HYBRID ANAEROBIC BAFFLED REACTOR FOR REMOVAL OF BOD AND PHOSPHATE CONCENTRATION IN DOMESTIC WASTEWATER

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ABSTRACT

Hybrid Anaerobic Baffled Reactor (HABR) is a development technology from the Anaerobic Baffled Reactor (ABR), which was already known as a technology that is successful in treating domestic waste. Aims: The objectives of these studies were to investigate the efficiency of reducing BOD and phosphate levels in HABR with zeolite (ZE) and activated carbon (AC) media. Methodology and Results: HABR reactor made of acrylic material with a size of 90 cm x 20 cm x 30 cm. The reactor designed has 7 compartments, with details the first 5 compartments are suspended growth microorganism reactors and the next 2 compartments are attached growth microorganism reactors. Conclusion, significance, and impact of study: The result of the research showed that the efficiency of reducing BOD concentration in the reactor with ZE and AC media were 59.30% and 65.12%, respectively. The final BOD concentration in the AC reactor is 30 mg/L, this value meets the domestic wastewater quality standard required by East Java Governor Regulation Number 72 of 2013 concerning Wastewater Quality Standards for Industry and/or Other Business Activities. The final BOD concentration in the ZE reactor exceeded the required quality standard with a value of 35 mg/L. The final phosphate levels of the two reactors meet the wastewater quality standards for business and/or laundry activities with a maximum phosphate concentration of 10 mg/L. The final phosphate levels in the ZE and AC reactors were 3.74 mg/L and 8.79 mg/L, respectively. The efficiency of phosphate removal in ZE and AC reactors were 70.58% and 30.87%, respectively.

KEYWORDS

- Activated carbon
- Domestic wastewater
- Hybrid anaerobic baffled reactor
- Zeolite
1. INTRODUCTION

Domestic wastewater generated from household activities is usually not treated properly. The domestic wastewater is directly discharged to the receiving water body without regard to the required quality standards. This not only causes problems related to disease vectors and sanitation, but also contamination of surface and ground water (Ratnawati & Ulfah, 2020). Moreover, domestic wastewater contains high organic matter and nutrients (Suastuti et al., 2015). Alternative domestic wastewater treatment is needed to overcome these problems and to meet the quality standards based on East Java Governor Regulation Number 72 of 2013 concerning Wastewater Quality Standards for Industry and/or Other Business Activities.

Alternative technologies for dealing with domestic wastewater are quite diverse. One of the wastewater treatment technologies that has a simple operation and relatively low cost is the Hybrid Anaerobic Baffled Reactor (HABR) technology. HABR is a development technology from the Anaerobic Baffled Reactor (ABR), which was already known as a technology that is quite successful in treating domestic waste. HABR technology is a modification in the biological treatment process which is carried out by combining the growth of suspended and attached biomass in one reactor (Figure 1). The advantage of this reactor design is that it can maintain high concentrations of biomass. Thus, it can improve the efficiency of domestic wastewater treatment which has a high content of organic matter and nutrients.

![Figure 1 Differences in HABR and ABR reactor unit designs (Aqaneghad et al., 2017)](image)

HABR technology also uses a reactor that has several separators, but the reactor used in this technology is a combination of a suspended reactor and an attached reactor (Aqaneghad et al.,...
Previous studies reporting the success of HABR technology in wastewater treatment have been carried out by Aqaneghad et al., (2017), Khalekuzzaman et al., (2018) and Khalekuzzaman et al., (2019). Research conducted by Aqaneghad et al., (2017) concluded that the way HABR works is the same as ABR. The difference lies in the combination of suspended reactors in the initial compartment, which is followed by an attached reactor containing the media. The performance of HABR in treating domestic wastewater is also influenced by the type of media used in the attached reactor. This media is used as a place to attach microorganisms that help reduce pollutant levels in domestic wastewater.

Aqaneghad et al., (2017) drained wastewater into a reactor unit with 5 compartments, which were divided into a suspended reactor in the initial compartment and 4 attached reactor compartments filled with media and succeeded in reducing the pollutant load of total BOD and phosphate levels by 94.5% and 30.2%. Khalekuzzaman et al., (2018) stated that the more the number of compartments, the higher the efficiency of HABR performance. Research conducted by Khalekuzzaman et al., (2018) with the HABR design consisting of 7 compartments resulted in a more optimum reactor performance compared to 5 compartments. The types of media used in the attached reactor are quite diverse, including activated charcoal (Mifbakhuddin, 2010) and zeolite (Ronald, 2008). This reactor maintains microorganisms that carry out the processing in a state attached to the media, where this attachment is called a biofilm (Nilasari et al., 2016). The life cycle of the biofilm phase is the biofilm attachment phase to the media, the growth phase, and the detachment phase (Hastuti et al., 2017).

