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Reviewing Rotating Biological Contactor's Different Aspects for Wastewater Treatment with Experiment

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Abstract : One of the wastewater treatment processes is Rotating Biological Contactors. Which also known as RBC and provides acceptable organic removal efficiency and effluent quality at a low cost. The simplicity of operation makes it very attractive. In addition, the operation cost is always low and it does need a small land to operate. In this review the advantages and disadvantages of RBC, types of RBC systems and the factors affecting the RBC performance discussed. In addition to an experimental works to verify the effect of different factor affecting the RBC system performance and removal efficiency. The experimental work confirmed that the HRT, media material and speed of rotation have a great influence on the removal rates and performance. Rotation speed used was 5, 8 and 10 RPM while the best speed was 5 RPM. Media materials varied between geotextiles, steel and other materials. Steel cylinder showed the highest removal rates as it had the highest surface area, which allowed more microorganisms to grow, and thus, the removal efficiency of COD, BOD and TSS were increased.

KEYWORDS: Geotextile, Steel cylinder, Sugarcane straw, Wastewater treatment, Rotation Speed.

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1. INTRODUCTION

The treatment processes of wastewater follows certain standards that contribute to the insurance of environmental sustainability **[1].** Many processes used for the treatment of wastewater, which includes biological, chemical, and physical processes. Almost all of these processes involves having advantages plus restrictions. **[2].** As an example, using conventional biological processes, high effluent quality is achieved but comes with expenses of largely reactor aeration high energy usage. It accounts for almost 55% of wastewater treatment energy budget. Wastewater treatment technologies can increase removal efficiency of pollutants and more improve effluent quality **[3].**

Rotating Biological Contactor is an attached growth process in which, microorganisms attached to the media develops a film. For biodegradable matters in addition to nitrogen removal, RBC considered a distinctive substitute treatment process. Some of the RBC advantages compared to the conventional treatment processes are as follows: it requires less area, the process is simply monitored, costs of maintenance and operations are low, concentration of biomass is high, produces low excess sludge, short hydraulic retention time, more efficiency in oxygen transfer, sludge recirculation is no more needed and the process is shock resistant and also resists compact design and toxic loads and it's simply controlled **[4, 5, 6]**.

2. History of RBC

The first RBC was in Germany nearly 1920s and that first RBC initially described as a mass of rotating aerobic fixed to a media support **[7].** While on a plant scale, the first one was in the USA and called the biological wheel and sometimes the contact filter **[8].** On the Commercial side, it was nominal, until the drip body immersion system was developed. This led to the first experimental RBC pilot scale development. This achievement unlocked new ways for RBC design which blossomed in the 1960s **[9].** Over the history, the RBC systems was used for the wastewater treatment of organic carbon removal. Later this process extended to include wastewater denitrification and nitrification. In Europe, primitive RBC systems began and kept operating since 1958 **[10]**. Figure 1 shows a diagram of RBC.

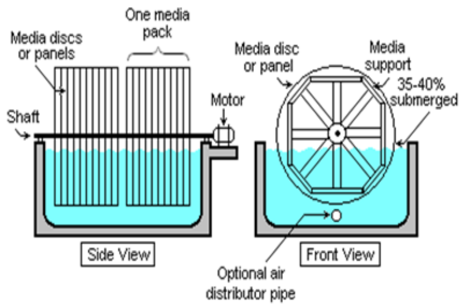

FIG 1. RBC unit diagram.

3. TYPES OF RBC

There is two main types of RBC, modular and integral. Modular systems include separate units for solids treatment, primary treatment and biological process of RBC and its capacity of treatment of population equivalents (PE) is bigger than 1000. More flexible configurations could be reached through the treatment capacity **[11].** On the other hand, the integral systems is a single unit, which combines all the steps, primary settlement, final clarifier and biological zone of RBC. The Integral systems treatment capacity is less or equal to 250 population equivalents (PE) **[12].** RBC Parallel flow RBC can be operated for acceptable limits of loading. However, if effluent quality is a concern, units of RBC is placed in series. Usually the used submergence percentage of the disc is 40% **[4].** Less oxygen will be supplied to the microorganism if submergence is increased and reactor conditions becomes anaerobic and the denitrification will be more favorable for the process **[13].**

RBC wastewater treatment process provides both organic removal efficiency and acceptable effluent quality at a much more less costs. The simplicity of operation makes it highly attractive, it produces low sludge, its foot-print is small, operational cost and maintenance is low. Complete denitrification / nitrification could be achieved by using different levels of disk submergence and operating the process in a single unit under both anoxic / anaerobic conditions. In addition, nitrification efficiency for a two stages RBC system is higher than a one-stage RBC system **[14]**.

