The Treatment of Nata de Coco Processing Wastewater Using Anaerobic Bio-Filter

Muhammad F. Radityo, Yuli Pratiwi*, and Sri Hastutiningrum

***Abstract*—Liquid waste of Nata de Coco industry is acidic and contains high organic matter, hence, it requires proper treatment before being released into the environment. This research aims to determine the quality of Nata de Coco industrial wastewater and the toxicity of liquid waste (LC_{50} 96 hours) to goldfish bio-indicators before and after being treated with anaerobic bio-filters. The research phase includes: 1) Liquid waste treatment using anaerobic bio-filters with wasp nest media, 2) determination of optimal processing time duration with variations of 48, 72, and 96 hours, 3) toxicity tests before and after processing such as acclimatization, preliminary, and actual tests, and 4) analysis of research data using probit analysis and linear regression. The results showed that biochemical oxygen demand (BOD) and COD (chemical oxygen demand) values are higher than standard values according to the Regulation of the Minister of Environment of Indonesia Number 5 of 2014, while the pH is lower than the standard value. The optimal processing time duration is 48 hours with a decreased percentage of BOD, COD, and pH of 53.24%, 30.37%, and 46.15%, respectively. The actual LC_{50} value of 96 hours of liquid waste before and after treatment is 28.20% and 47.21%, respectively.**

***Index Terms*—Anaerobic bio-filter, liquid waste, Nata de Coco, toxicity**

I. Introduction

One of the benefits of the Nata de Coco industry is its ability to increase the selling value of coconut water used as a raw material in the production process. However, this industry also produces liquid waste with acidic characteristics and high organic matter content. This means when this wastewater is not treated properly, it can cause environmental pollution and consequently disrupt the life of organisms. The high content of organic matter in wastewater can decrease dissolved oxygen levels in the water, thereby impacting the life and balance of organisms, specifically aquatic biota. According to Regulation of Minister of Environment of Indonesia number 5 the year 2014 [1], wastewater quality from the Nata de Coco industry has to follow the standard, as shown in Table I. Therefore, the Nata de Coco wastewater must meet the Indonesian Standard before being released into the environment. The liquid waste quality can be enhanced by performing biological and physicochemical treatment [2]. The biological method can be performed either by aerobic or anaerobic treatment, depending on biochemical oxygen demand (BOD). In general, wastewater with BOD below and above 300 mg/L can be treated effectively using aerobic and anaerobic systems, respectively [3].

TABLE I: Wastewater Standard for Coconut Industry [1]

Parameter	Maximum [mg/L]	Maximum [kg/ton]
BOD	75	1.1
COD	150	2.2
TSS	100	1.5
Fatty acid	15	0.2
pH	6–9	
Wastewater	15 m^3/ton product	

Several research have been conducted on liquid waste treatment. Khurshid *et al*. [4] utilized tea waste biochar as an adsorbent filter for wastewater treatment. Maximum COD (Chemical Oxygen Demand) removal efficiencies were found to be 89.35 ± 0.5% and 95.5 ± 0.5% for single and combined modified biochar, respectively. Sela *et al*. [5] and Beyan *et al*. [6] treated liquid waste in the textile industry. Sela *et al*. [5] processed the cephalothorax and abdomen shell of the prawn to obtain chitosan, which is used to reduce the value of BOD and COD of wastewater of textile industry. These research showed that the reduction rate of BOD and COD was significant and in the acceptable range of discharge water quality. Meanwhile, Beyan *et al*. [6] used activated sugarcane bagasse as an adsorbent for reducing BOD and COD of textile effluent at rate constants of 0.028 and 0.0274 mg/L min^{-1}, respectively.

Other biomaterials as an adsorbent of liquid waste treatment were Carica papaya leaf MgO-nano powders [7], Avacado peel carbon [8], and activated carbon [9]. Oladipo *et al*. [7] evaluated the COD and BOD reduction efficiency of MgO-nano powder for a raw tannery wastewater. The result showed that COD reduced from 2725.9 mg/L to126.5 mg/L and BOD decreased from 1899.5 mg/L to 104.5 mg/L. Devi *et al* [8] found that the maximum percentage reduction of COD and BOD concentration under optimum operating conditions using Avacado peel carbon was 98.20% and 99.18%, respectively. Meanwhile, Hami *et al*. [9] stated that for dosages of activated carbon in the range of 50–150 mg/L, the removal efficiencies for BOD increased from 27–70% to 76–94%, while for COD it rose from 16–64% to 72–92.5%. Recently, Pratiwi *et al*. [10] used silica sand as a filter for wastewater treatment in a slaughterhouse.

