

Rough and Splitted on the Surface of Disk in Rotating Biological Contactor to Treat *Tempe* Wastewater

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ABSTRACT

Wastewater of *tempe* is derived from the water used to wash and boil the soybean. This wastewater usually contains of high organic and nitrate matter. Therefore, it needs appropriate treatment system to reduce the content of wastewater. This research was aimed to develop a design for rough and splitted on the surface of discs as contactor in RBC. The method employed was to vary the parameter of Chemical Oxygen Demand (COD) and Total Suspended Solid (TSS). Then, rotor rotation was set in 7 rpm, and 40% disc was immersed into wastewater with a temperature around 27°C - 29 °C; while the used pH was between 6.52 – 7.84, neutral pH. The treatment would significantly remove the COD was varied 85.17% to 93.27% , the TSS removal ranged from 29.9% to 67.44% and nitrate removal range from 36.25% to 57%. Hydraulic retention time (HRT) in this process was varied from 3.5 to 4.2 hours, while the organic loading was varied from 11.91 to 43.18 gCOD/m²day. The identified bacteria dominantly grow in biofilm and were able to degrade the organic loads, *Bacillus sp.* and *Pseudomonas sp.*

KEYWORDS : surface disc, biofilm, organic loading, carbon removal, nitrate removal.

INTRODUCTION

Rotating Biological Contactor (RBC) was a treatment device used to remove soluble organic material in wastewater through an aerobic process. The process was developed by modifying the surface into rough and splitted on disc. The disc was used as media to cultivate microorganism that is immersed and rotated gently into the wastewater. Biofilm that formed from microorganism on in the discs would be utilized to degrade the pollutants identified from any wastewater.

RBC was chosen in this treatment because although high cost in the beginning, but low costs in further operation and treatment, besides it was also easy to operate and more efficient concerning to the areas and energy needed to generate the process [6, 22]. Other researcher, Baban (2009) [10] has also figured out the same evidence derived by comparing energy utilisation in wastewater treatment of grey water by using Membrane Bio Reactor (MBR) that required the energy of 1.7 kWh/m³ and 1.2kWh/m³. Compared to other reactors, RBC provides more complex to treat wastewater [2, 4, 13]. In addition, RBC also provides surface of contact media that were generally good for generating the growth of microbe in the wastewater [18]. Some researches about RBC that had been developed widely were meant to reduce the organic matter in the waste. Meanwhile, in the last decade, there were some trends to develop some materials and media such as pipe [12]; wavy [16]; Packed Cake RBC [21]; Rotating drum [20]; net-like rotating biological contactor (NRBC) [8]. However, among those researches about RBC, the hydraulic retention time (HRT) obtained was quite long (less than 5 days). HRT factors were influenced by the thickness of the layer surface of microorganism utilized as organic decomposed materials in wastewater. If the layer biofilm surface thicker, the efficiency of instrument becoming less, therefore the HRT would take longer. From this reason, rough and splitted discs were developed to widen the microorganism layer surface. This might cause the random flow surrounding the layer surface. Finally, the DO transfer rate would also become higher.

The reactor of RBC consisted of one series of disk contactor rotating in one semi circular container. The distance between one contactor and another was quite near. It was about 40% from the contactor part immersed in the wastewater. In the process of RBC, wastewater was put regularly in one container or tank and the disk was rotated slowly. The disk rotation in the process system of RBC was intended to make the microorganism absorb oxygen an increase the turbulence in the tank of RBC, so that the oxygen transfer could increase [7, 19].

Throughout the process, some the microorganisms grow and form layers on the surface of the discs, called biofilm. This was the microorganism that did decomposition and removed the organic content of wastewater. When rotating, disc surface that is immersed in the water would decompose organic matter and when it is dried out, it will get a contact with the oxygen in the air, then biomass will absorb the oxygen, and

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finally this will lead to an aerobic condition. The rotation of the discs is actually a mechanism for maintaining biomass in suspended condition. An excessive biomass would also be released then sedimented in secondary sedimentation tank^[3].

