The Reduction of COD Levels in Domestic Waste Water Using Combination of Activated Sludge Methode – Activated Carbon Continously

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Abstract. Domestic waste water produced from Pujasera Politeknik Negeri Bandung has a relatively high organic compound. It can cause environmental pollution, so waste water treatment is required to reduce the concentration of organic compounds. The purpose of this study is to determine the efficiency of processing organic compounds in domestic wastewater using active sludge in combination with Activated carbon. The acclimation process is carried out in batches, while the waste water feed is continuously fed by varying the retention time and activated carbon concentration. Variation of retention time of 12, 18, 24 hours and variation of activated carbon concentration 50, 100, 150 ppm. The parameters used in aerobic wastewater treatment are COD, pH, and MLSS measurements. Based on the results of data analysis showed that the percentage decrease of COD from 861 mg / L to 160 mg / L with a pH range of 6.5 to 7 and MLSS averaged 2951 mg / L. The optimum retention time 24 hours with efficiency of COD effluent reduction without activated carbon was 74.91%. With the same operating conditions, at 24 hours of retention time using a combination of activated sludge - activated carbon of 150 ppm, the efficiency of COD effluent reduction was 89.97%.

Keywords: Domestic wastewater, aerobic/activated sludge, activated carbon, retention time.

1. Introduction

Domestic wastewater that produced from the canteen is one of the trash that forever pollutes the environment. Pujasera Bandung State Polytechnic is a canteen that produces domestic wastewater every day. This waste water comes from oil and food scraps, containing organic and inorganic compounds such as proteins, carbohydrates, fats and other minerals dissolved.

Thus these substances and cannot be used as chemicals (COD) in the wastewater produced are more than quality standards. Biological methods with mud-active processes are frequently found in domestic wastewater treatment. The method used to measure COD levels by oxidizing compounds in wastewater with the help of oxygen and the growth media of microorganisms.

The performance of the treatment system with activated sludge method can be improved by using a processing system. The addition of activated carbon powder into the sludge that works to improve color and as a medium for the growth of microorganisms, in addition there will be good interaction between biomass particles with activated carbon which produces more and smaller than organic pollutants become larger [1].
2. Theory

Based on the Ministry of Environment and Forestry Regulation no. 68 of 2016, water that has been used in the activities of everyday human life is domestic wastewater. The presence of wastewater can have a negative impact on the environment with a certain concentration and quantity especially disruption to human health, ecosystem balance, and aesthetic disturbances so that it is necessary to handle waste [2].

2.1 Characteristics of Domestic Wastewater

Domestic wastewater which is sourced from different places, has substances and their concentration will vary, each source will produce wastewater with certain characteristics. The following are the characteristics of domestic wastewater which are presented in Table 2.1 [3].

| Parameter                  | Specification           |
|----------------------------|-------------------------|
| Color                      | Gray                    |
| Odor                       | Musty                   |
| Dissolve Oxygen            | > 1.0 mg/L              |
| pH                         | 6.5 – 9.0               |
| TSS                       | 100 – 350 mg/L          |
| BOD₅                      | 100 – 300 mg/L          |
| COD                       | 200 – 500 mg/L          |
| Flow                      | 100-200 gal/person. day |
| Total Nitrogen             | 20 – 85 mg/L            |
| Total Phosphorus           | 6 – 20 mg/L             |
| Fecal Coliform             | 500,000-3,000,000 MPN/100 mL |

2.2 Domestic Wastewater Treatment with Activated Sludge

In general, there are two main components in the treatment process using the activated sludge method, namely aeration and settling processes. Aeration containing active sludge exhaled with air so that the microorganisms in the activated sludge will oxidize organic compounds (C, H, O, N, S) that is in wastewater being, H₂O, CO₂, NH₄ and new biomass cells. Energy produced from the degradation process of organic compounds, is used by microorganisms for the growth process [4].