Organic based on nanomaterial has obtained attention as a promising adsorbent for wastewater treatment [11] due to the low cost and large surface area to volume ratio [12]. The large surface area to volume ratio at the nano level improved the adsorption capacity and made it better adsorbing materials than conventional ones. In addition, the small size and active surface with high porosity of the nanomaterial enable them to adsorb, separate, and remove contaminated materials from the water [13–15]. Organic nanomaterial adsorbents used in water treatment are nanoclay for organic compounds and heavy metals, while micelles are used for

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The authors are with the Department of Environmental Engineering, Faculty of Applied Science, Institut Sains & Teknologi AKPRIND, Indonesia.

*Correspondence: yuli_pratiwi@akprind.ac.id (Y.P.)

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organic compound adsorption [16]. Activated carbon nanomaterial from the agricultural waste of eucalyptus bark, wood sawdust of rubber plant, Moso and Ma bamboo, Palm shell, olive stone, etc, were also used to efficiently remove heavy metals from the wastewater [17, 18].

Considering the high concentration of organic matter in liquid waste of the Nata de Coco industry, wastewater needs to be treated using an anaerobic bio-filter. Therefore, this research aims to investigate the performance of the bio-filter on reduction of BOD and COD, enhancement of pH, and toxicity of the waste.

II. Material and Method

This research was conducted at the Environmental Engineering Laboratory of IST AKPRIND Yogyakarta. Fig. 1 displays a schematic diagram and photograph of the experimental setup. The liquid waste sample came from one of the Nata de Coco industries in Bantul Regency, which does not yet have a wastewater treatment plant. The wastewater treatment process starts with seeding by using microorganisms found in anaerobic bio-waste and dissolved in water for 8–12 hours before being used for treatment tests. The wastewater is continuously drained into the bio-filter reactor containing the bio-ball media until a biofilm layer is formed, which takes ± 14 days. During the seeding process, the media was observed daily to determine when it had formed a layer of mucus that was brownish-black in color and was not easily separated. It can be ascertained that microorganisms had grown on the media. The next is the acclimatization process, namely adapting microorganisms used for the test by recirculating wastewater which aims to reduce the death rate. This is followed by the wastewater treatment process using an anaerobic bio-filter starting from the equalization tank and flowing to the anaerobic tank. It is filled with bio-ball media located in the center of the reactor tube and occupies 60% of the tube. The discharge used is adjusted according to variations in contact time, namely 0, 48, 72, and 96 hours. Furthermore, the parameters of BOD, COD, and pH were measured according to variations in contact time. BOD is measured using BOD meter, while COD is calculated using Eq. (1), as follows:

$$COD = \frac{(A-B) \times N\,FAS \times 1000 \times BeO2 \times P}{V_{sample}} \tag{1}$$

Where A is the blank titration (mL), B is sample titration (mL), NFAS is normalized FAS, BeO_2 is equal to 8, P is the dilution (mL), and v is the volume.

The initial stage of the toxicity test before and after the treatment using a bio-filter was conducted with the bio-indicator, *Cyprinus carpio L*, which is the acclimatization stage of the test fish. This stage aims to adjust the test fish from actual laboratory conditions. The water used for acclimatization was aerated for two days and replaced every two days to ensure it is clean and does not interfere with the health of the test fish. An aquarium equipped with an aerator and filter was used for acclimatization, which is useful for providing air supply and filtering dirt. This was followed by a preliminary test to determine the concentration limit of the waste that can kill the test fish by 50%. There are 11 samples of wastewater concentrations used in the experiment. Each sample has a concentration of 0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, and 100% which were put in 11 aquariums with a volume of 10 L and observed at 0, 24, 48, 72, and 96 hours. The next step is to conduct the actual test, using the concentration of wastewater resulting from the preliminary test with observations of 0, 24, 48, 72, and 96 hours. LC_{50} value of Nata de Coco industrial wastewater on test fish was determined from 0 to 96 hours before and after treatment using an anaerobic bio-filter and linear regression with the SPSS (Statistical Package for the Social Sciences) program.

