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# Aerobic Tofu Industrial Wastewater Treatment Installation Planning Using Rotating Biological Contractors (RBC) (Case Study at "Sari Murni" Tofu Factory, Krajan Village, Mojosongo Village, Surakarta City)

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A R T I C L E I N F O

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A B S T R A C T

The planned advanced processing technology is aerobically using Rotating Biological Contactors (RBC). The research method used was la iterature study, in-depth interviews, and direct observation to the Sari Murni tofu factory to determine the existing conditions of the existing Wastewater Treatment Plant (IPAL), as well as to determine the discharge and characteristics of the tofu wastewater. From the results of observations in the field, it is known that the maximum discharge of tofu wastewater produced every day is 25 m3 with an average BOD parameter value of 200 mg/L. Furthermore, the researchers calculated the required RBC dimensions so that the BOD parameter value could be below standard (<150 mg/L). Based on the calculation results, it can be seen that the surface area of the Rotating Biological Contractors (RBC) required is 450 m2, the number of disks required is 131 pieces, and the length of the Rotating Biological Contractors (RBC) rotor required is 2.5 meters.

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## INTRODUCTION

Both as a side dish and as a snack, tofu is now often consumed by the general public. Tofu is a processed soybean food that is very popular in East and Southeast Asian countries. Currently tofu consumption continues to increase, not only in Asia but also in Europe and America (Wresta et al., 2021). Soy protein extract called tofu has been coagulated using acids, calcium ions, or other coagulants (Kristanto, 2002). Special equipment is needed to make tofu, especially to crush the peanuts into a pulp. Protein in soybeans must be dissolved using water as a solvent before tofu can be produced. After the protein has dissolved, another attempt is made to precipitate by adding a precipitating agent, and this process is repeated until the protein clumps forming tofu are visible. The process of making tofu is usually done in a traditional way. In addition to producing the main product, namely tofu, this activity also generates waste during the production process, namely solid, liquid and gas waste.

Tofu dregs are a source of solid waste that can be used to make various kinds of culinary delights, one of which is tempeh gembus. (Pohan, 2008), while the liquid waste generated during washing and boiling tofu is generally not treated properly and tends to only be disposed of into the nearest waterway (Effendi et al., 2019). This of course can pollute the environment and give off an unwanted aroma. When tofu is boiled or fried, wood or sawdust is used as fuel, which produces waste gas in the form of smoke. The liquid waste generated during tofu production can be disruptive and cause problems, especially if it is discharged into waterways without any processing (Arsil and Supriyanto). According to a study, the amount of organic compounds in wastewater is relatively high, ranging from 4,000 to 12,000 parts per million (ppm), and the biochemical oxygen demand (BOD) is between 2,000 and 10,000 ppm. The liquid waste also has low acidity, with a pH of 4-5. (Kristanto, 2002).

Wastewater Treatment Plant (WWTP) can be used to treat tofu waste before it is discharged into the environment as an effort to reduce the hazards that may arise (Tanaka, 2008). The tofu industry is one of the fastest growing industries among small-scale industries in Indonesia (Oktorina et al., 2019). The "Sari Murni" tofu factory is one of the tofu factories in Krajan Village, Mojosongo, Surakarta City. In the tofu industrial center in Kampung Krajan, there are around 120 heads of families who depend on home-based tofu-making businesses (Sudaryantiningsih, & Pambudi, 2021). The city of Surakarta is currently a popular tourist destination city, a cultural center and a city for the main destination of MICE (Meeting, Incentive, Convention and Exhibition) (Pambudi et al, 2022), therefore the management of industrial wastewater in Surakarta City like tofu liquid waste needs to be done properly so as not to pollute the environment and disturb the beauty of the city.