The objectives of this study were to investigate the efficiency of reducing BOD and phosphate levels in HABR technology processing with activated carbon and zeolite media, and compare the final concentrations of BOD and phosphate of domestic wastewater quality standards as required by East Java Governor Regulation Number 72 of 2013 concerning Wastewater Quality Standards for Industry and/or Other Business Activities.

2. RESEARCH METHODOLOGY

2.1 Domestic Wastewater

Domestic wastewater comes from drainage channels in Kembangbahu Village, Kembangbahu District, Lamongan. The initial characteristics of domestic wastewater have BOD and phosphate levels that exceed the quality standards based on the Regulation of the Minister of Environment
and Forestry of the Republic of Indonesia Number 68 of 2016 (Table 1). Initial BOD and phosphate levels were 86.00 mg/L and 12.71 mg/L, respectively.

### Table 1: Characteristics of domestic wastewater

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Results</th>
<th>Quality standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physics Test</td>
<td>mg/L</td>
<td>436.00</td>
<td>50</td>
</tr>
<tr>
<td>Total Suspended Solid</td>
<td>mg/L</td>
<td>436.00</td>
<td>50</td>
</tr>
<tr>
<td>Temperature value</td>
<td>°C</td>
<td>30.00</td>
<td>-</td>
</tr>
<tr>
<td>Chemical Test</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH value</td>
<td></td>
<td>7.00</td>
<td>6-9</td>
</tr>
<tr>
<td>BOD concentration</td>
<td>mg/L</td>
<td>86.00</td>
<td>30</td>
</tr>
<tr>
<td>COD concentration</td>
<td>mg/L</td>
<td>187.00</td>
<td>50</td>
</tr>
<tr>
<td>Phosphate concentration</td>
<td>mg/L PO_4-P</td>
<td>12.71</td>
<td>-</td>
</tr>
<tr>
<td>Ammonia concentration</td>
<td>mg/L NH_3-N</td>
<td>30.19</td>
<td>-</td>
</tr>
</tbody>
</table>

\*East Java Governor Regulation Number 72 of 2013 concerning Wastewater Quality Standards for Industry and/or Other Business Activities

#### 2.2 Seeding and Acclimatization

Seeding and acclimatization are done by adding domestic wastewater into the HABR reactor naturally. The seeding stage is carried out for the growth of microorganisms, while acclimatization is carried out to adapt the microorganisms formed with organic materials to be processed. To determine the steady state condition of the growth process of microorganisms in the form of a biofilm layer, a permanganate test was carried out (Ratnawati & Kholif, 2018).

#### 2.3 Experimental Design

HABR reactor made of acrylic material with a size of 90 cm x 20 cm x 30 cm (Figure 2). The reactor designed has 7 compartments, with details the first 5 compartments are suspended growth microorganism reactors and the next 2 compartments are attached growth microorganism reactors.
Compartments 6 and 7 contain zeolite (ZE) and activated carbon (AC) media, respectively. Each medium is placed in a different reactor, so the total reactor required with duplo is 4 reactors (Table 2). Domestic wastewater flows into each HABR reactor as much as 24 liters per day or 1 liter per hour. Domestic wastewater will go through compartment 1 which has a wider space than compartments 2-7, serves as a place for sedimentation. Compartments 2-5 are suspended reactors with a zigzag flow system that functions to mix domestic wastewater homogeneously. In addition, in compartments 2-5 decomposing microorganisms can float freely in search of their energy source. Wastewater enters compartments 6 and 7 where there is a medium which is a medium for growing microorganisms from the reactor attached to the last two compartments of HABR technology. Sample collection was carried out for 5 consecutive days. Wastewater samples were taken at the outlet of the HABR reactor, then parameter analysis was carried out which included BOD concentration, phosphate concentration, pH values, and temperature values (APHA et al, 2005).

**Table 2** Experimental condition

<table>
<thead>
<tr>
<th>Reactor code</th>
<th>Media HABR</th>
<th>Replicate</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZE</td>
<td>Zeolite</td>
<td>2</td>
</tr>
<tr>
<td>AC</td>
<td>Activated carbon</td>
<td>2</td>
</tr>
<tr>
<td>Total reactor</td>
<td></td>
<td>4</td>
</tr>
</tbody>
</table>
3. RESULTS AND DISCUSSION