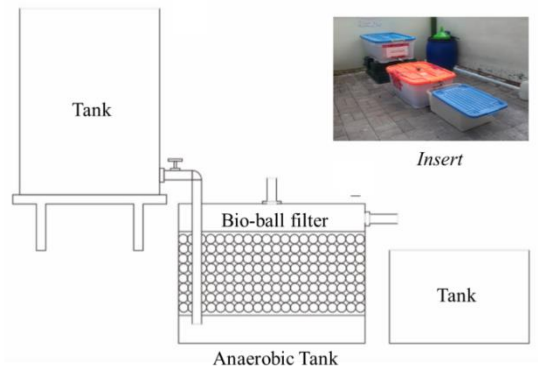

Fig. 1. Schematic diagram of the experimental setup and the photograph (Insert).

III. Results and Discussion

Fig. 2 shows the reduction percentage of BOD liquid waste using bio-filter treatment for a residence time of 0, 48, 72, and 96 hours. The result showed that the treatment with a residence time of 48 hours was able to reduce BOD in the wastewater from 308 mg/L to 144 mg/L, at a removal efficiency of 53.24%. This means that microorganisms carry out a process of decomposition of organic matter in the anaerobic bio-filter. However, the BOD of 144 mg/L is higher than the Standard value implemented by the Ministry of Environment Number five year 2014. A linear regression analysis obtained a correlation coefficient of −0.339 between residence time and BOD concentration. This indicates that the relationship between the treatment duration and the concentration of BOD is not unidirectional and insignificant.

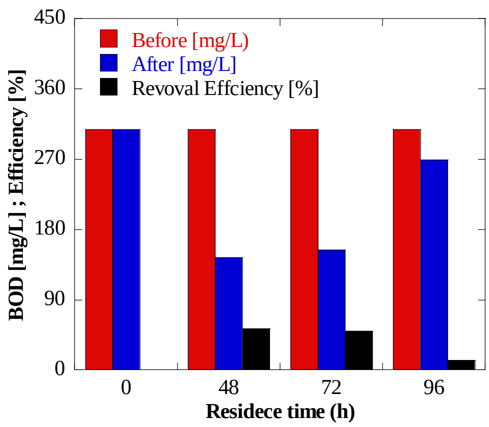

Fig. 2. BOD concentration and removal efficiency.

The COD concentration before and after treatment and removal efficiency of the bio-filter is shown in Fig. 3. The treatment residence time of 48 hours reduced COD in Nata de Coco industrial wastewater from 846 mg/L to 589 mg/L, meaning the COD removal efficiency is approximately 30.37%. This indicates that there has been a decomposition process of organic matter by microorganisms in the bio-filter, marked by the presence of a bio-film layer attached to the surface of the media. However, the COD of 589 mg/L is still higher than the upper limit of the Indonesian Regulation. Using linear regression, the correlation coefficient between residence time and the COD concentration was found to be −0.734, which means that there is no unidirectional and insignificant relation between both variables

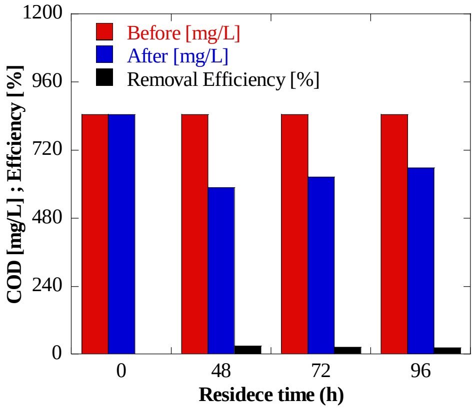

Fig. 3. COD concentration and removal efficiency.

Fig. 3 shows the pH enhancement of the liquid waste produced by the Nata de Coco industry using bio-filter. Optimum pH of 7.6 was obtained at a residence time of 48 hours, indicating an enhancement efficiency of 46.15%. This pH is the Standard value of the Indonesian Regulation for waste treatment in the coconut processing industry. According to Jennie *et al*. [19], biological reactions capable of increasing pH are photosynthesis, denitrification, breakdown of organic nitrogen, and sulfate reduction. Based on linear regression analysis, the correlation coefficient between residence time and pH was 0.975. This means there is a significant and unidirectional relationship between both variables.

