of sewage systems. Likewise, 24% of wastewater is treated and an unknown percentage of industrial wastewater is not treated. [10]. According to the World Health Organization (WHO), water pollution represents a threat to public health. This is evidenced by the volume of 40 m^3 /sec of water that is not adequately processed and therefore is discharged directly into rivers and about 40,000 hectares are affected in agriculture. [11].

The problems of this broad issue of wastewater management mainly in urban areas and in developing countries, are deficient and scarce in the treatment before its final disposal in water bodies, such as rivers as well as not treated enough for its reuse in industry and some services. In Mexico, city authorities often do not have the budget to do so, and they do not know of many alternatives to solve the problem, so the situation worsens every day as wastewater flows increase, posing a challenge to the authorities in charge of wastewater disposal. [12].

Considering the problem of excess water in the bioreactor at the wastewater treatment plant in the Morococha Carhuacoto sector, the bioreactor is the focus. For this reason, an adequate design is proposed for the effluent liquids, taking as a fundamental basis the installation of the wastewater treatment plant that is in the place.

The wastewater treatment plant uses sequential biological reactor (SBR) technology, which are discontinuous reactors in which the wastewater is mixed with a biological sludge with air injection (process called wet combustion), its process capacity is 5 m^3 /h, 110 m^3 /day and the average monthly capacity is 115 m^3.

With such information from the plant an effluent surplus was highlighted giving as main point the proposal to improve the capacity of the (DWWTP), since it presents a Rushton turbine in the SBR bioreactor. [13] these effluents are discharged directly into the river. For this reason, agitators will be implemented to optimize a constant flow inside the bioreactor, improving the water quality of the effluent for turbidity, dissolved oxygen, pH and residual chlorine, improving the reaction rate, and controlling the treatment flow and water hygiene for the population as well as contributing to safeguarding the biodiversity of the city of Carhuacoto. The objective of wastewater treatment is to ensure that domestic and industrial processes are treated without endangering human health and with the least impact on the environment. [14].

Installation of wastewater treatment systems
Is one of the strategies to reduce pollution in rivers. These systems aim to reduce organic and inorganic pollutants in these waters through physical, chemical and biological processes. [4] in this regard. The Rushton turbine is of the radial flow type showing efficiency in its operation, thus it is determined that it is viable for wastewater treatment. [15].

1.1. Environmental Standards in Peru.

Only two levels of headings should be numbered. Lower-level headings remain unnumbered; they are formatted as run-in headings.

Table 1. Environmental Quality Standards.

Parameters	Unit of measure	Primary contact	Secondary contact
Biochemical Oxygen Demand (BOD5)	mg/l	5	10
Chemical Oxygen Demand (COD)	mg/l	30	50
Dissolved Oxygen (minimum value)	mg/l	≥ 5	≥ 4
Hydrogen Potential (pH)	pH unit	6,0 a 9,0	**
Turbidity	UNT	100	**

The impact indicators include the Environmental Quality Standards (EQS) of the water shown in Table 1, which reports the authorization of discharges of treated wastewater. Applying the turbine design, the parameters are within the range.

(LMP). It is the measure of the concentration or degree of elements, substances or physical, chemical, and biological parameters that characterize an emission, which when exceeded causes or may cause damage to health, human welfare, and the environment. Its compliance is legally enforceable by MINAM (Ministry of the Environment) and the agencies that make up the Environmental Management System.

Table 2. Physical Parameters.

Sampling time	Inflow of treated effluent to the PTARD – Initial Chamber				
	PH (6.5 – 8.5)	O_2(≥4 mg/lt)	TºC(<35ºC)	Turbidity (<20NTU)	Chlorine (0.5 – 1.5 mg/l)
08:00	8.58	5.01	13.1	26.4	0.70
13:00	8.59	5.17	14.7	25.5	0.68
17:00	8.57	5.13	14.0	22.8	0.59

According to the regulations, Table 2 shows that the Maximum Permissible Limits (MPL) are exceeded in the following parameters such as pH, dissolved oxygen, settled solids, turbidity, and oxygen. A Rushton turbine will be implemented in the wastewater treatment process to obtain better results from the treated water.

2. Methodology

A Rushton turbine is designed with the mathematical criteria complementing with the Solid works program, AutoCAD for the elaboration of the design and operation for the correct functioning in the wastewater treatment in the city of Morococha, mainly in the secondary treatment, inside the bioreactor SBR [16] and aerobic for the retention of the liquid, taking into account the diameters of the tank, considering the established dimensions that are: Agitator measurements, impeller bore distance, impeller diameter, length and width of blades, deflector plates dimensions. [17].