From the results of observations in the field, it is known that the tofu waste treatment technology used at the "Sari Murni" factory is currently only in the form of waste treatment with an anaerobic system using a simple biodigester. From the results of research conducted previously by Pambudi & Gunawan (2014) it can be seen that the values of several parameters of tofu wastewater processed by the anaerobic process still cannot meet the Wastewater Quality

Standards set by the government in Regional Regulation (PERDA) of Central Java Province No. . 5 of 2012 concerning Amendments to Central Java Provincial Regulation Number 10 of 2014 concerning Quality Standards for Tofu and Tempeh Industry Wastewater. From the results of research conducted by Pambudi and Gunawan (2014) it is known that the WWTP at the Sari Murni tofu factory has not been able to reduce the BOD content of processed tofu wastewater, the BOD parameter value of tofu waste is still above the wastewater quality standard of 200 mg/L (Pambudi and Gunawan, 2014).

Based on these problems, it is necessary to study the addition of an advanced treatment unit that allows a decrease in the value of the BOD parameter in wastewater using simple technology and easy to operate (appropriate technology). According to Pambudi et al. (2021), the combination of anaerobic and aerobic treatment processes can provide benefits such as saving electricity, and better effluent quality so that it can be accepted by the community, especially tofu factory business owners. One of the advanced aerobic treatment technologies that can be selected is Rotating Biological Contactors (RBC). RBC is a biological wastewater treatment technology with a type of microbial growth attached to a particular medium (Abdelfattah et al., 2020). RBC was chosen because it has several advantages, namely easy to operate, saves electricity when compared to activated sludge, produces less sludge, and is able to accept a higher Volumetric Organic Loading (VOL) than activated sludge so it saves more space (Waqas & Bilad, 2019). Based on this background, the researchers conducted research on the Aerobic Advanced Planning of the Tofu Industrial Wastewater Treatment Plant using Rotating Biological Contractors (RBC), Case Study at the Sari Murni Tofu Factory, Krajan, Mojosongo, Surakarta.

## THEORETICAL REVIEW

*Rotating Biological Contactors (RBC)*

1). RBC Principle

German scientists created Rotating Biological Contactors (RBC) in the 1960s. Although not completely ruling out the possibility for use in anaerobic settings, RBC is one of the technologies to treat wastewater biologically by growing microbes attached to the media. Rotating Biological Contactors (RBC) are very easy to use and use less energy. Because of this, RBC is given preference when developing countries choose aerobic process technology. The RBC consists of a number of rotating disc-shaped contactors housed in a semicircular tank (figure 2). The space between the contactors is relatively small, and 40 percent of the surface area of the contactors is covered in waste.

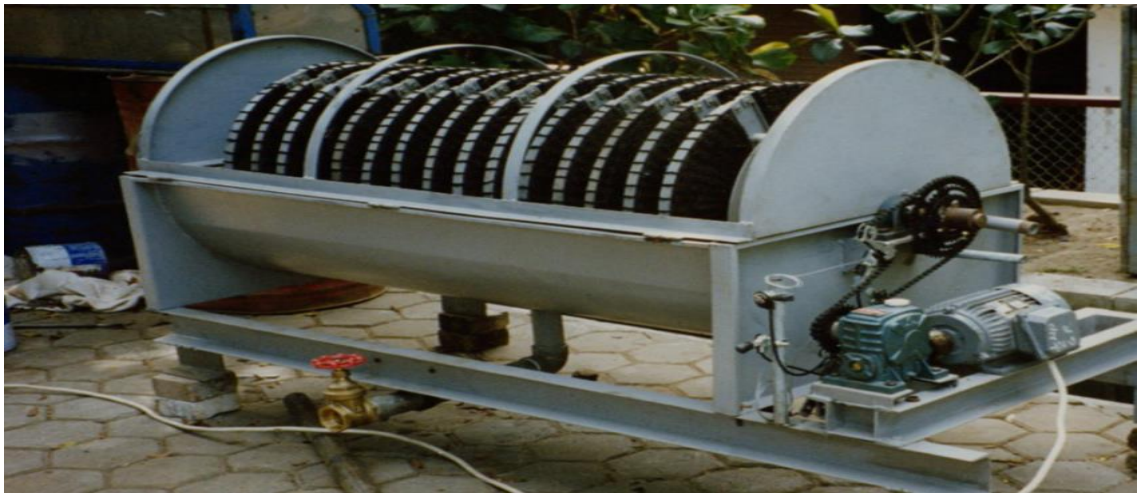

Figure 1. The Shape of Rotating Biological Contactors (RBC)

