



RESEARCH ARTICLE

RECENT DEVELOPMENTS IN THE REMOVAL OF ORGANIC MATTER USING A SPIRAL SUPPORT SYSTEM

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ABSTRACT

There are various processes for treating wastewater and one of the most efficient is biological treatment, which consists of reducing the organic load, the elimination of pathogens and the reduction of dissolved solids. The biodisks are part of a secondary biological treatment system, known as attached growth. In the system of Conventional Independent Biodisks (hereafter, CIB), the support for the microbial fixing consists of several parallels and disks with a short distance between each of them and with a central axis passing through their centres. In this study, a system known as a Spiral Support Biodisk (hereafter, SSB) was designed and its performance was compared to CIB. A substrate in domestic sewage was used, and this was obtained from a wastewater treatment plant at Los Reyes Ixtacala in the municipality of Tlalnepantla de Baz, México City. The results showed a higher efficiency of operation and removal of organic matter with the SSB, and it was also possible to optimise the contact area and increase the turbulent flow.

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INTRODUCTION

There are several processes for wastewater treatment and one of the most effective is biological treatment, which basically consists of reducing the charge of organic matter, eliminating pathogens, microorganisms and harmful physical and chemical characteristics of water and the environment in general. Fortunately, there are various biological systems highlighting the use of biodisks, which have minimal requirements (area of coverage, for example), easy operation, minimal generation of solids, and reduced energy consumption. Biodisk systems have numerous applications, both in urban and industrial wastewater. Romero (2000) notes that biodisk systems can be used as a complement to other technologies. Sometimes, these systems are installed in order to improve the performance of conventional treatment plants that are already outdated or undersized. This technology can also be used in processes of nitrification/denitrification, in addition to previous forms of treatment. The biodisk system for treating wastewater can have a high performance, and Pano (1983) notes that in terms of the biochemical oxygen demand (BOD), the system can have an operation efficiency of up to 85%, the suspended solids can be

reduced by up to 96%, the total nitrogen can achieve reductions of 40%, and the bacterial load can be reduced to less than 1000 cfu/100 ml, with a yield of 92% in fecal coliforms. Installing a biodisk is simpler than a conventional activated sludge plant, although the system involves the construction of conventional units for pretreatment and a secondary clarifier. With regard to maintenance, Muller *et al.* (1995) noted that their installation required no further addition of biodisks, resulting in a normal maintenance programme of: environmental and facility cleaning; collection of sludge or biosolids, maintenance of pumps and motors, reactor, pipeline, noise, odour, hydraulic loading sand flow control; performance monitoring; and overload control in the influent wastewater. However, the use of this biological treatment system shows serious operational problems, such as clogging and a long residence time, so that the implementation of improvements to the basic design would bring enormous benefits to the scaling process. In the present work, system with Spiral Support Biodisk (SSB) in parallel is designed and compared with a Conventional Independent Biodisk (CIB). By using a spiral biodisk, it is assumed that there will be a greater transport of organic matter, nutrients, contaminants, and dissolved oxygen diffusion. In a CIB system, continuity is lost and physical barriers are generated, which reduce efficiency, whereas the SSB system provides continuity to the process, increases the turbulent flow, and optimises the contact area due to the spiral

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system of these biodisks. Other important factors that influence the level of degradation of organic matter, system performance and the ability to operate in the manner established by Cisnero (2000) were also considered. These factors are: a) temperature, b) static, c) vertical precipitation, d) rotational speed of the disks, e) engine power that allows the spinning of the disks. At the end of the experiment, the results showed an increment in efficiency and performance of SSB compared to CIB, in terms of organic matter and concentration of chemical oxygen demand (COD). Also, there was a reduction of suspended and settleable dissolved solids. Hence, this research was aimed at providing specific treatment engineering knowledge for this type of system.

## METHODS

Both SSB and CIB systems used in this study were designed and built by using pilot models in the laboratory, following the general guidelines for building these systems which consisted of: a) primary sedimentation tank, b) 2 acrylic reactor tanks, c) 11 polyesteramide disks, d) polyesteramide spiral, e) air supply by dual aerator, f) two metering pumps (HANNA Instruments BL), g) gear motor, h) pulley system, i) secondary sedimentation tank, j) current regulator, k) electrical installation. The volume of the reactor tanks was determined according to the method proposed by Ramalho (1993) (Fig. 1). However, the actual volume to be occupied for the treatment of wastewater was established according to the percentage of immersion of the disks (40%) and the gap between the edge of the disk and the bottom of the tank (8%). The determination of design flow was based on considerations of hydraulic type and process; the dosing of wastewater using the pumps was applied in order to maintain a constant flow in considering the reactor volume and residence time used.