The advantage of RBC in the process of wastewater treatment was that the operation was quite easy, that was by rotating the disk. Due to the width of surface was big; it can also be used to treat the wastewater that has a large capacity, 1000 gal/day until 100000 gal/day. Meanwhile the sloughing biomass could be separated from the water that had already been treated/ processed^[9,23].

The Evolution of RBC media panel begins from flat surface media panel that remains utilized until up to now. Therefore, some researchers have developed its utilisation by making the media surface wider to enable micro-organism attached. Flat disc has been widely used by reseachers; however, some have modified the materials used for media. One of them was *plastic disc*, COD of influent 16000 mg/l, 5 days HRT, decreased concentration upon 88%^[17]. tube shape media, decreased COD 2000 of mg/l, A/Q ratio > 1200 m²h/m³, for 95% COD removal^[12].

RBC is an alternative technology on wastewater management that is aptly employed in small scale industries or enterprises, such as garment and food product industries. This is due to its simple procedure of operation and saving electricity. The only constraints of this technology is high organic wastewater yielded from the process of industries. The current RBC available was just for organic loading varied from 8 to 20 gBOD/m².day^[15]. however, such a constraint still can be managed by enlarging the surface of the contactor by making the rough surface and splitted on the sides so that the selected contactor would be found easy to operate, consuming less energy, not requiring wide range of area for the process, and yielding low *sludge*.

MATERIALS AND METHODS

An experiment was carried out to determine and calculate the design of the device. Reactor RBC was made of fiber plastic with its dimension: width= 30 cm; length every stage= 24 cm; total: 3 stages= 92 cm; height: 12 cm. Disk RBC made of novotex plastic, disk diameter= 20 cm, thickness= 8 mm, 1 stage consisted of 10 disks. Shaft from iron connected with motor and pulley to control the rotation speed of motor RBC. The tool specification could be seen on table 1. Meanwhile, the schematic experimental setup was explained on figure 1.

The wastewater being investigated in this research was taken from the effluent wastewater from the process of *tempe* making. The wastewater used in this research was that of *tempe* making, that had formerly fluctuate characteristics with COD around 23230 mg/L, BOD₅= 11615 mg/L, TSS= 5500 mg/L, pH=5 NO₃= 15,2 mg N/L, PO₄= 1 mg/L. The bacterium which was bred was taken from the wastewater of *tempe* industry itself. The concentration of COD was treated to make it dilute, and controlled at about 600 mg/L up to 8000 mg/L. TSS and nitrate were following the controlling result of concentration COD. pH was controlled at pH neutral, and DO was measured at pH neutral, while DO was measured during the research was conducted with the detention time at 0,7 hours up to 4,2 hours.

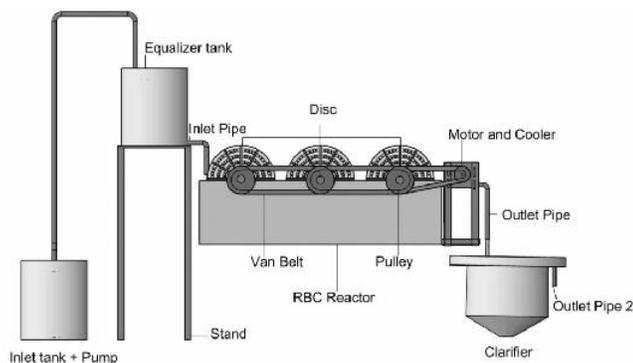


Figure 1. Schematic representation of the small-scale RBC evaluated in this study.