The operating concept of RBC is as follows: after regularly adding wastewater to the vessel and rotating the contactor slowly, microorganisms will develop and form a film on the surface of the contactor. These bacteria will decompose waste organic matter and remove it. Media clogging can occur due to excessive organic loading. Aerobic microbial reactions depend on the organic concentration and also on the oxygen concentration in the system. If the BOD representing the organic concentration is still low, the BOD Flux will increase proportionally depending on the BOD. If the BOD concentration is higher, there is a shortage of oxygen to process it, so the BOD Flux becomes stable independent of the effluent BOD.

2). RBC Advantages and Disadvantages

RBC has a number of advantages over standard aerobic procedures such as activated sludge, including the following:

a. Anyone can operate it because it's easy to do just by rotating it. The concentration of microorganisms in the aeration tank needs to be continuously monitored and managed during the activated sludge process. In addition, a symptom called bulking occurs occasionally and needs to be treated with care.

b. When compared to the activated sludge process, RBC is much more effective in supplying oxygen to organisms while using less electricity.

c. Compared to the activated sludge method, RBC produces less sludge because the bacterial species are more varied. This microbial diversity results in a micro-ecosystem effect where one organism replaces another, reducing the amount of sludge.

d. RBC can accept higher volumetric organic loading than the activated sludge process, and can also be placed on top of construction to be stacked, thus saving space, suitable for locations where land is limited.

In addition to the advantages, RBC also has a few weaknesses, the weaknesses of the Rotating Biological Contactors (RBC) are:
a. In large-scale WWTPs, activated sludge is generally more economical than RBC in terms of initial investment
b. If the effluent quality is to be very high, it is generally more suitable to be treated by an activated sludge process
c. If the organic loading is too high, blockages can occur

3). RBC Parameters

The following variables are used in the RBC design and have an impact on the performance of the RBC system namely:
a. BOD Surface Loading

BOD Surface Loading is the daily addition of BOD to the total contactor surface area. It results from a microbial response that depends on the organic matter in the system. This parameter is the basic and important parameter for RBC. BOD Surface Loading which is commonly used in Japan is 5-15 g/m2.day for domestic wastewater and 10-50 g/m2.day for industrial waste water.

b. Hydraulic Loading

Hydraulic Loading is the amount of wastewater per day per surface area of all contactors treated with RBC facilities (L/m2.day). An example of a hydraulic loading value is 50-100 L/m2.day if the influent BOD is 200 ppm, and 10-20 L/m2.day if the influent BOD is 500-1000 ppm.

c. Stage Number

If the RBC vessel and rotor are divided into several parts, there will be variations in the types of microorganisms that arise in each of these parts. This section is referred to as the stage. The diversity of these microorganisms will result in an increase in RBC efficiency. Even in one vessel there are often differences in the types of microorganisms in the upstream and downstream parts and this is influenced by the type of media used.

d. G Values

G Value is the ratio between the volume of the RBC vessel and the surface area of the contactor (L/m2). If the G Value is too high, it is feared that the contact efficiency between microbes and wastewater will decrease, if the G Value is too low there is a risk of media clogging. The commonly used G Value is 5-8 L/m2.

e. Diameter

The diameter of the contactor is closely related to the surface area. The diameter of the RBC used commercially is between 1-3.6 m.
In general, one large-diameter RBC is less expensive than several small-diameter RBCs if a large enough surface area is required. The thing that must be considered is that the large RBC must be strong enough in structure.

f. Spin Speed

More oxygen is produced in the RBC housing with the faster rotation of the RBC rotor. The metabolism of aerobic microorganisms will be assisted by oxygen, but the faster the rotor rotates, the more electricity is consumed. In addition, rotating the rotor too fast inhibits the formation of the microbial film, and once it has developed, it is easy to peel off again. Peripheral speed, which is usually used to determine the rotational speed of the RBC rotor and ranges from 15-20 m/min. The number of rotations per minute required will depend on the RBC diameter and peripheral speed.

g. temperature

Temperature affects how bacteria respond. The range of 15 to 400 Celsius is the operating temperature range for RBC.