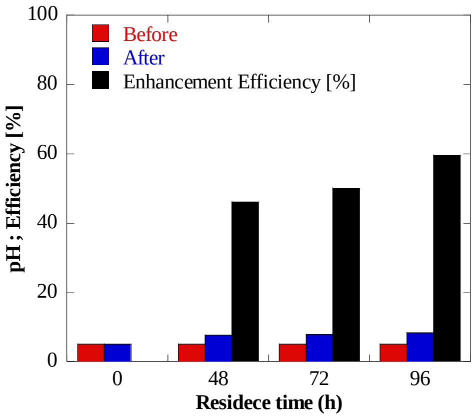

Fig. 4. pH and enhancement efficiency.

The toxicity test for BOD, COD and pH was conducted at a residence time of 48 hours to obtain their optimum values. The preliminary test before and after treatments are displayed in Figs. 5 and 6. It can be seen that the higher the concentration of the liquid waste and the longer the contact time between the test fish and the liquid waste, the greater the mortality rate of fish. This indicates that the liquid waste from the Nata de Coco industry is untreated or treated with an anaerobic bio-filter at a concentration of 10–100%.

The LC_{50} value was observed for 96 hours in the Nata de Coco industrial wastewater before and after processing using probit analysis at a concentration of 25.396%, and 45.197%. This means that the concentration before and after treatment ranged from 21% to 30%, and 41% to 50%, respectively. Furthermore, there is a correlation between the concentration of wastewater and the mortality of fish for 96 observation and processing hours by linear regression in SPSS to obtain 0.891, and 0.976. Based on the value of the correlation coefficient, it can be interpreted that there is a positive relationship between the concentration of Nata de Coco industrial wastewater and the mortality of the fish tested for 96 hours of observation, which means the higher the concentration of the liquid waste, the greater the mortality rate of fish.

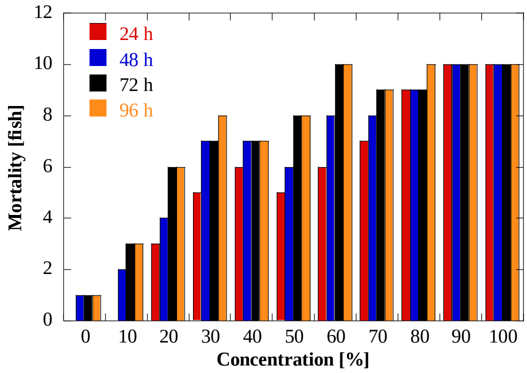

Fig. 5. An effect of concentration of Nata de Coco's liquid waste before treatment on preliminary mortality test.

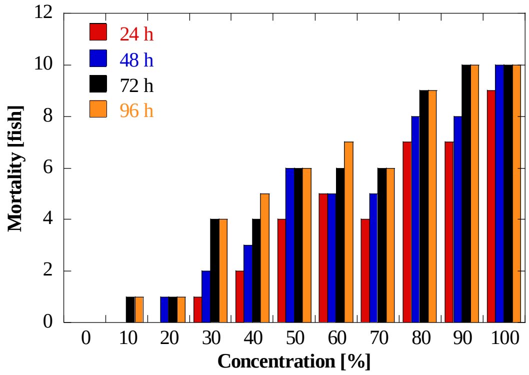

Fig. 6. An effect of concentration of Nata de Coco's liquid waste after treatment on preliminary mortality test.

Meanwhile, Figs. 7 and 8 show the actual toxicity test of the Nata de coco industrial wastewater before and after being treated with an anaerobic bio-filter on *Cyprinus carpio L*. It can be observed that the higher the concentration of the waste and the longer of contact time between the test fish and the waste, the greater the mortality rate. This applies to the industrial wastewater which is neither treated nor untreated with an anaerobic bio-filter.

Fig. 9 presents the liquid waste's LC_{50} (0–96 h) before and after treatment. Fig. 8 displays the percentage reduction of LC_{50} after the use of bio-filter treatment. Based on this figure, the toxicity of Nata de Coco industrial wastewater to test fish for 0–96 hours was relatively higher in untreated wastewater compared to the 48 hours of treated wastewater using an anaerobic bio-filter. This indicates that the mortality of test fish based on LC_{50} 0-96 hours without treatment occurs at a lower liquid waste concentration of 28%–29% when compared to those treated with an anaerobic bio-filter at a concentration of 47%–48%. The decrease in the toxicity of the Nata de Coco industrial wastewater treated for 48 hours with an anaerobic bio-filter to the test fish based on LC_{50} 0-96 hours was 38.67%–40.27%. Although bio-filters are cheap, they are effective for the treatment of Nata de Coco processing wastewater, and highly effective in the filtration processing.