Table 1. Reactor design and operating parameters for the laboratory scale RBC

SPECIFICATION	VALUES
Number of stages	3
No. of disc/stage	8
Diameter of disc (mm)	200
Thickness of disc (mm)	8
Spacing between the disc (cm)	3
Total surface area of discs (cm ²)	26350.744
Working volume (L)	17.0
Submergence (%)	40
Rotations per minute	7

RESULTS AND DISCUSSION

The ability to remove organic loads from *tempe* making industries by means of RBC media with rough and splitted on the surface could be explained as follows:

Biofilm in RBC

Biofilm growth on the disc and can be marked through an existing whities that grows during seeding within 2 days and the thickness was about 2,5 mm in stage 3; 2 mm in stage 2; and 1 mm in stage 3, yet biofilm fails to cover over disc surface. On the 6th day, the thickness of biofilm became 3 mm in stage 1.25 mm in stage 2, and 1.5 mm in stage 3. Meanwhile, on the 10th day, 12 and 14 showed that the thickness of biofilm decreased into 2.5 mm. In this stage, the thickness of biofilm became stable and was ready to acclimatize.

In the process of acclimatization, biofilm was attached to a disc which thickness is about 3 mm at stage 1; 2,5 mm at stage 2 and 2 mm at stage 3, while the wide of the RBC surface becomes 100% in each stage. The process makes the color of the layer of biofilm changing into yellowish white. In 2.5 mm thickness, biofilm layer is considered stable and the RBC is ready to proceed.

The research result has identified which microorganism are dominantly found in biofilm to decompose organic loads in *tempe* wastewater, as depicted in Table 3 below.

Table 2. Identified dominant microorganism in biofilm

Stage	Identification
Stage1	<i>Bacillus</i> sp.
	<i>Pseudomonas</i> sp.
	<i>Staphylococcus</i> sp
Stage2	<i>Bacillus</i> sp.
	<i>Pseudomonas</i> sp.
	<i>Staphylococcus</i> sp.
Stage3	<i>Bacillus</i> sp.
	<i>Pseudomonas</i> sp.

Table 2 above showed that there were some varieties of microorganisms living in each different stage, and it was also identified that the most varied ones are found in stage 1 and 2. This was due to the fact that the highest partial denitrification happen at the first stage, so that it emerged the domination of microorganism^[11]. Meanwhile, the domination level of stage 3 is quite low because the organic load degraded by its biofilm was lower than its previous stage. Therefore, the diversity level of microorganism in stage 3 is lower. Conversely, in stage 3 the domination quite low because organic loads that can be degraded by biofilm is lower compared to the previous stage. Below is the figure of biofilm on disk.



Figure 2. Biofilm on the disk, growing optimally 2.5-3.0 mm

The removal of organic parameter of *tempe* wastewater

The roughness disc has made the surface media wider so this could enhance more DO. Such a design has enabled the flow penetrating the splitted disc, then to change it into turbulence. The rough and splitted surface initiates random flow around the layers of micro-organism that effectively enhance oxygen transfer then at the same time it would enhance the performance of the device.

The content analysis result of *tempe* wastewater organic that had been treated in a reactor with concentration COD input less than 2000 mg/L, had already fulfilled the required regulation. The qualification standard of effluent COD waste was not more than 300 mg/L.

a. Removing COD with concentration was less than 2000 mg/L

The removal efficiency of organic content was not only optimal for COD inlet 637.52 but also for COD inlet 1926.08 mg/L with the elimination process 85.17% at HRT 4.2 hours. This was related to the Organic Loading wastewater from industry with its criteria of 10-50 g/m²/day^[23].

The research result showed that using *tempe* wastewater test, the Organic Loading could reach up about 11.91 – 43.18 gr/m²/ day. From this achievement, the elimination of COD content of wastewater was more than 80%. Meanwhile, the value of Hydraulic Loading Rate (HLR) that fulfilled the requirement or criteria as what Metcalf & Eddy [15] suggested about 0.037 – 0.074 at HRT = 2.1 – 4.2 hours and COD inlet was 637.52 mg/L; 844.51 mg/L and 1926.08 mg/L, RBC could work optimally.