4). Design Procedure

BOD Surface Loading is the main design factor which is usually used to design RBC. The BOD processed with RBC is calculated and this amount is divided by the BOD Surface Loading value that will be used. The results of these calculations indicate the surface area of the contactor needed to treat the waste. In the explanation above, BOD Surface Loading which is commonly used in Japan is 5-15 g/m2.day for domestic wastewater and 10-50 g/m2.day for industrial waste water. The BOD Surface Loading value can change depending on the characteristics of the wastewater, the BOD target, the type of RBC to be used, the local climate and so on.

*Processing Efficiency*

The ratio between the amount of organic matter removed during the treatment process and the initial concentration is the success of waste treatment (Greenham et al., 2019). To find out the efficiency of the wastewater treatment plant (IPAL), the following formula can be used:

$$\%\ Efficiency = \frac{(\text{Influent Concentration} - \text{Effluent Concentration})}{\text{Influent Concentration}} \text{ x } 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

## METHODOLOGY

*Research Sites*

The location of this research is at the "Sari Murni" tofu factory located in Krajan Village, RT 03, RW 03, Mojosongo Village, Jebres District, Surakarta.

*Data collection technique*

Data collection techniques used in this study, namely:

a. Deep interview

The researcher conducted in-depth interviews with everyone at the research location who was deemed eligible to share knowledge related to the research problem.

b. Observation / Observation

Researchers also made direct observations at the research location and took photos, recorded events, and measured the discharge of waste.

c. Study of literature

Researchers search for and examine documents relevant to the research title, these documents are in the form of previous studies, books, journals, internet browsing, and other written materials relevant to the research title.

*Research Implementation Steps*

The stages in carrying out this research are:

a. Researchers interviewed the owners and employees of the "Sari Murni" tofu factory to find information or primary data related to factory operating hours, tofu production capacity in one day, water usage in one day, waste discharge generated in one day, and wastewater treatment techniques used. So far this has been done by the "Sari Murni" factory.

b. Researchers directly observed the tofu production process, the amount of water used, the amount of waste generated in one day, as well as the waste water treatment building at the study site.

c. Researchers search for various literature that is relevant to the research title.

d. From reading the results of a previous study conducted by Pambudi & Gunawan (2014), researchers know that the WWTP at the "Sari Murni" tofu factory has not been able to reduce the value of the Biochemical Oxygend Demand (BOD) parameter of the tofu wastewater.

e. Researchers plan to have an advanced aerobic wastewater treatment process to reduce the value of the Biochemical Oxygend Demand (BOD) parameter by using Rotating Biological Contactors (RBC) technology.

f. The researcher observed that the BOD parameter value resulting from anaerobic treatment from the existing WWTP was fluctuating so that the planned RBC construction could treat waste with a higher BOD value, the researchers took the highest effluent BOD number resulting from anaerobic treatment from the existing WWTP which was 200 mg/l.

g. The researchers determined that the BOD reduction efficiency of tofu waste treated with RBC reached 90%, so the effluent BOD to be achieved (targeted) was 20 mg/l.

h. The researcher calculated the RBC surface area needed to reduce the BOD value of wastewater and also calculated the number of disks and the required RBC rotor length.

i. The researcher compiled a research report.

## RESULTS AND DISCUSSIONS

The main design parameter that is commonly used to design the Rotating Biological Contactors (RBC) process is BOD Surface Loading (Han et al., 2019). The BOD processed with RBC is calculated and this amount is divided by the BOD Surface Loading value that will be used. The results of these calculations indicate the surface area of the contactor needed to treat the waste. In the explanation above, BOD Surface Loading which is commonly used in Japan is 5-15 g/m2.day for domestic wastewater and 10-50 g/m2.day for industrial waste water. The BOD Surface Loading value can change depending on the characteristics of the wastewater, the BOD target, the type of RBC to be used, the local climate and so on.