4. Advantages and Disadvantages of RBC

RBCs are generally easy to use, need short start-up times, are easy to manage, efficiently oxygenate and have little biomass sloughing **[15]** proven that RBC can be very effective in the treatment of wastewater from wineries and bottling plants.
The RBC is used for its advantages including high specific surface area, high activated sludge concentration, better settling of sludge, stable processes and low maintenance and power usage.

RBC is therefore an effective wastewater treatment system, since it is simple to operate and maintain. The consumption of RBC energy is equal to or less than the extended aeration activated sludge plants. RBC's capital cost is lower than activated sludge facilities when the plants are small. Because of the large active surface, short contact times are required. RBCs are able to accommodate a large variety of flows. Sloughed biomass has usually strong settling properties and can be easily isolated from the waste stream. The operating costs are low as little skill is required in the operation of the plant. Its retention time is short. It requires low operating power requirements. They deliver low output of sludge, and excellent process control **[16].**
Units in northern climate need protection against freezing as a disadvantage for rotating biological contactors. Frequent maintenance is expected on shaft bearings and mechanical drive units.

5. Rotating biological contactors against other wastewater treatment systems

Rotating biological contactors deliver a higher treatment level than conventional high-rate packed-bed reactors **[17].** The efficiency of both systems in the treatment of UASB reactor effluent compared: At 3.3 hours of HRT, rotating biological contactors removed 50 percent of COD while packed-bed reactor removed 70 percent. However, at much shorter

HRT of 0.24 h the RBC still achieved a COD elimination of 40–80 percent.

The rotating biological contactors and the activated sludge processes can deliver high treatment levels. However, rotating biological contactors are generally less susceptible to disturbance due to changes in loading and technology; it is less in complications than activated sludge. Both biological processes compared using a lab-scale for the treatment of chemical industrial wastewater (5,239 mg COD/l and 2,615 mg BOD5/l) **[18]**. As both were successful in generating effluents within the allowable limits, the engineering design of each (full-scale) treatment system was developed, and the cost estimate suggested that construction costs were comparable for both systems, while the operating costs of the rotating biological contactors were approximately twice less than the activated sludge. Therefore, the use of rotating biological contactors recommended.

Estimates show that rotating biological contactors need just about a quarter of the energy consumption of an activated sludge system **[19]** and 70 to 80 percent of a packed-bed reactor **[6]**. The manufacturers of full-scale conventional rotating biological contactors specify a power consumption of 1 to 1.5 kWh per kg of BOD5 removed **[20].** In a full scale, rotating biological contactors packed with offcuts of cylindrical PVC, **[21]** also showed that the pilot's rotating biological contactor had electrical power consumption of 0.005 kWh per m2 d at a rotational speed of 1 rpm.

6. FACTORS AFFECTING THE RBC PERFORMANCE

The performance of the RBC systems depends on multiple design variables. HRT considered the most basic variable affecting the performance of RBC, and rates of hydraulic and organic loading. In the past, those variables was thought that it only control the performance of the treatment unit. A study made on the RBC process showed that a collection of factors contributes to the overall RBC performance and the overall behavior of the treatment process established by the relationship between these variables.

The main important variables are the speed of rotation speed (RPM), organic loading rate, hydraulic loading rate, HRT, the media of disk, characteristics of wastewater, microorganisms types, temperature, submergence level, dissolved oxygen, sludge recirculation and step-feeding.

6.1. HYDRAULIC RETENTION TIME

Organic and hydraulic loading of the influent wastewater is directly related to HRT. The longer HRT the more removal efficiencies improvement and proper degradation of the substrate substances **[22, 23].** This also applies for heavy and toxic metal substrates **[24, 25, 26].** While when HRT is short, this will result in poor treatment process and that is due to improper degradation of the substrate. On the other hand, the longer HRT, the more effect to the process economics. The optimized selection of HRT is very an important factor to obtain the targeted quality of effluent and at lowest cost **[24].**