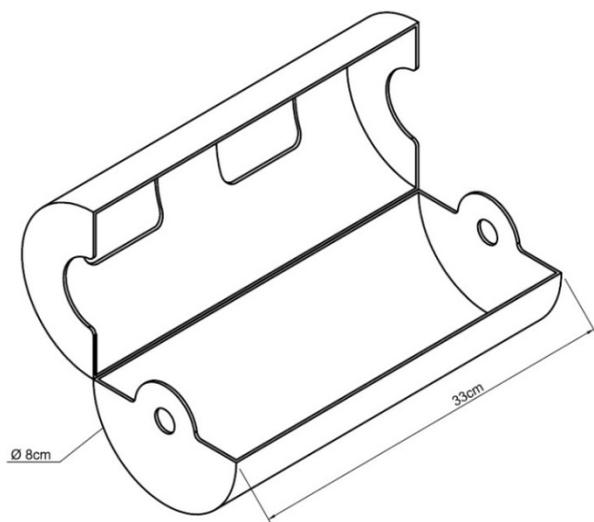


Fig. 1. Reactor housing

The support systems of SSB and CIB were manufactured in polyester amide material. The dimensions were 13 cm diameter and 1 cm thickness, joined through a galvanized steel shaft traversing the container longitudinally, having a length of 45 cm with two bearings and keeping a distance of 8 cm from the base (Fig. 2). To calculate the area of the spiral of SSB, MATLAB software was used. The area of the spiral is defined by a system of equations formed by definite integrals from 0 to 26, since the length of the spiral, measured from 0 to 360°, is 26 cm.

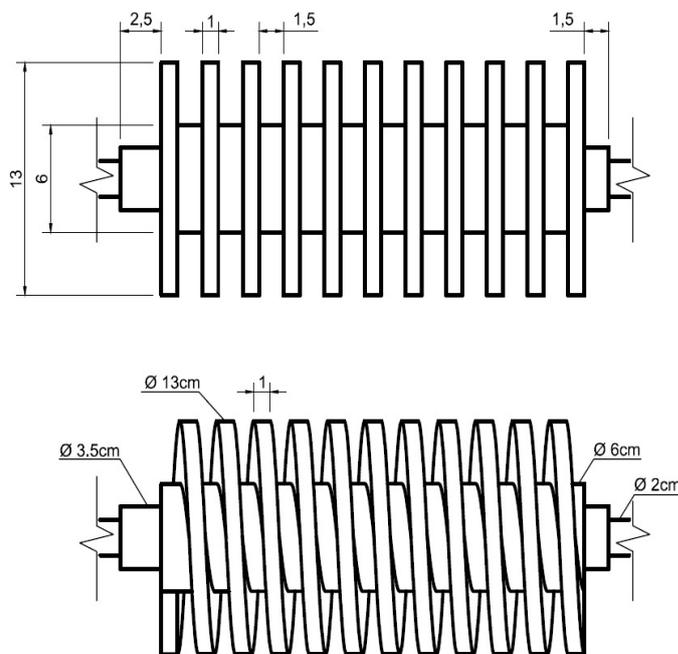


Fig. 2. Support of disks (top) and support of spiral (bottom), both manufactured in polyesteramide

To increase the contact surface of biodisks, it was necessary to implement a surface scraping procedure to increase surface roughness for each unit of both the CIB and the SSB. This also helped to increase the adherence capacity of the biofilm in the polyesteramide disks. To operate the biodisks, it was necessary to make a gradual start of the reactor, with acclimatisation of biomass. When launching the rotary disk system, the speed was regulated to 1 rpm. In order to accelerate growth of biomass, the cometabolism technique was used with the object of stimulating biomass using units of disaccharides as sole source, that easily assimilated carbon for a rapid formation of biofilm. The influent was obtained from the treatment plant of wastewater Los Reyes Ixtacala in the municipality of Tlalnepantla, Mexico City. This influent was obtained from the effluent of the primary treatment (screening, grids and skimmers of the plant). In order to carry out the design of biological reactors, it was essential to establish a kinetic of the reactions that occur in the tanks and the percentage mass balance, in order to determine the rate at which microorganisms degrade a specific residue. The reaction kinetics were determined by monitoring, every 12 hours for a period of 180 hours, the following parameters: total solids, COD, pH, total dissolved solids, turbidity, conductivity, dissolved oxygen, flow rate of air, total suspended solids, volatile suspended solids.