2.3 Conventional Activated Sludge Systems

Process, sludge, active is the process of decomposing organic compounds in wastewater by microorganisms with the help of oxygen to H₂O, CO₂, NH₄ and new biomass cells. Equipment or equipment used in conventional activated sludge processes include:

a) An aeration process, microorganisms degrade organic compounds in a waste water.

b) A settling basin for a place to return the mud to the aeration tank and separate the mud from the supernatant.

c) Circulation system. To return part of the sludge carried from the aeration process, it is then reversed to become sludge concentration according to good operating conditions.

d) Excess sludge treatment system that functions to remove some of the sludge.

e) Equipment. Air supply such as a diffuser which functions to supply oxygen to aerobic microorganisms in degrading of parameters on wastewater.

f) The stirring system serves to make sludge and wastewater that enter the aeration process, mixed homogeneously.

2.4 Variable Operational

The handling variables commonly used in treating wastewater through activated sludge processes are as follows:
a) Volumetric Loading Rate
BOD loading is the BOD concentration in wastewater that enters the aeration bath (influent) divided by the reactor volume. BOD load can be determined using the following equation:

\[
BOD\ Loading = \frac{Q \times S_0}{V} \text{ [kg/m}^3 \text{.d]}
\]

where:
- \(Q\) = discharge of incoming wastewater (m\(^3\)/day)
- \(S_0\) = BOD concentration in incoming wastewater (kg/m\(^3\))
- \(V\) = reactor volume (m\(^3\))

BOD load parameters commonly used in activated sludge process range from 0.3 - 0.8 kg/m\(^3\).day [5].

b) Sludge Age
Sludge age is the average residence time of microorganisms in a sewage treatment system with activated sludge method. The age of sludge can be formulated as follows:

\[
\text{(day)} = \frac{MLSS \times V}{SSe \times Qe + SSw \times Qw}
\]

where:
- \(MLSS\) = mixed liquor suspended solids (mg/L)
- \(V\) = The volume of the aeration process (L)
- \(SSe\) = suspended solids in wastewater effluent (mg/L)
- \(SSw\) = solids suspended in sewage sludge (mg/L)
- \(Qe\) = waste effluent rate (m\(^3\)/day)
- \(Qw\) = waste influent rate (m\(^3\)/day)

For conventional activated sludge systems, mud life can vary between 5-15 days [6].

c) Food to Microorganism ratio (F/M)
The F/M ratio is used to control the balance between available food ingredients (BOD or COD) and microorganisms represented by MLSS in the aeration process. F/M can be obtained by the following equation:

\[
F/M\ ratio = \frac{Q \times S_0}{MLSS \times V}
\]

where:
- \(Q\) = flow rate of wastewater (m\(^3\)/day)
- \(S_0\) = BOD concentration in wastewater that enters the aeration (mg/L)
- \(MLSS\) = mixed liquor suspended solids (mg/L)
- \(V\) = reactor volume or aeration process (m\(^3\))

This ratio can be regulated by adding or reducing the concentration of biomass contained in the aeration process besides by adjusting the BOD load that enters the aeration process. The good F/M ratio in the wastewater treatment process using conventional sludge systems is 0.2 - 0.5 kg BOD5 per kg MLSS per day [6]. The F/M ratio for the active sludge process is presented, in Table 2.2.

| Process               | BOD\(_5\)/MLSS | COD/MLSS |
|-----------------------|-----------------|----------|
| Conventional          | 0.2 – 0.4       | 0.5 – 1.0|
| Contact stabilization | 0.2 – 0.6       | 0.5 – 1.0|
| Extended aeration     | 0.05 – 0.15     | 0.2 – 0.5|
| Oxidation ditch        | 0.05 – 0.15     | 0.2 – 0.5|
| Pure oxygen           | 0.25 – 1.0      | 0.5 – 2.0|
d) Hydraulic Retention Time (HRT)
Time, hydraulic stay (HRT) is the time taken for wastewater to enter the aeration bath to be evenly mixed with activated sludge, where the value is inversely proportional to the level of dilution that occurs (D) [7]. The amount of residence time is influenced by the volume of the aeration process and the waste discharge in aeration process (m$^3$/hour).