6.2. SPEED OF ROTATION (RPM)

Speed of Rotation have a direct relation to the levels of dissolved oxygen in the wastewater. As the speed of rotation increases, the level of dissolved oxygen is also increasing. This is because when the speed of rotation rises, the microorganisms contact with the air also increases which results in an increasing oxygen level. This will also increase the substrate degradation and increase the performance of the bioreactor rate **[27].** However, when the speed of rotation increases, more power is being consumed which will affect the treatment process economics. With the increase in the speed of rotation, media can get its microorganisms detached from its surface and deteriorate the effluent, which will give poor treatment. On the other hand, low speed results in decrease on level of dissolved oxygen in the bioreactor. And this will result in a slow degradation process **[28].**

6.3. MEDIA

One of the main variables that affects the RBC system performance is media. To enlarge the surface area, variety of media could be used. Microorganisms is growing more when the surface area of media increases. The more growing of microorganisms increases the removal efficiency. However, media costs should be taken into considerations when they are being selected **[29].**

Many materials could be used as RBC media, like foam, polycarbonate sheets, High density polyethylene and more. High density polyethylene is one of the most used material as an RBC media and could be found in multiple shapes and configurations based on the process requirements **[6, 27].** These configurations could show mass transfer improvement, increased surface area and enhanced structural stability.

7. RBC EXPERIMENTAL WORK

After reviewing and discussing the benefits, types and factors affecting the rotating biological contactor systems, the next section will present an experimental work using RBC.

7.1. RBC SYSTEM MODEL

A scale model of the RBC system was built for the purpose of wastewater treatment and to determine the impact of various factors on the RBC process operation. These experimental works were carried out at the Zenin wastewater plant at Giza, Egypt. The mentioned system consists of two identical units of the RBC system connected in series. The dimensions of each unit were 35×30×25cm, as shown in Figure 2. Since the goal is to study the effect of various factors on the performance of the RBC system, the media used is variable, as will be mentioned later. The materials used to shape the models is SIROPOL-8340 from Saudi Industrial Resins Limited.

Each RBC unit was raised on a steel frame in order to raise the model above the ground and to give good stability while operating.

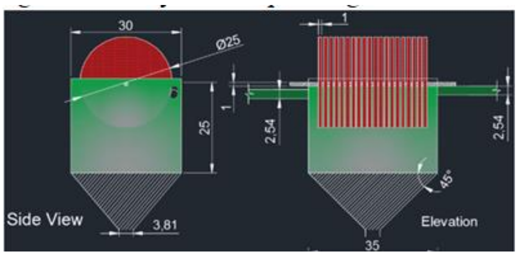

FIG 2. RBC model dimensions.

7.2. THE MEDIA MATERIALS

As mentioned previously, variable media were used in order to study the effect of the media on the efficiency of the wastewater treatment process of the system. In this study, different types of media were used from different materials and different shapes. The following section will present a simplified overview of each media that used.

7.2.1. GEOTEXTILE

Geotextiles or as it is scientifically known as polypropylene is a good media for the growth of microorganisms. Two different geotextiles were used with different weights of 800 g/m2 and 1000 g/m2 respectively. As for the shape, two forms of this material were used, circular discs and gear-shaped discs in order to increase the surface area.

7.2.2. STEEL CYLINDER

A hollowed steel cylinder with holes along its surface. The diameter of the cylinder was 25 cm, along the length of the model, and the steel cylinder was easy to clean.

7.2.3. SUGARCANE STRAW

Sugarcane straw was also used as a media to determine its effectiveness in the treatment process. This Sugarcane straw was placed inside a transparent plastic cylinder with holes with a diameter of 25 cm along the model length.

7.2.4. BANANA LEAVES

Banana leaves placed inside a transparent plastic cylinder with holes with a diameter of 25 cm along the model length.

7.3. ROTATION SPEED

As the rotational speed is one of the important variables affecting the efficiency and performance of the RBC system. The rotational speed used in this experiment ranged between 5, 8 and 10 rpm. It was found from some initial experiments that the rotational speed of 5 rpm is the most appropriate rotational speed that gave the highest results. Accordingly, a rotational speed of 5 rpm was used in the rest of the experiment.

7.4. COLLECTING & ANALYZING OF SAMPLES

Samples were collected from different places such as the wastewater inlet source, then from the water outlet of the first unit and the outlet of the second unit to obtain water specifications before and after each treatment process.

These samples were collected in plastic jars taken into consideration that this water does not interact with any medium in which it is placed to ensure the safety of the samples.

PH, COD, BOD, TSS and temperature measurements were carried out on each of the collected samples. These readings were noted according to the day, the place from which the sample was taken, and the material used as a media.