## RESULTS AND DISCUSSION

The calculations required for the design and construction of the system biodisks are as follows: Volume= 6,635 lt. The actual volume is set according to the percentage of immersion of the disks (40%) and the separation between the edge of the disk and the bottom tank (8%). Thus, 32% of the tank volume (2.1232 Lt) is used. Considering a debugging reactor tank time of 48 hrs, the water flow was 0.0123 ml/sec. With this information a surface charge of  $8.93^{-9} \text{L/cm}^2 \text{seg}$  was obtained. The number of disks, in considering the equation of Viñas, (2004), allowed to calculate  $N = \text{Number of disks} = 11$ . The total area of the disk was calculated using a MATLAB®

programme that allowed to run the data stream of the disks (Fig. 3), and the value obtained was  $AT = 3.3694^3 \text{ cm}^2$ . The contact area of the disk ( $A_c$ ) was identified with the ideal diameter of the disk (13 cm), the percentage of contact, the  $N$  and  $AT$ , hence  $A_c = 1.078^3 \text{ cm}^2$ .

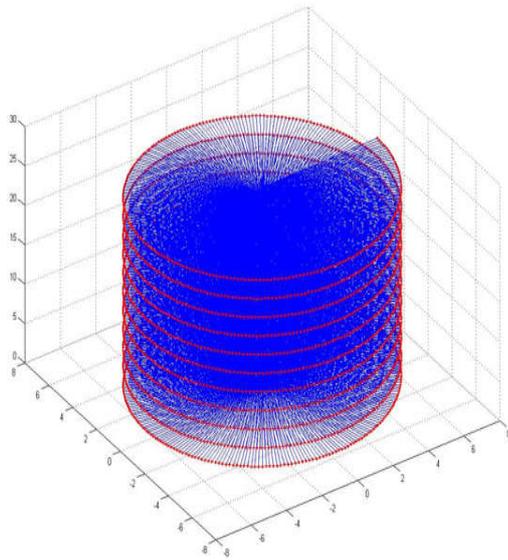


Fig. 3. Area of spiral in 3D =  $AT = 3.3694^3 \text{ cm}^2$

In Fig. 4, it is possible to see the startup of the biodisks reactor, which was carried out by filling the reactor with residual water until the disk was submerged up to 40% and by operating the rotary system at 1 rpm. The cometabolism process of the polysaccharide mixture and the residual water allowed the proliferation of biomass for a period of 15 days after startup.



Fig. 4. Reactor tank 1 SSE (left-side) and reactor tank 2 CIB (right-side)

The development of the reaction model kinetics is very useful as a diagnostic tool to better understand and to evaluate the performance and operational processes generated within each tank or process that forms the system of biodisks. With these parameters, the obtained kinetics, compared with time, indicated a trend in removal, depending on the parameter which reflected the percent efficiency in the process, for both the CIB as SSB. The main parameter for obtaining the kinetics was the Chemical Oxygen Demand (COD) (Fig. 5), since this reflected the degradation of organic matter in the water and bacterial behaviour.

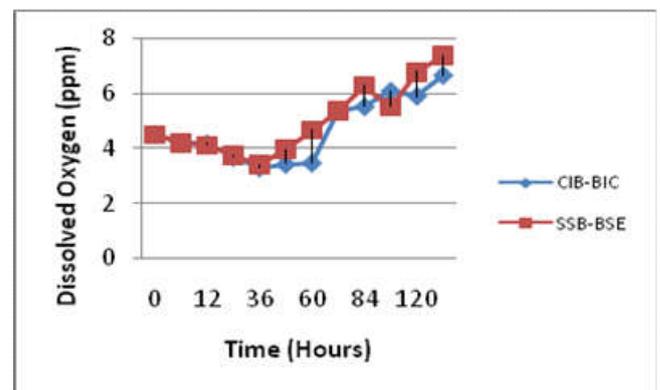
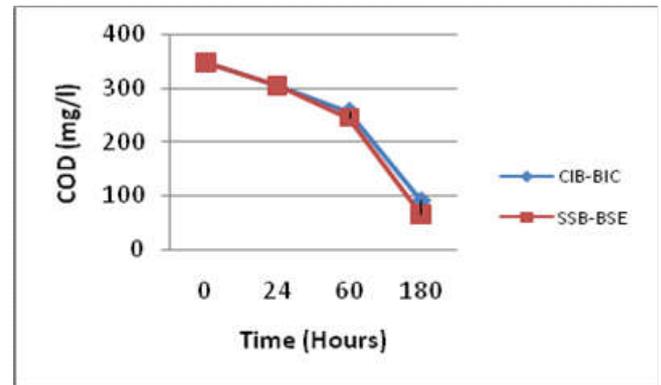