$$HRT = \frac{1}{D} = \frac{V}{Q}$$

where :
- $V$ = reactor volume or aeration tank (m$^3$)
- $Q$ = flow rate of wastewater (m$^3$/h)
- $D$ = dilution rate (h$^{-1}$)

e) Settled Sludge Volume (SSV)
This variable shows the volume of activated sludge that settles within a certain time, the usual time used is 30 minutes (SSV$_{30}$), SSV is expressed in millimeters of sludge that settles in 1 liter of sample (mL/L) or in % of precipitation volume [3]. SV$_{30}$ values were obtained by taking 1000 ml of sludge samples from an aeration bath, then remaining in an imhoff funnel for 30 minutes to settle the biomass by gravity [6].

f) Sludge Circulation Ratio
The sludge circulation ratio is the ratio between the waste water entering the aeration basin and the amount of sludge circulated from the sedimentation tank into the aeration bath.

g) Sludge Volume Index (SVI)
Sludge Volume Index is a measure of the quality of deposition, the amount of SVI is expressed in terms of the volume occupied by 1 gram of sludge. SVI can be obtained by the following formula:

$$SVI \text{ (ml/g)} = \frac{SSV \left( \frac{\text{ml}}{L} \right) \times 1000}{MLSS \left( \frac{\text{mg}}{L} \right)}$$

where :
- $SSV$ = volume of sludge for 30 minutes in 1 liter of sample (ml/L)

A high Sludge Volume Index (SVI) (greater than 150 mL/g) indicates a bulking condition, while a low SVI (less than 70 mL/g) indicates the dominance of pinflocs (small flocks) [6].

2.5 Addition of Activated Carbon in activated sludge
The performance of biologically active sludge treatment systems can be increased by adding activated carbon to the processing system, some of the advantages of which are:
1. Reducing BOD and COD levels in liquid waste
2. Causes removal of color and toxic substances
3. Reducing the appearance of foam by adsorption on the surface of activated carbon
4. Improve processing efficiency
5. Reducing the formation of bulking sludge
6. Reduce / eliminate odors in waste

In the process of activated sludge organic compounds are described biologically by the activity of suspended microbes that grow throughout the depth of the liquid in the bioreactor. The mechanism that occurs through two stages, namely is physical chemical absorption and interaction between dissolved particles into suspensions which are then separated from wastewater. Next is the stabilization phase which can take place in parallel through absorption of organic pollutants into the biomass particles which are broken down into H$_2$O and CO$_2$ by microbial activity.
The addition of activated carbon powder into the activated sludge absorbs the color by adsorption and as an active sludge growth medium, so that the activated sludge biomass increases, in addition there will be absorption interactions that synergize between the biomass particles of activated sludge and activated carbon resulting in absorption capacity and reduction of organic pollutants becomes larger and activated sludge can be maintained more stable [1].

2.6 BioActive
The BioActive is a nutrient-enriched solid product containing most of the activated carbon. This bioactive can be used in the biological treatment process of activated sludge and has three main functions, which can increase the efficiency of decreasing COD and BOD, as an absorbent of dyes and odors and increase the growth rate of microorganisms in activated sludge.

3. Methods

3.1 Tools and materials
Research conducted on domestic wastewater treatment processes using a combination of activated carbon-activated sludge method uses the main equipment as in Figure 3.1 below:

![Figure 3.1. Schematic diagram of the research](image)

3.2 Stages of Research Activities
Research activities carried out to meet the research objectives of this final project are divided into six stages, namely the preparation stage.

![Figure 3.2. The process flowchart](image)
3.2.1 Preparation phase At this stage, the activities carried out are the preparation of tools and materials which include the manufacture of feed tanks, activated sludge tanks, sedimentation tanks, as well as the installation of aerators in aeration tanks as air suppliers for aerobic bacteria in accordance with the experimental tool circuit scheme.

3.2.2 Preliminary Research stage The collection of domestic waste from the canteen in the Bandung State Polytechnic (Polban), then conditioned before being put into the bait tank. Analysis of the initial conditions of waste before processing includes pH, COD and TSS.