8. RESULTS & DISCUSSION

8.1. RESULTS AFTER PHASE I

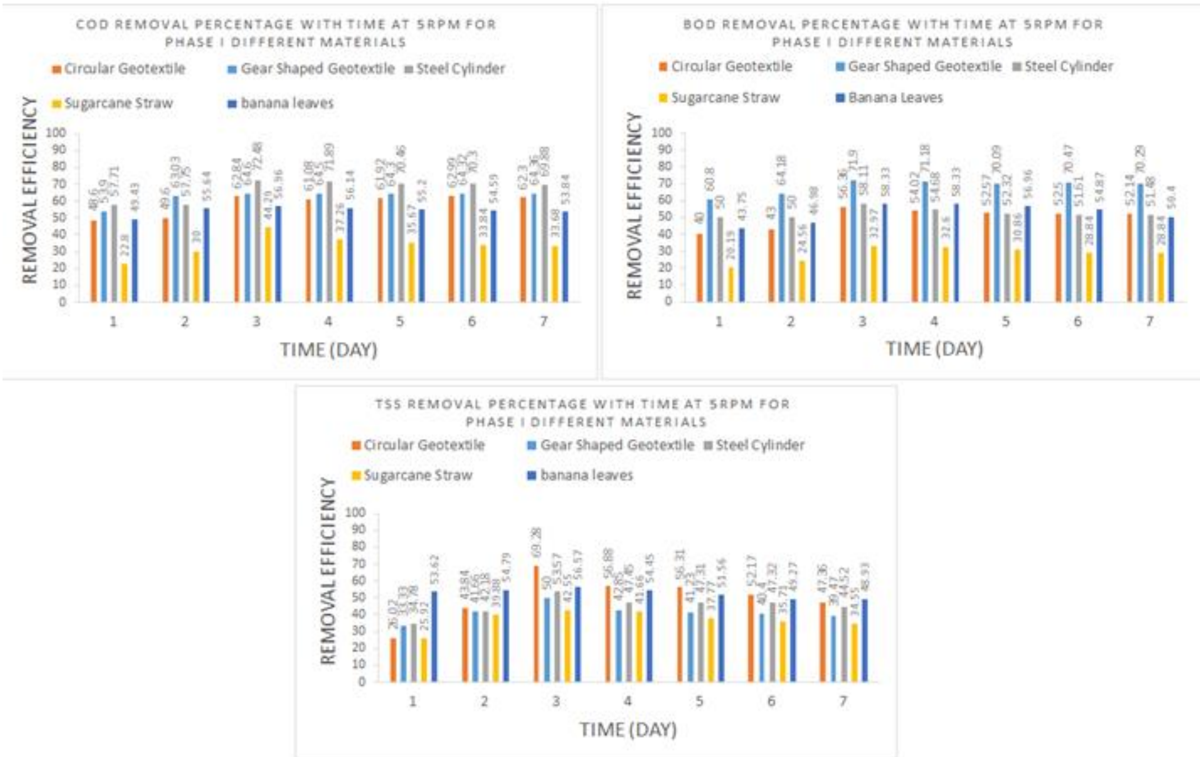

FIG 3. COD, BOD and TSS results for Phase I at 5 RPM for all materials

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Figure 3 shows the results of wastewater treatment for all kind of materials used at 5 RPM only for Phase I. It also shows the removal efficiencies for BOD, COD and TSS. Referring to the previous charts it can be noticed that removal rates keep increasing until it reaches the third day then begin to decrease and this confirms that the best HRT is on the third day of treatment. Comparing COD, BOD and TSS, it is obvious that the steel cylinder gave the higher removal efficiency for COD. While for BOD, the gear-shaped geotextiles gave the higher removal efficiency. Circular geotextiles showed the higher removal efficiency for TSS.