Furthermore, to eliminate the nitrate (NO₃) at HRT 4.2 hours was only reaching up to 57% at COD inlet 1926.08 mg/L. This elimination process required longer HRT to reduce the nitrate content because the chemical characteristic of nitrogen was very complex. Nitrogen was assumed to have many kinds of different oxidation calculations and it could be changed by many kinds of processes that could persist in living creatures.

Concerning to nitrate elements, the removing nitrate (NO₃), in HRT 4.2 hours, it can only be diminished until 57% in COD inlet 1926.08 mg/L. There needs a longer process of HRT to diminish nitrate due to chemical nature of nitrogen that is considered complex. Nitrogen was assumed to have various oxidation numbers that are subject to change due to the influence of various processes existed in living beings. Nitrate is formed from the result of nitrate oxidation and the oxidation process changes nitrate to be the supply of oxygen in RBC, although it is under the limit. On the other hand, longer HRT would enable to end with higher organic concentration.

Below is figure 3, removing the organic loads in concentration of COD, 637.52 mg/L, 844.51 mg/L and 1926.08 mg/L on *tempe* wastewater.

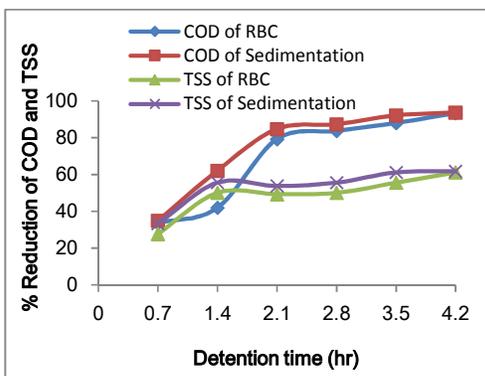


Figure 3.
The Removal of COD and TSS in COD
Inlet 637.52 mg/L

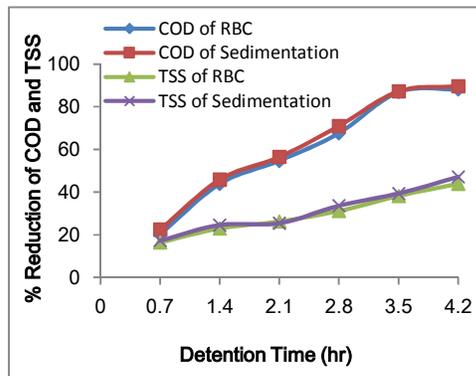


Figure 4.
The Removal of COD and TSS in COD Inlet
844.51 mg/L

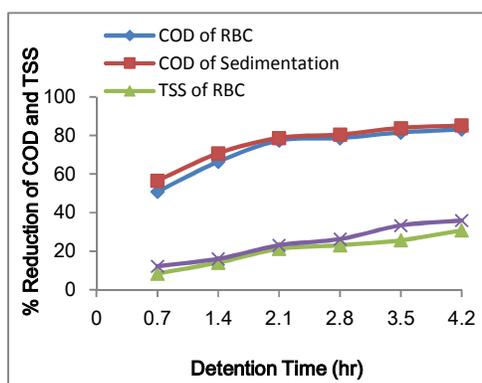


Figure 5.
The Removal of COD and TSS in COD
Inlet 1926.08 mg/L

In terms of parameter of Total Suspended Solid (TSS), that the result of RBC analysis was still below that of being required, as the result of removing TSS only arrives at 29.9% - 61.8% in HRT 4.2 hours. This percentage shows that the HRT increases subsequently higher; however, arriving at HRT 4.2 hours the removal fails to arrive at optimum level. This was due to the contents of the wastewater, that contains organic COD and high BOD. Not to mention, the wastewater also loads N elements, in this case, the NO₃ was identified higher than the wastewater in origin that is 15.2 mg/L. This element was a nutrient for microorganism that could lead to form solid TSS. Therefore, this sedimentation needed to be well processed before being treated by RBC to make TSS removal be optimal.

b. Removing COD with concentration was more than 2000 mg/L

The capability of RBC removal in *tempe* wastewater with its concentration is more than 2000 mg/L, that are 2370, 3273.6, 4815.2, 6091.2, and 8519 mg/L is concentration of high organic parameter. This was called a removal process. Moreover, this was related to the criteria of Organic Loading in one industry around 10-50 gBOD/m².day.