3.1 Seeding and Acclimatization Result

The seeding and acclimatization stages were carried out to determine the steady state conditions for the growth of microorganisms. Steady state conditions in the reactor can be determined by testing the levels of permanganate in each reactor. If a stable value of permanganate is obtained, then the growth of bacteria in the media is good and stable. The ZE and AC reactors have experienced stable conditions on the 5th day. On the 3rd day, stable conditions began to appear in each reactor (Figure 3). Permanganate test levels in the ZE media reactor on days 3, 4, and 5 were 72.68 mg/L, 64.26 mg/L, and 75.84 mg/L, respectively. The same trend is also seen in AA, on day 3 to day 5, permanganate values are stable with values of 82.16 mg/L, 81.53 mg/L, and 85.95 mg/L, respectively. The time required to reach a stable condition in this study is the same as the research conducted by Kholif et al., (2020) regarding the combination of filtration and ABR reported that the time required for the seeding and acclimatization process was 5 days to arrive at a stable condition.

![Figure 3 Biofilm growth during the seeding process](image)

3.2 Changes in Temperature

Temperature values during the study were in the range of 29-30°C (Figure 4). This temperature
range is included in the mesophilic temperature (20-45°C), which is in the optimum conditions for the decomposition of organic matter (Ratnawati & Kholif, 2018). Mustamin et al., (2020) reported that this value range indicates that the temperature is still within the range of microbial life requirements, namely 25-30°C, high temperatures will damage the process by preventing enzyme activity in cells. During the process of decomposition of organic matter, microorganisms will decompose the substrate and produce heat (Ratnawati et al., 2020). Sufficient substrate material will cause microorganisms to thrive, resulting in rapid degradation of organic matter by microorganisms. The increase in temperature value comes from the heat energy produced by microorganisms during their metabolic processes.

![Figure 4](image_url)

**Figure 4** Temperature value in domestic wastewater during degradation process

### 3.3 Changes in pH value

The pH values during the study ranged from 7-7.9 (Figure 5). The pH value is in the range of neutral pH values which is the optimum value range for the growth of microorganisms (Ratnawati & Kholif, 2018). This pH stability is thought to be due to the activity of good microorganisms found in domestic wastewater. The decomposition process runs perfectly when the pH value is 6-9, because a pH that is too high (> 9) will inhibit the activity of microorganisms while a pH value below 6 will result in fungal growth and competition with bacteria in the metabolism of organic matter (Mustamin et al., 2020)
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Sugito, Ratnawati, Afiafani
p-ISSN 2579-9150; e-ISSN 2579-9207, Volume 5, Number 1, page 14-27, October 2021
Accredited SINTA 2 by Ministry of Research, Technology, and Higher Education of The Republic of Indonesia No. 23/E/KPT/2019 on August 8th, 2019 from October 1st, 2018 to September 30th, 2023

3.4 Changes in BOD Concentration

The decrease in BOD levels occurred in both HABR reactors at the beginning of the study until the end of the study (Figure 6). The initial BOD level in both reactors was 86 mg/L. In the ZE reactor, the highest decrease in BOD levels was on day 5, with the final BOD concentration of 35 mg/L. The final BOD concentration in the AC reactor was reached on the 5th day of the degradation process with a value of 30 mg/L. The decrease in BOD levels in the HABR reactor was due to the microorganisms present in the reactor breaking down complex organic matter into simpler forms (Ratnawati & Ulfah, 2020). The biofilm layer functions to decompose organic substances in wastewater. The decrease in BOD levels can also be due to the growth of microorganisms requiring organic matter as a source of nutrients (Ratnawati & Kholf, 2018).

The decrease in BOD levels is also influenced by the media present in HABR, both activated charcoal and zeolite because it can help capture and precipitate pollutant materials, both organic and inorganic substances (Nurmaliakasih et al., 2017). The molecules contained in the wastewater will stick to the surface of the adsorbent so that the adsorbent diffusion process occurs through the pores of the adsorbent (Kholf et al., 2020). Pollutant molecules present in wastewater will be absorbed on the outside, go to the pores, and then enter the inner wall. The absorption of these molecules will cause the removal of organic substances in wastewater (Widayaningsih, 2016).
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The final BOD level in the AC reactor has met the quality standards required by the East Java Provincial Governor Regulation Number 68 of 2016 concerning the Domestic Wastewater quality standard, which is 30 mg/L and in the ZE reactor the decrease in BOD5 levels is still above the quality standard of 35 mg/L. In the ZE reactor, the final BOD content did not meet the required quality standards.

Figure 6 BOD concentration in domestic wastewater during degradation process

The efficiency of reducing BOD levels in both reactors increased from the beginning to the end of the study (Figure 6). The highest efficiency of reducing BOD levels in the ZE reactor was achieved on day 5 with a value of 59.30%. The AC reactor has a higher BOD reduction efficiency than the ZE reactor with a value of 65.12% on the 5 day of the domestic waste biodegradation process.