3.2.3 Seeding. In this stage aerobic microorganisms are nursed by providing nutrients. The composition of the nutrients given in the form of glucose, KNO₃ and KH₂PO₄ with a ratio of 100: (5-15): 1. In the nursery, the pH is maintained in the range 6.5 - 8.5, adding sodium hydroxide (NaOH) if the pH value is too low and adding sulfuric acid (H₂SO₄) when the pH is too high. In this process analysis of pH, DO, MLSS, MLVSS, SV30, and SVI was carried out to determine the conditions of activated sludge. The seeding process can be stopped when the MLVSS value is as desired, namely (> 2000 mg / L) and the growth in the number of MLVSS is stable.

3.2.4 Acclimatization stage. Acclimatization is the adaptation of microorganisms with wastewater to be treated. This acclimatization process is carried out after the seeding process is complete, which is marked with the MLVSS value as appropriate, namely (> 2000 mg / L). At the acclimatization stage, glucose is replaced with waste water by mixing ½ the volume of the aeration bath with domestic wastewater to be treated, accompanied by an analysis of pH, DO, MLSS, MLVSS, SV30, SVI and COD. Acclimatization was stopped when glucose was replaced by complete wastewater, followed by the peculiarity of the MLVSS number and the decrease in COD was relatively stable.

3.2.5 Trial Phase. After the acclimatization stage is completed which is marked by the relatively stable MLVSS value, then an experiment is conducted to find out how the residence time effect on the efficiency of reducing pollutant levels such as pH, COD and BOD. Variation of residence time used is 12; 18; and 24 hours. To get the desired residence time, the flow rate of the influent coming out of the feed tank to the activated sludge basin is regulated using a small valve, with a flow rate of 60; 45; and 30 L/hour. This experiment was carried out continuously and whole sludge recirculation was carried out manually in the settling tank to the activated sludge bath.

4. Result and Discussion
In this domestic wastewater treatment process, an acrylic aerobic reactor with a volume of 30 L aeration process and 15 L sedimentation tank is used. The condition of the reactor has been free from leaks, but this reactor is not equipped with a circulation pump in the sedimentation tank so that the return of sludge is done manually from the sedimentation tank to the aeration bath. Design parameters used in the reactor are presented in Table 4.1.

| Parameters                     | Unit             | Value                |
|--------------------------------|------------------|----------------------|
| Residence time                 | Hour             | 12; 18; 24          |
| Age of the Sludge              | Day              |                      |
| Rasio F/M                      | kg BOD/kg MLSS.day | 0.15; 0.24; 0.36  |
| BOD                            |                  | 0.43; 0.57; 0.86    |
| SV₃₀                           | ml/L             | 260 - 280           |
| SVI                            | ml/g             | 97.6-108            |
| Ratio of Sludge Circulation    | v/v              | -                   |
4.1 Characteristics of Domestic Wastewater
Analysis of the characteristics of domestic wastewater originating from the Bandung State Polytechnic Pujasera was conducted to determine the parameters of the initial pollutants contained in wastewater. The results of the pollutant analysis can be seen in Table 4.2 below.

| Parameter | Unit | Test Result | Quality Standards |
|-----------|------|-------------|-------------------|
| COD       | Mg/L | 861         | <100              |
| BOD       | Mg/L | 430         | <30               |
| pH        | -    | 5.1         | 6-9               |
| TSS       | Mg/L | 255         | 30                |

Based on Table 4.2 it can be seen that domestic wastewater produced from a food container (Pujasera) has suspended solids of 255 mg/L which are sourced from the washing process of food scraps. Domestic wastewater has an acidic pH, it shows that the wastewater contains high mineral acids or organic acids, and due to the presence of CO$_2$ gases produced from the decomposition of substances by microorganisms, then after diffusion with water carbonic acid will form acidic [8].

The measured COD value is 861 mg / L, this value causes a slight foul odor around the canteen location due to the absence of processing facilities, in processing wastewater with COD levels aerobic processing can be used.

4.2 Seeding
Seeding stage is carried out by adding ± 500 ppm of sugar every day and adding nutrients every other day. At the nursery stage, there are several things that need to be considered in supporting the growth of microorganisms in the aeration basin, such as temperature, pH, dissolved oxygen content, and nutrition. At the end of the nursery stage, the values of pH, temperature and dissolved oxygen meet the desired criteria, indicating that activated sludge is in good condition.