Generating the efficiency of the water velocity holding capacity by applying the equation with the Reynolds Number is 2.36*10^{-14} and the power number is 2.28*.$10^{-14}$to identify the angular velocity is 1917. Where the Rusthon turbine has six deflector plates with a width of 1/10.

The Rushton turbine has the function of analyzing fluids using the impellers at the same time being constant with speed, air, bubbles can also operate at low agitation conditions from 200 rpm to 600 rpm. [15]

2.1. Final Indicators.

Retention time is efficient.

Regarding the retention time, it will be between 120 and 240 hours since it presents a more efficient reduction of organic matter as well as the reduction of thermotolerant coliforms. [18].

The SBR reactor is a viable alternative, as it shows efficiency in the treatment of industrial wastewater with respect to organic load, mainly in the removal of Total Organic Carbon (TOC) showing optimal effluent quality results. [19]. The SBR Bioreactor process is divided into two processes: the first one consists of the biological removal of phosphorus (EBPR) and denitrification (DN) in the main reactor (SBRP) [20], where a reduction of BOD, TSS and total nitrogen is obtained.
The reactor consists of two zones: preliminary and main. Both areas are separated by a baffle wall. The wastewater continuously reaches the primary zone and enters the main reactor through openings in the lower zone of the baffle. Ensuring that the inflow of raw water does not affect the quality of the wastewater in the sedimentation stage. [21].

Aerobic reactor with biofilter with aeration for different aeration rates in the reactor, showing that the process achieves higher nutrient removal with carbon demand Low and efficient aeration rate. [20].
As this interaction progresses, volatile suspended solids concentrations decrease because microbial cells die faster than newly synthesized cells, which determines the rate of degradation of the substances and their specific residue [22].

3. Results

3.1. SBR Reactor Analysis.

Sequential Biological Reactor (SBR). [16]This bioreactor processes anaerobic microorganisms. [23]. The SBR system consists of at least four cyclic processes: filling, reaction, sedimentation and emptying of both wastewater and sludge. [24]. The design of the bioreactor is cylindrical as it has several advantages, such as less possibility of dead sludge formation, and the size, volume, collection point and flow rate can be manipulated. The bioreactor design is basically implemented for "Organic Matter Removal". Which includes process steps, filling, aeration agitation, sludge settling and discharge of treated water. [23]. This is the only bioprocess in which reaction, aeration and SBR cleaning are combined in the same vessel. In the first stage, known as static filling, excess water is introduced into the system under static conditions. Filling can be dynamic if it occurs during the response time. In the second stage of the cycle, the wastewater is mechanically mixed to remove any surface scum and prepare the microorganisms for oxygen uptake. [24]. In this second (reaction) stage, air is introduced into the system. The reaction stage is a time-varying process in which the wastewater is continuously mixed and aerated, allowing biodegradation to occur. The third cycle, known as the sedimentation phase, creates resting conditions throughout the basin where the sludge can settle. In the final stage, or emptying phase, the treated water is sucked out of the tank by the removal system over the liquid surfaces. Finally, the sludge generated can be filtered clean to maintain the concentration at a constant level. [24].

3.2. Diagram your capabilities.

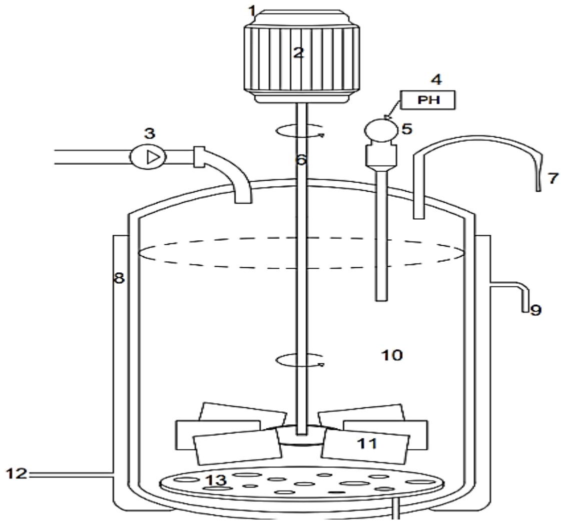

Fig. 1. Design of the Bioreactor with the Turbine.

In Fig. 1, the improved design of the sequential biological reactor (SBR) is shown, being more effective and homogeneous in the treatment of wastewater, incorporating the Rushton turbine, which is more suitable for the removal of organic matter.

Table 3. Turbine Part of Bioreactor.

Nª	Part of the Turbine Bioreactor
1	Agitation System
2	Engine
3	Feed Pump
4	PH Controller
5	Acid/Base Container and Pump
6	Agitator shaft
7	Waste
8	Jacket
9	Cooling Water Outlet
10	Crop Mixture
11	Rushton Turbine
12	Cooling Water Inlet
13	Air Bubble Distributor
14	Sterile Air

The parts of the turbine bioreactor can be seen in Table 3, which consists of 14 parts, as shown in Fig. 1. The design of the Bioreactor implementing the Rushton turbine.