Research conducted by Aqaneghad et al., (2017), reported that the efficiency of reducing BOD levels with the HABR reactor was able to reach 94.50%. Ratnawati & Kholif (2018) concluded that the treatment of Slaughterhouse liquid waste with ABR technology for 10 days was able to produce an efficiency of reducing BOD levels reaching 93-94%. The treatment of domestic wastewater using activated carbon media has also been studied by Ratnawati & Ulfah (2020) it is found that the efficiency of reducing BOD levels is 62.92-67.01%.
3.5 Changes in Phosphate Concentration

The decrease in phosphate levels occurred in both HABR reactors, either with ZE or AC media (Figure 7). Initial phosphate levels in both reactors were 12.71 mg/L. Phosphate levels gradually decreased from the beginning to the end of the study. In the ZE reactor, the highest decrease in phosphate levels occurred at the end of the study. The final phosphate level in the ZE reactor was 3.74 mg/L. The trend of decreasing phosphate levels also occurred in the AC reactor, phosphate levels experienced the highest decrease on the 5th day of the study. The final phosphate level in the AC reactor has a value of 8.79 mg/L. The decrease in phosphate levels in both reactors occurred due to degradation by microorganisms originating from wastewater. Organic phosphate in wastewater will be remodeled into inorganic phosphate by microorganisms which are used for microorganism life activities (Alifia and Ratnawati, 2020; Munawaroh et al., 2013).

ZE or AC media in the HABR reactor are able to absorb phosphate ions in wastewater, resulting in a decrease in phosphate levels. ZE and AC have an open pore structure and have a large internal surface area so that they are able to absorb phosphate pollutants (Ratnawati et al., 2019). The final phosphate levels of the two reactors meet the wastewater quality standards for business and/or laundry activities as required East Java Governor Regulation Number 72 of 2013 concerning Wastewater Quality Standards for Industry and/or Other Business Activities with a maximum phosphate concentration of 10 mg/L. The final phosphate levels in the ZE and AC...
reactors were 3.74 mg/L and 8.79 mg/L, respectively.

![Phosphate concentration in domestic wastewater during degradation process](image1.png)

**Figure 7** Phosphate concentration in domestic wastewater during degradation process

The efficiency of reducing phosphate levels in both reactors increased from the beginning to the end of the study (Figure 8). In the ZE reactor, the highest efficiency of reducing phosphate levels occurred on day 5 with a value of 70.58%. The same trend also occurs in the AA reactor. At the end of the study, the AA reactor had the highest efficiency of reducing phosphate levels compared to other days. The efficiency of reducing phosphate levels in the AA reactor has a lower value than the ZE reactor, which is 30.87%.

![Efficiency phosphate concentration removal in domestic wastewater during degradation process](image2.png)

**Figure 8** Efficiency phosphate concentration removal in domestic wastewater during degradation process
4. CONCLUSION

The efficiency of reducing BOD concentration in the ZE and AC reactors were 59.30% and 65.12%, respectively. The final BOD concentration in the AC reactor is 30 mg/L, this value meets the domestic wastewater quality standard required by East Java Governor Regulation Number 72 of 2013 concerning Wastewater Quality Standards for Industry and/or Other Business Activities. The final BOD concentration in the ZE reactor exceeded the required quality standard with a value of 35 mg/L.

The final phosphate levels of the two reactors meet the wastewater quality standards for business and/or laundry activities which are required based on East Java Governor Regulation Number 72 of 2013 concerning Wastewater Quality Standards for Industry and/or Other Business Activities with a maximum phosphate concentration of 10 mg/L. The final phosphate levels in the ZE and AC reactors were 3.74 mg/L and 8.79 mg/L, respectively. The efficiency of reducing phosphate levels in the ZE and AC reactors were 70.58% and 30.87%, respectively.

5. ACKNOWLEDGEMENT

The authors gratefully acknowledge the Research and Public Service of the Universitas PGRI Adi Buana for the Adi Buana Research Grant, contract No. 105.3/LPPM/VI/2021. We also thank Ms. Annisa Rifka Alifia for her scientific contribution.

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Volume 5, Number 1, page 14-27, October 2021
Accredited SINTA 2 by Ministry of Research, Technology, and Higher Education of The Republic of Indonesia No. 23/E/KPT/2019 on August 8th, 2019 from October 1st, 2018 to September 30th, 2023

DOI : 10.25105/urbanenvirotech.v5i1.10571


Regulation of the Governor of East Java No. 52 of 2014 concerning Wastewater Quality Standards for Industry and Other Business Activities.
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p-ISSN 2579-9150; e-ISSN 2579-9207, Volume 5, Number 1, page 14-27, October 2021
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