Fig. 5. Comparison of COD for both reactors (left-side: chemical oxygen demand (COD); right-side: dissolved oxygen; blue-colour line: Conventional Independent Biodisks (CIB) reactor; red-colour line: Spiral Support Biodisk (SSB) reactor)

Organic matter is directly related to the COD, as this parameter quantifies indirectly the oxidation of organic matter. The COD in the SSB presented an 82% removal of COD, compared to 74% of the CIB. In the case of SSB, there was a removal greater than 80%, in comparison to a mixed reactor for activated sludge (IMTA, 2006), matches the characteristics of efficiency and removal. However, the removal differences between both reactors SSB and CIB were noticeable and SSB presented removals in an amount that is above the ordinary. The causes may be due to a concentration of microorganisms in each reactor. The SSB has a larger specific area, thus it possesses a superior number of organisms. Another aspect can be the difference in propagation of organic matter, nutrients and aeration which is facilitated by the turbulent motion generated by the spiral as compared with disks. The biological treatment by the use of biodisks is becoming increasingly known by the agencies responsible for wastewater treatment, in part because this method combines the operational experience with modern technology, and it is an exceptional and versatile system (Cisnero, 2000).

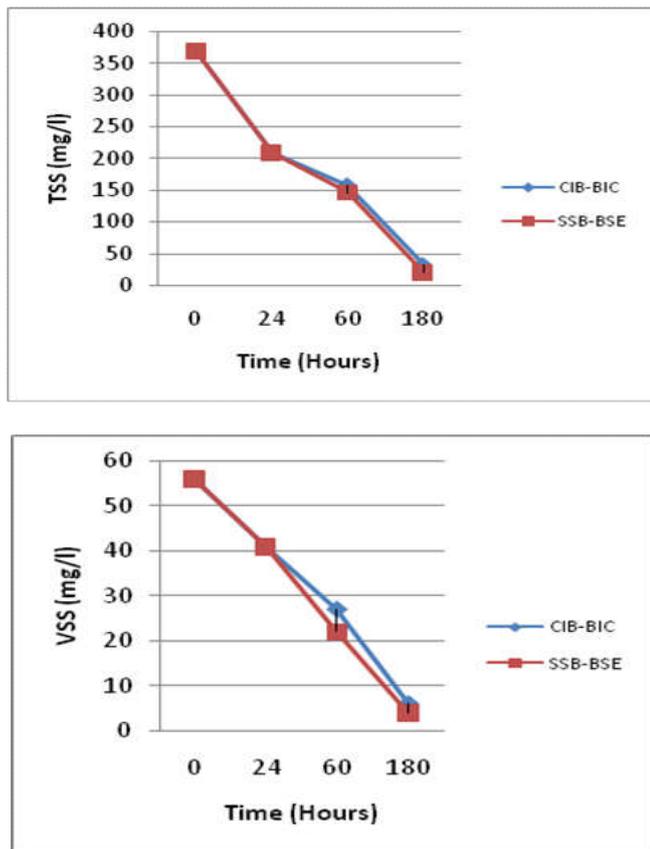


Fig. 6. Comparison of total solids and volatile suspended solids for both reactors (left-side: Total solids; right-side: Suspended volatile solids; blue-colour line: Conventional Independent Biodisks (CIB) reactor; red-colour line: Spiral Support Biodisk (SSB) reactor)

The biomass is directly related to the parameter Settled Sludge Volume (fig 6) as this parameter quantifies indirectly the biomass produced in the reactor, which is not representative of the SSV measured in the water tank. This behaviour is explained by the fact that in this system of biodisks, the biomass is hosted in the walls of the biodisks in the form of

biofilm, unlike the systems of activated sludge where the concentration of SSV in the body of water truly represents the biomass content of the system.

## Conclusion

The SSB and CIB reactors represent a functional and effective method to remove organic matter and COD; especially the SSB as it showed greater COD removal efficiency due to the proper propagation of matter, which was facilitated by the turbulent motion induced by the spiral of SSB in comparison to the CIB disks. It is important to mention that no technical problems were present due to obstruction, saturation or clogging in the polyesteramide spiral of the SSB that could have allowed a decline in the hydraulic system and motor.

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