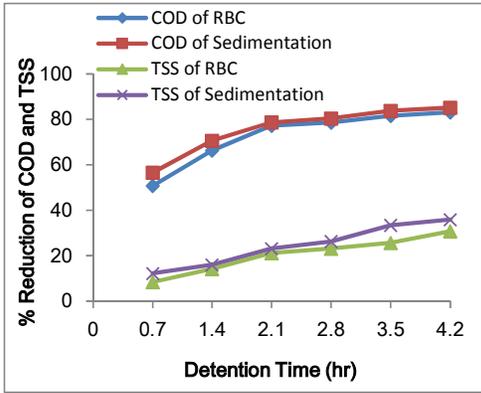


Figure 6.
The Removal of COD and TSS in COD
Inlet 2370 mg/L

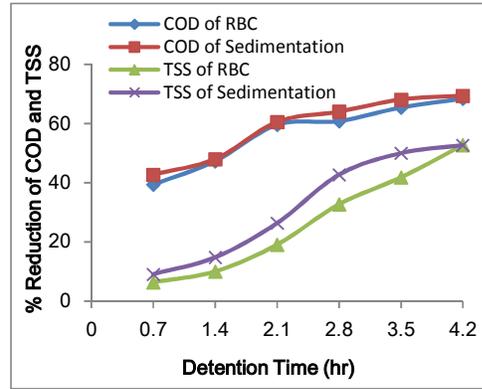


Figure 7.
The Removal of COD and TSS in COD
Inlet 3273.6 mg/L

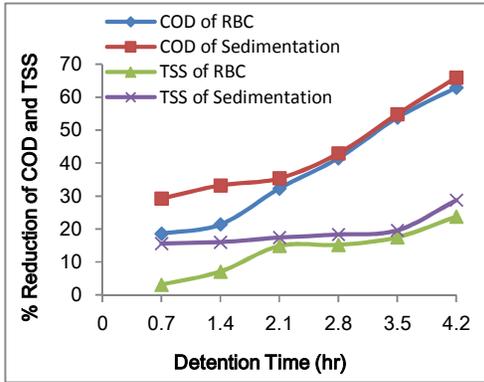


Figure 8
The Removal of COD and TSS in COD
Inlet 4815.2 mg/L

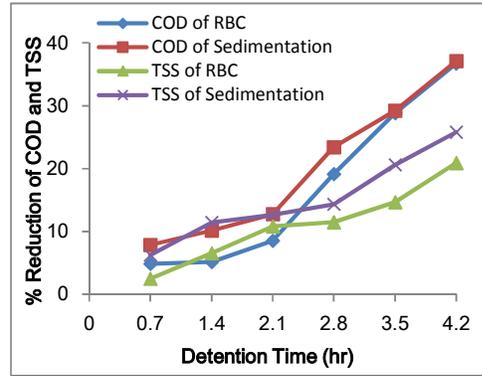


Figure 9
The Removal of COD and TSS in COD Inlet
6091.2 mg/L

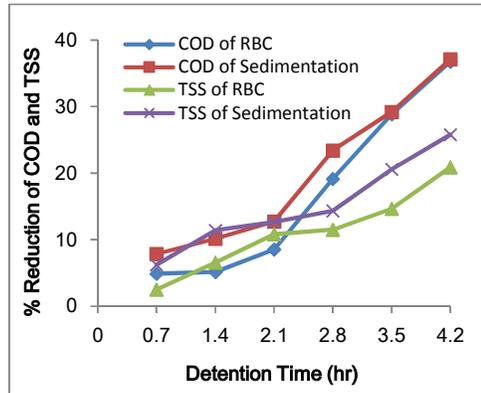


Figure 10
The Removal of COD and TSS in COD Inlet
8519 mg/L

Based on the result above it was known that the use of RBC had not been capable of reducing TSS optimally because the original TSS content was very high. Besides, the nitrogen content or nitrate element (NO₃) in tempe wastewater was also very high. Meanwhile, the main function of RBC was to decompose the organic content in the wastewater water. If the TSS content was too high, the extra/additional installation or