3.3. Turbine Analysis.

The Rushton turbine has a modern technology that recovers wastewater with oxygen injection (process called wet combustion). It has a process capacity :5 m3/hour and with a process capacity per day: 110 m3 and with an average/monthly process: 115 m3. The efficiency of oxygen transmission is improved by the design of the Rushton turbine, as well as the energy saving, therefore, the results show the operation of the system that favors the efficient mixing of water and oxygen. It was possible to determine the oxygen transmission rate which was influenced by the size and number of bubbles caused by the type of aeration system as it reduces the low availability of dissolved oxygen. [25].

3.4. Overall Dimensions.

It was determined with respect to using the implementation of the turbine, considering the data of the pond measurements, the respective measurements to be included in the agitator will be shown below.

Table 4. Agitator Power Calculation.

Dimensions	Unit
Distance bottom to base of impeller(E)	345mm
Impeller diameter (Da)	345mm
Pallet length (g)	90
Pallet width (W)	70
Dimensions of baffle plates (4 each @ 45°)	
Plate width (J)	205
Space between plate and tank (f)	20

In the turbine, the measurements were considered, which was carried out with the calculations of the agitator in table 4, taking into account the general dimensions.

Reynolds number (Re)

For the Reynolds value, the characteristic of the fluid is identified if it is laminar or turbulent, defining that the change from laminar to turbulent regime is slow[26], as it goes through a transition will be presented below:

Reynolds is 2.36*10^{-14} which is within the laminar regime range: Re<10 laminar favoring the design.

Reynolds number

$$Re = \frac{Nd^2 * \rho}{c} \qquad (1)$$

Table 5. Description of equation 1

Dimensions	Unit
Density Caustic Soda (ρ)	1100
Viscosity (µ)	0.001
Angular Velocity (N)	1917
Stirrer diameter (d)	335

Applying the Reynolds Number formula, equation 1 was found as shown in table 5, obtaining the caustic soda density, viscosity, angular speed and the diameter of the agitator, with their respective results.

Power number (Np)

$$Np = \frac{P}{N^3 d^5 * \rho} \qquad (2)$$

Table 6. Description of Equation 2

Dimensions	Unit
Angular Velocity (N)	1917
Stirrer diameter (d)	335
Density Caustic Soda (ρ)	1100

In equation 2, the power number (Np) was calculated to determine the angular velocity, angular diameter and caustic soda density as evidenced in table 6.

Table 7. Equation 2

Impeller type	KL	KT
Square pitch propeller, three blades	41.0	0,32
2 pitch propeller, three blades	43,5	1,00
Turbine, six flat blades	71,0	6,30
Turbine, six curved blades	70,0	4,80
Fan turbine, six blades	70,0	1,65

Two flat blades turbine	36,5	1,70
Closed turbine, six curved blades	97,2	1,08

Table 7 below shows the KL and KT constants for ponds with six baffle plates with a width of 1/10 of the pond diameter that was considered for turbine optimization.

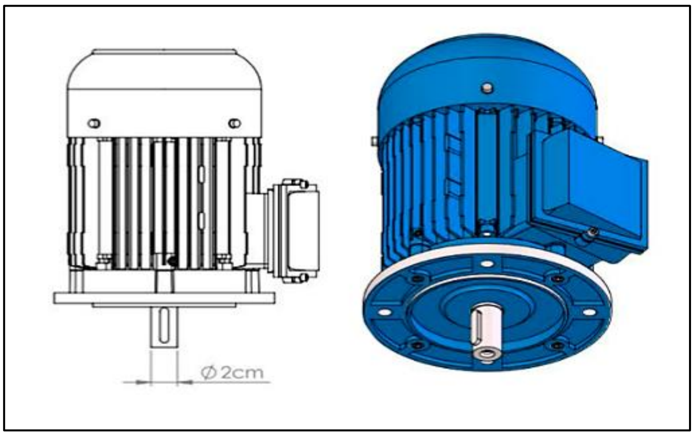

Fig. 2. Three Phase Electric Motor

Fig. 2, shows the most efficient three-phase motor with a good weight, size and power ratio, since it is of the squirrel cage type and has one or several groups of coils distributed 120° apart in its circular state. being more compact and lighter than the initial engine.

In the industrial environment, the three-phase motor is used because it is an efficient motor with a good ratio of weight, size, and power, since it is of the squirrel cage type, where the motor has one or several groups of bovines distributed at 120° of distance in its circular stator, being more compact and lighter where the motor is very efficient.