If you already know the relationship between BOD effluent and BOD Flux. Based on this relationship, we can determine the surface area more precisely depending on the targeted BOD. In this study, the targeted BOD was 20 mg/l (90 percent efficiency). In the case in the field it is known that the BOD of the wastewater to be treated is 200 mg/L with a waste discharge of 25 m3/day. The targeted effluent BOD is 20 mg/L, so what surface area of Rotating Biological Contactors (RBC) is needed to reduce the BOD parameter value of Sari Murni's tofu factory wastewater according to the target to be achieved (90% efficiency) and how many disks or discs required and what is the length of the RBC rotor?

*Calculate the Required RBC Surface Area*

1. Influent BOD is 200 mg/L
2. The effluent BOD target to be achieved is 20 mg/L
3. Wastewater debit = 25 m3/day
4. BOD calculations that will be eliminated are: (0.2 g/l – 0.02 g/l) x 25 m3/day = 4.5 Kg/day
5. After knowing the BOD to be removed, then it is necessary to know the relationship between effluent BOD and Flux BOD, in other words, how many grams of BOD can be reduced per contactor surface area per day. To find out the BOD Flux, we can pay attention to Figure 3 below:

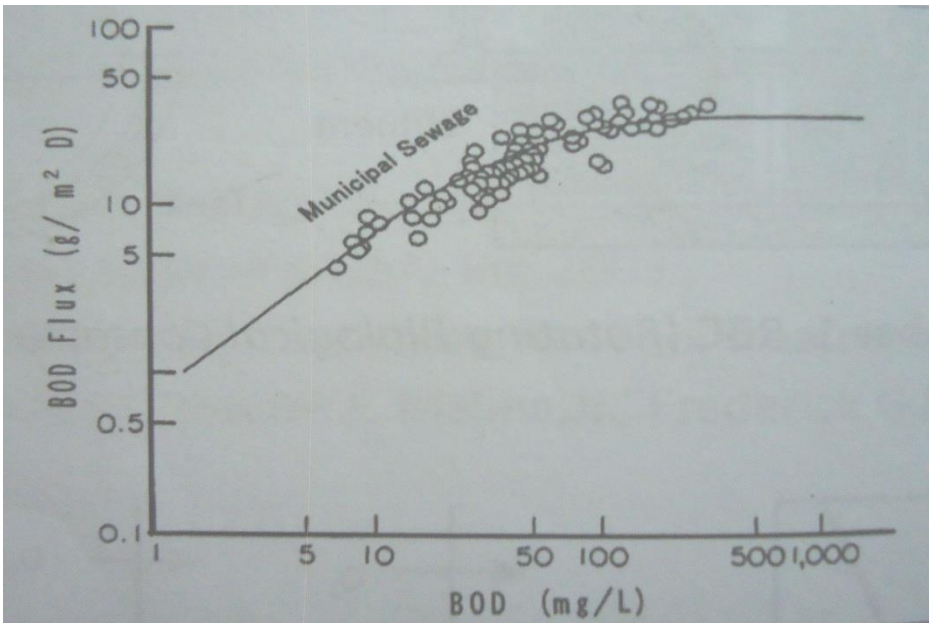


Figure 2. The Relationship Between BOD and BOD Flux

In Figure 2 above, we can see that if the BOD effluent is targeted at 20 mg/L, then the BOD Flux is 10 g/m2, so the required Surface Area is: 4.5 Kg/day: 10 g/m2 = 450 m2.