structure before RBC that was sedimentation vessel is required. This functioned to reduce the suspension of high solid matter. This extra structure could increase the RBC performance in order to remove the organic content. Therefore in this research, the researcher had provided this sedimentation vessel after RBC processing, and this secondary clarifier was effective to reduce the organic content of TSS. This could be proved from the figure 3 and 4 above. It was known that the removal of organic content in the secondary clarifier is increasing.

Parameter of dissolved of oxygen, pH and temperature

The RBC treatment is a kind of biological treatment in aerobic condition. It required soluble oxygen to grow up. In this research, DO was concentrated at COD less than 1000 mg/L. DO has been identified to range about 1.1 – 1.4 mg/L. This is due to the reason that the microorganism that is supposed to decompose the organic loading does not hard enough so that microorganism fail to complete the capacity of DO. However, reserved DO in wastewater enables microorganism to decompose so that the result of removing organic loading is high as well.

Wastewater from *tempe* making process in this research reveals that the effluent has neutral pH, between 6.52 – 7.84. Parameter pH affects the biological process of water flowing that ranges within 6,5 – 8,5. Excessively high pH (more than 8,5) would impede the activity of biofilm, but if the pH is lower than 6,5, it would proliferate the growth of the fungi and this would lead a competition with the bacteria inside the metabolism of organic material.

Temperature is settled under room-temperature by making room ventilation open so that the air flows freely in and out, while wastewater temperature in RBC is made to ranged from 23,5°C to 28°C, this condition would lead mesofolic micro-organism dominate the process of decomposing pollutant in RBC reactor. Optimal temperature for process RBC ranges within 15°C - 40°C. If the temperature was too high the process would impede the activities of the enzyme in the cell. Therefore, increasing temperature would affect the efficiency of the process.

The shape effect of disc to the device performance

In RBC performance, contactor was designed to diminish the power of fluid and hydraulic cords. For more than 30 years, researches on the use of RBC for contactor have been undertaken and this found that contactor in RBC that is designed to provide as wide as possible, a surface would be able to enhance the growth of microorganism. Moreover, drainage flow was needed to be installed to all contactor along with the rotating disk so that the power of water drag can be diminished. As a result, micoba can grow optimally^[23].

Disc surface with rough and splitted on the side, will further expand the surface layer of microorganisms, and if the process continues, the outer most layer of microorganisms will shed alternately. The roughness surface could increase the dissolved oxygen delivery capacity. This leads to random flow around microorganisms layers, so the DO transfer rate was also high. This is evidenced by the organic loading values that can be achieved by RBC, in the range of 11.91 - 43.18 g / m².day. The percentage of COD removal is more than 80%.

CONCLUSION

RBC with the roughness disk surface could maximally remove COD of 93.27% at HRT 4.2 hours with COD inlet 637.52 mg/L. The removal efficiency of organic content by reactor RBC was not only optimum for COD inlet 637.52 mg/L but also for COD inlet 1926.08 mg/L with its removal of 85.17% in HRT 4.2 hours. the TSS removal ranged from 29.9% to 67.44% and nitrate removal range from 36.25% to 57%. The range temperature at 26⁰C – 28⁰ C with the pH 6.52 – 7.84, is the neutral pH and DO maximum of research results 1.3.

This reactor works optimally at Organic Surface Loading (OSL) 11.91 – 47.33 gBOD/m².day and Hydraulic Loading Rate (HLR) 0.03 – 0.074 m³/m².day. This was the range of numbers for waste water is due to a process of nitrification.

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