The seeding process takes place for approximately 4 weeks, during this process observations are made on increasing Mixed Liquor Suspended Solid (MLSS) and Mixed Liquor Volatile Suspended Solid (MLVSS). The following is the result of MLSS measurement data during the seeding process:

![Figure 4.1 Graph of time against MLSS and MLVSS increases](image)

Based on Figure 4.1, microbial growth tends to be slow in the 2nd week seen in MLSS increase from 2865 mg/L to 3024 mg/L, while in the 3rd and 4th weeks increases and tends to be stable with MLSS
value of 3578–3401 mg/L, the value according to [6] has met the requirements of conventional activated sludge design criteria with MLSS values less than 3500 mg/L. Slow growth at the beginning of the seeding process is the effect of the initial pH value of the low activated sludge ranging from 4-5, while the growth of good aerobic microorganisms is at pH 6-8, so it needs to add NaOH to the aeration process during the seeding process. At the beginning of the seeding process there is a stiff white foam on the surface of the aeration process as shown in Figure 4.2, according to [6] due to MLSS in low activated sludge with a high organic load, so the ratio between BOD and MLSS loads is high.

![Figure 4.2](image)

**Figure 4.2** Foam on the surface of the aeration process.

With the addition of NaOH to a pH value of 7-8 and regular addition of nutrients every two days, the white foam disappeared within one week.

### 4.3 Acclimatization stage

The acclimatization stage is done after the seeding stage is complete. This stage is carried out in batches with the addition of domestic wastewater into an aeration tank containing activated sludge using a ratio of 1:4 with a total volume of approximately 30 liters. This acclimatization process is carried out so that the microorganisms contained in activated sludge are able to adapt to the new environment, including its food source.

When the acclimatization process is carried out, it is expected that the active sludge will grow and be able to degrade the organic compounds contained in the wastewater before the continuous testing phase is carried out, so that when given the waste feed, the microorganisms do not require a relatively long time to degrade the waste, and with this acclimatization process can be known the time of activated sludge to degrade waste.

At this stage an observation and calculation of the value of MLSS, MLVSS and a decrease in COD in activated sludge in Appendix C.6. The data is presented in Figure 4.3 and Figure 4.4.

![Figure 4.3](image)

**Figure 4.3** Graph of time against MLSS & MLVSS in the acclimatization process.

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With the addition of NaOH to a pH value of 7-8 and regular addition of nutrients every two days, the white foam disappeared within one week.
The COD value shows the amount of oxygen equivalent to the content of organic matter in wastewater which can be oxidized by strong chemical oxidants [9]. At the beginning of the measurement, the measured COD value of 1201 mg/L decreased to 1120 mg/L and so on up to 280 mg/L within four days, it showed that the biomass contained in the aeration basin had grown and degraded organic compounds but the level biodegradability is still weak. This is said to be said [10] that in the acclimatization process, the activity of active and growing microorganisms can be assumed by a decrease in COD concentration.

In the acclimatization stage of this study, the efficiency of the COD value was 75 % which showed a positive result, according to the criteria for increasing MLSS and MLVSS values. The acclimatization process was stopped on the fourth day with the final COD value of 280 mg/L, because it had shown the results of a good COD reduction efficiency. To determine the efficiency of COD reduction based on residence time, discussed the effect of residence time and COD reduction.

4.4 Effect of Retention Time on Decreasing COD

After the acclimatization process went well, that is by showing an increase in MLVSS and COD removal in domestic wastewater which was added to the aeration process. The operation is continuously by adding waste water continuously into the aeration process with a variation of the residence time in the aeration baths which are 12, 18 and 24 hours. In this operation, the discharge of domestic wastewater is adjusted to the time of stay. The relationship of residence time to processing efficiency and calculation results can be seen in Figure 4.5.