8.2. RESULTS AFTER PHASE II

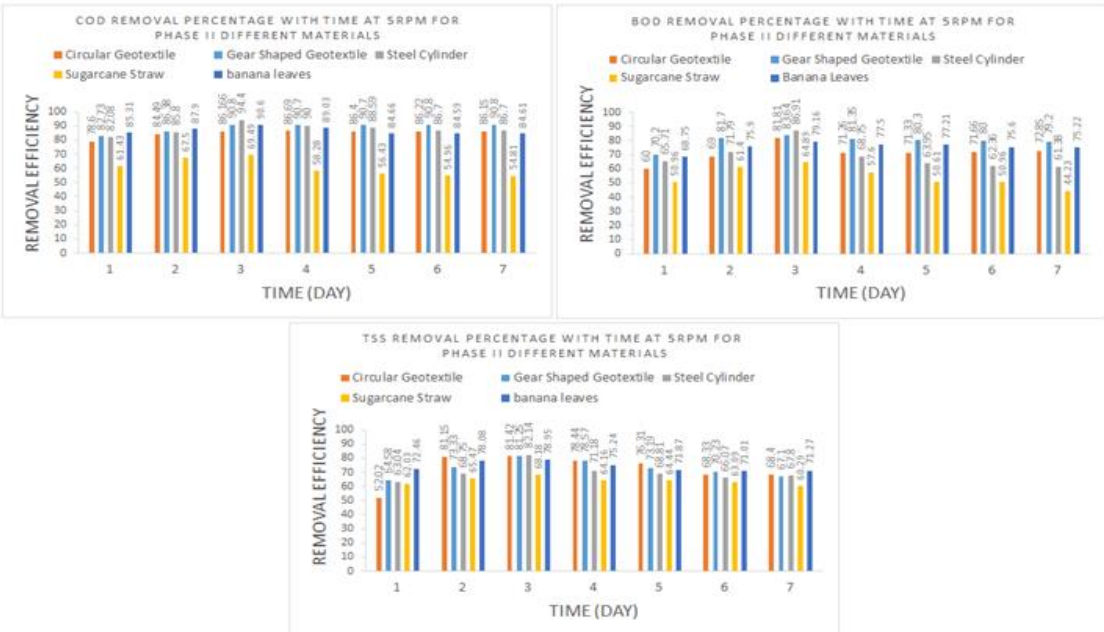

FIG 4. COD, BOD and TSS results for Phase II at 5 RPM for all materials.

Figure 4 shows the wastewater treatment results for wastewater treated in Phase I. Phase II results shows that removal rates keep increasing until it reaches the third day then begin to decrease and this confirms again that the best HRT is also on the third day of treatment. While comparing COD, BOD and TSS results, it is clear that the steel cylinder gave the higher removal efficiency for both COD, BOD and TSS. This shows that the steel cylinder was the best suitable media on this experiment

8.3. EFFECT OF MEDIA

As shown on the previous results and as it is known that, the media have a great effect on RBC system results. Microorganisms is growing more when the surface area of media increases. The more growing of microorganisms increases the removal efficiency **[27].** Therefore, as the Steel Cylinder was having the highest surface area, it allowed more microorganisms to grow which increased the removal rates. While other types of media like the banana leaves bottle showed also a good removal efficiency compared to rest of materials **[30]**.

8.4. EFFECT OF HYDRAULIC RETENTION TIME

The hydraulic retention time has significant effect on wastewater treatment using RBC. As found during the previous results, the best HRT found to be on the third day of treatment, after that the results almost kept steady. While on some other results it decreased. This agreed with the findings of **[31].** With a HRT of 3 days, it has observed a 96% reduction on the molecular absorbance of light at 538.

8.5. EFFECT OF ROTATION SPEED

One of the major factors affecting the treatment process of wastewater using Rotating Biological Contactors systems is the rotation speed. Rotation speed has a great influence on the results of wastewater treatment. In this study different rotation speeds was used (10, 8 and 5 RPM) along with different materials, it was obvious that regardless of material the rotation speed affects the results significantly. Rotation speed of 5 RPM found to be the best rotation speed **[32]**. This was in match also with **[33]** who carried out a study to evaluate the suitability of polyethylene foam as disc material for rotating biological contactors and found that, the Optimum values of submergence and RPM found to be 40% and 5 RPM.

9. CONCLUSION

In line with the results presented and discussed, this concludes that The rotation speed is one of the key factors having a great influence on the removal rates of both COD, BOD and TSS. The media shape greatly affected the removal efficiency for wastewater parameters such as BOD, COD and TSS. The greater the surface area, the greater efficiency of wastewater treatment and higher removal rates. Using two stages of RBC highly increased the removal rate. HRT has a great influence on the treatment process. Geotextile materials showed a very high efficiency in wastewater treatment, as it is a vital medium for the attachment and growth of microorganisms, beside it is a cheap material. Steel cylinder removal rates were almost 86.9%, 94.4 and 82.14% at 5 RPM for BOD, COD and TSS respectively, which showed the highest removal rates among all other materials.

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