*Calculate the number of disks or discs needed and the length of the RBC to be made*
1). Calculates the number of disks or RBC discs required
It is planned that the diameter of the disc or RBC discs to be made is 1.5 meters (r = 0.75 m). Calculating the required RBC disc or disks :

(0.75)2 x π x 2 x 0.98 = 3.46 m2……..……(2)

Where :
- (0.75)2 x π = formula for the area of a disk circle for the planned RBC
- 2 = both sides of the disc surface
- 0.98 = disk diameter minus the axle diameter (2%)

So the number of disks or discs needed is = 450 m2 : 3.46 m2 = 131 pieces

2). Calculate the required RBC rotor length
- The disc surface width is defined as 15 mm
- The distance between the discs is set at 3 mm
- The required RBC rotor length is:

(15 mm + 3 mm) x 131 disks = 2358 mm = 2.35 meters
- RBC is divided into 2 (two) stages, the distance between stages is 0.15 m, so the length of RBC is 2.35 m + 0.15 m = 2.5 meters

3). Planned RBC sketch drawing

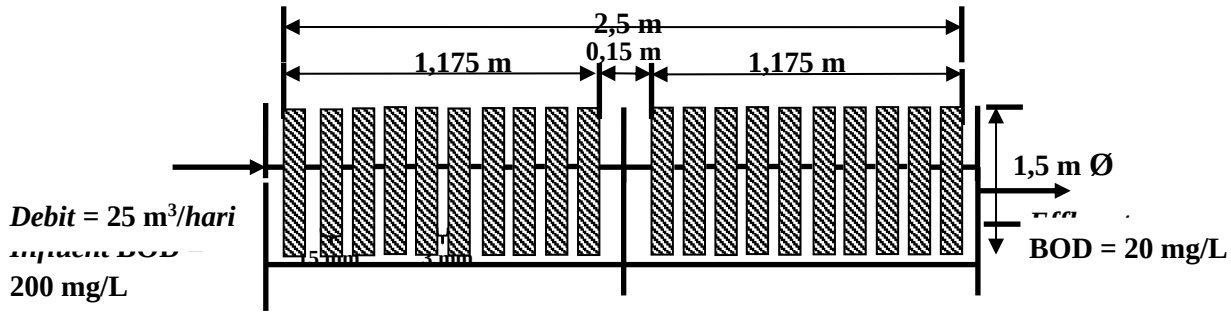


Figure 3. RBC Sketch for Sari Murni Tofu Factory

Based on the calculations performed, it can be seen that the surface area of the Rotating Biological Contractors (RBC) required is 450 m2, the number of disks required is 131 pieces, and the length of the Rotating Biological Contractors (RBC) rotor required is 2.5 meters. It is planned to make 2 (two) stages of Rotating Biological Contractors (RBC) so that the load of the supporting iron or RBC rotor axle is not too heavy to hold the disk or disc load so that the service life or life of the RBC can last longer. Disc media or discs that will be used should have high efficiency and longevity. A good media as RBC disc or disc material is a three-dimensional lattice made from polypropylene plastic waste which has an efficiency of 3 (three) to 4 (four) times greater than conventional RBC (Tanaka, 2008).

## CONCLUSIONS AND RECOMMENDATIONS

*Conclusions*

The surface area of Rotating Biological Contactors (RBC) required to reduce the Biochemical Oxygend Demand (BOD) parameter value of Sari Murni's tofu factory wastewater from 200 ppm to 20 ppm according to the 90 percent efficiency target is 450 m2, while the number of disks needed is as many as 131 pieces, and the required length of Rotating Biological Contactors (RBC) is 2.5 m.

*Recommendations*

Seeing that the BOD parameter values of Sari Murni's tofu wastewater processed by the existing WWTP (anaerobic) do not meet the quality standards set by the government, the factory owner should consider using advanced wastewater treatment technology with an aerobic process such as Rotating Biological Contactors (RBC) to obtain efficiency. higher wastewater treatment, so that through a wastewater treatment process that combines anaerobic and aerobic processes can produce a low Biochemical Oxygend Demand (BOD) effluent parameter value and is safe for the environment.

**FURTHER STUDY**

Furthermore, the researchers calculated the required RBC dimensions so that the BOD parameter value could be below standard (<150 mg/L). The target for processing efficiency with RBC is determined to be 90 percent, so the target effluent BOD is 20 mg/L, so what surface area of RBC is required, the length of the RBC rotor and how many disks or discs are needed by the RBC.

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