![Graph of decrease in COD levels in the acclimatization process.](image)

**Figure 4.4** Graph of decrease in COD levels in the acclimatization process.

![Graph of effect of retention time on decreasing COD.](image)

**Figure 4.5** Graph of effect of retention time on decreasing COD.
Based on Figure 4.5, it can be seen that the COD value of domestic wastewater has decreased along with the length of stay. From the COD value the initial domestic wastewater was 861 mg/L, to 302.4 mg/L at 12 hours of residence with an efficiency of 64.8%. For the residence time of 18 hours the effluent concentration was 259.2 mg/L with an efficiency of 69.9 %, while at 24 hours residence time the effluent concentration was 216 mg/L with an efficiency of 74.9 %. From the results of the study showed that the longer the residence time in the aeration basin, the higher the efficiency of COD reduction. This is in accordance with what was explained by the previous study which state that the longer the contact time between wastewater and activated sludge, the smaller the effluent produced and the removal efficiency will be high [11].

Based on the results of data analysis obtained, COD effluent content from the processing with a variation of residence time of 12, 18, 24 hours without activated carbon has not met the quality standards set by the Minister of Environment and Forestry Regulation number: P.68/MENLHK/setjen/kum.1/8/2016 because the COD value is still above the 100 mg/L number, the factors that cause this include a short stay, and a series of inadequate tools, especially the absence of a circulation pump that functions to circulate mud from sedimentation tanks to the aeration bath, so that the mud is circulated manually which causes less optimal processing. The optimum decrease in COD can be investigated with carbon addition discussed in the effect of the addition of activated carbon to the decrease of COD.

### 4.5 Effect of Activated Carbon Addition to COD Decrease

In this study, the residence time used was 24 hours, with variations in the concentration of activated carbon added by 50 ppm, 100 ppm, and 150 ppm. The following is a graph of the effect of the addition of activated carbon on the reduction in the COD level of the calculation results presented in Figure 4.6.

![Figure 4.6 Effect of Activated Carbon Addition to COD Decrease](image)

Based on Figure 4.6 shows that the decrease in COD concentration becomes greater when activated carbon is added, it is seen a decrease in the previous graph with 24 hours residence time without the addition of activated carbon obtained an efficiency of 74.9 %, whereas if added activated carbon with a concentration of 50 ppm obtained efficiency of 77.4 %, for the addition of 100 ppm activated carbon, the efficiency was 79.9 %, and the addition of activated carbon was 150 ppm, the processing efficiency increased to 89.9 %. By adding activated carbon into the aeration basin, microorganisms will grow and develop on the surface of activated carbon so that the number of microorganisms that break down the organic pollutants in the aeration basin becomes more and the processing efficiency becomes higher and stable [12].

Based on the results obtained, the levels of COD effluent generated from processing with a 24-hour residence time with the addition of 50 ppm (mg/L) and 100 ppm (mg/L) of activated carbon have not
met the quality time, while with the addition of 150 ppm (mg/L) activated carbon has met the quality standard, because it produces the final COD value of 86 mg/L which is below the COD value standard is 100 mg/L. COD reduction results at the addition of 150 ppm showed an increase in the amount of effective activated carbon, in accordance with the active sludge conditions and the characteristics of wastewater in the treatment process.

5. Conclusion And Suggestions

5.1 Conclusion

Based on the research that has been done, it can be concluded as follows:

a) The longer the residence time, the greater the decrease in COD levels in domestic wastewater.

b) Efficiency of COD reduction in the variation of retention time without activated carbon as follows:
   - At 24 hours residence time of 74.9 %
   - At 18 hours residence time is 69.9 %
   - At 12 hours residence time is 64.8 %

c) Efficiency of COD reduction at 24 hours residence time with a combination of activated sludge, activated carbon as follows:
   - At 50 ppm by 77.4 %
   - At 100 ppm by 79.9 %
   - At 150 ppm by 89.9 %

At an additional concentration of 150 ppm, the level of COD of domestic wastewater has met the quality standard.

5.2 Suggestions

For further research the author proposes some suggestions as follows:

a.) Looking for an alternative circulation pump with very small discharge, so that the mud coming from the sedimentation basin can be continuously circulated.

b.) Shorten the ideal residence time, by setting the appropriate operational variables.

c.) Measuring other parameters stated in the standard quality of domestic wastewater that has been determined, such as oil, NH₃ and total coliform.

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