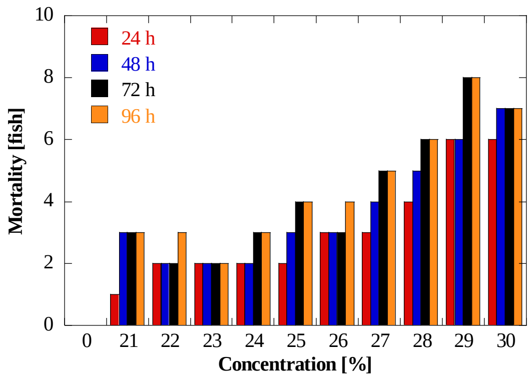

Fig. 7. An effect of concentration of Nata de Coco's liquid waste before treatment on actual mortality test.

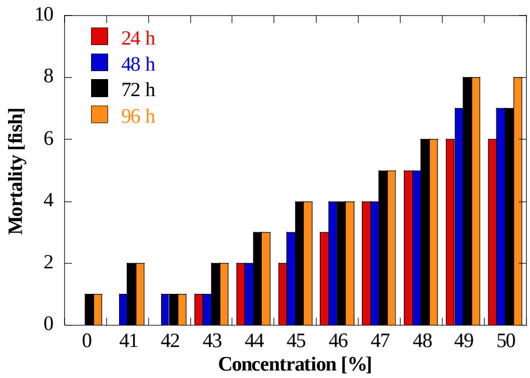

Fig. 8. An effect of concentration of Nata de Coco's liquid waste before treatment on actual mortality test.

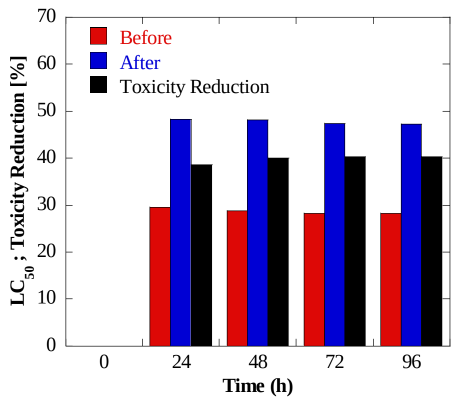

Fig. 9. LC_{50} (0-96 h) of before and after 48 h treatment.

IV. Conclusion

In conclusion, the quality of the Nata de Coco industrial wastewater improved after treatment using an anaerobic bio-filter. The optimum residence time with an anaerobic bio-filter based on parameters of BOD, COD, and pH levels is 48 hours, with BOD and COD removal efficiency of 53.25% and 0.37%, respectively. Meanwhile, the enhancement efficiency of pH at a 15% optimum residence time is 46.

The concentration of BOD, COD, and pH values improved after 48 hours of processing using an anaerobic bio-filter. BOD and COD declined from 308 mg/L to 144 mg/L and 846 mg/L to 589 mg/L, respectively, with a pH of 7.6. However, only the pH is in accordance with the wastewater quality standard for coconut processing industrial activities by the Regulation of Environment Minister of Indonesia Number 5 of 2014.

The mortality rate of the test fish based on LC_{50} for 0–96 hours occurred at a lower liquid waste concentration of 28% to 29%. However, when the liquid waste is treated with an anaerobic bio-filter, a concentration of 47% to 48% was obtained. The wastewater toxicity was treated for 48 hours with an anaerobic bio-filter to the test fish based on LC_{50} 0–96 hours at concentration of 38.67% to 40.27%. Furthermore, it is recommended that the wastewater from Nata de Coco processing industry have to be treated to avoid direct or indirect negative impacts on human health, abiding by the standards for health safeguards.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Muhammad F. Radityo conducted experimental research and data analysis. Yuli Pratiwi and Sri Hastutiningrum supervised the research. Finally, all authors contributed ideas for the paper writing and approved the final version of this manuscript.

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