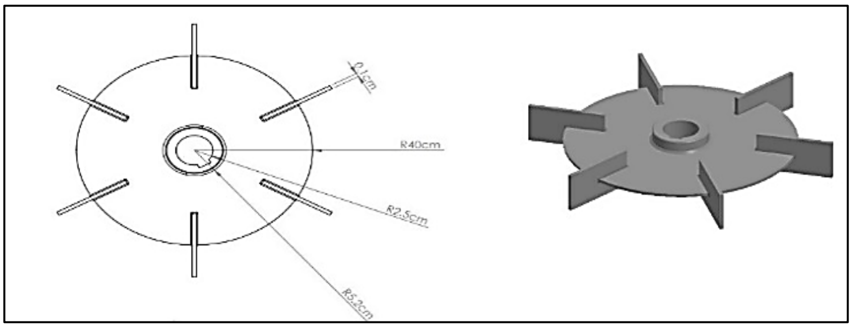

Fig. 3. Rushton turbine propellers

The fig. 3 shows one of the most widely used types of propellers in the industry, the 6-blade straight radial propeller, also known as the 6-blade Rushton turbine.[27] It is suitable for moving low-viscosity, high-velocity fluids. It is used for gas-in-liquid dispersion, solid dispersion, insoluble liquid mixing and heat exchange. Distributes energy evenly. Mixed flow type[28] Power 6 HP.

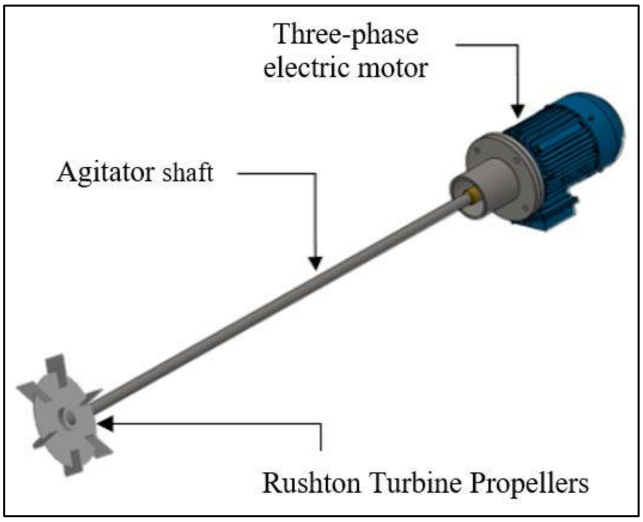

Fig. 4. Design and Shaft, turbine whit coupling to the electric motor

According to Fig. 4, the Rushton turbine was designed to achieve optimization within the bioreactor, thus improving dissolved oxygen, pH, and residual chlorine, improving the reaction rate, and controlling the treatment flow, avoiding excess wastewater and improving people's health and contributing to safeguarding biodiversity.

3.5. Effluent Quality

Table 8. Physical and Chemical Parameters of the Effluent.

Sampling time	Inflow of treated effluent to the PTARD – Initial Chamber				
	PH (6.5 – 8.5)	O_2(≥4 mg/lt)	TºC(<35ºC)	Turbidity (<20NTU)	Chlorine (0.5 – 1.5 mg/l)
08:00	8.29	4.01	1301	19.2	0.57
13:00	8.31	4.17	14.7	18.3	0.63

17:00	8.22	4.13	14.0	18.7	0.55

According to Table 8, it can be determined that the data with respect to the effluent output has a favorable result that shows a decrease in the three samples presented, which indicates that with the implementation of the Rushton turbine in the bioreactor, the quality parameters improve.

4.Conclusions

The implementation of the Rushton turbine design for the wastewater treatment plant, with respect to the flow rate, obtained adequate results since it is within the parameters established according to the Peruvian Environmental Quality Standard (PEQS) and Maximum Permissible Limits (MPL).

The speed is kept constant, due to the design of the Rushton turbine, which consists of six propellers, improving the efficient process performance of the SBR bioreactor in the domestic wastewater treatment plant.

With respect to the turbidity parameter the following result was manifested which was from 26.4 NTU to 19.2 NTU showing a remarkable decrease of 7.2 NTU due to the design of the Rushton turbine in the SBR bioreactor.

The main process for the implementation or planning of any design is the approval and evaluation of all possible changes to achieve the desired results. Water is available for reuse in irrigation.

The quality of the influent and effluent have a favorable difference when implementing the Rushton turbine design, since there is a significant change in the following parameters: pH with a decrease of 0.37, turbidity with a variation of 8.1 NTU in the wastewater, Chlorine is reduced by adding to the wastewater treatment plant at 21.43% mg/l, O2 decreases by 1.16 mg/l.

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