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Evaluating the Efficiency of Activated Sludge Processes in Treating Industrial Wastewater from Nata de Coco Production

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ABSTRACT

This study examines the effects of Chemical Oxygen Demand (COD) loading on the performance of the activated sludge process at the nata de coco Wastewater Treatment Plant (WWTP) in Gunung Putri, Bogor Regency, which has a daily capacity of 100 m³. From February 2019 to June 2023, bi-weekly assessments were carried out to measure pH in the aeration tank and COD concentrations at both the inlet and outlet of the treatment facility. COD measurements in the equalization tank varied from 933 to 5,080 mg/L, averaging 2,550 mg/L. The Biochemical Oxygen Demand (BOD)/COD ratio fluctuated between 0.34 and 0.40, suggesting a degree of biodegradability resistance. Initially, in February and March 2019, the treatment process achieved an average COD removal efficiency of 95.7%, with a COD load of 0.56 kg COD/m³.day. However, from April 2019 through June 2023, despite an increase in the average COD load to 0.64 kg COD/m³.day, the COD removal efficiency improved to 96.6%. The findings underscore the capability of the activated sludge process to consistently manage varying organic loads in wastewater from nata de coco production, maintaining a relatively stable COD removal efficiency and presenting a viable technical and economic solution.

1. INTRODUCTION

Coconut represents a significant export commodity for Indonesia. Derivative products from coconut, such as nata de coco, hold considerable economic promise, evidenced by a production volume of 200 tons in 2019 [1]. In 2024, the nata de coco market was valued at USD 0.185 Billion and is anticipated to reach USD 0.1396 Billion by 2031, demonstrating a compound annual growth rate (CAGR) of 4.15% during the period from 2023 to 2031 [2]. Among the agro-industries, the nata de coco production contributes to the high generation of waste by producing both liquid and solid waste [3]. PT Kara Santan Pratama is a nata de coco industry that uses such as coconut, sugar, vinegar, and Acetobacter Xylinum culture in its production process as main ingredients [4-6]. The production of nata de coco encompasses multiple stages, including mixing and stirring, harvesting and chopping, soaking and rubbing, sorting, and cooking (acidifying) the nata. The process begins with the extraction of coconut milk from the coconut meat, which is subsequently mixed with sugar and vinegar to produce nata de coco.

The production process generates wastewater in various forms, such as harvesting wastewater from the failed fermentation of nata de coco, washing wastewater from the first washing of nata de coco, soaking wastewater, rinsing wastewater, and tray wash wastewater from cleaning trays used in nata de coco production. This wastewater is acidic due to high concentrations of acetic acid [7].

The harvested wastewater has a low capacity but high organic substance concentrations, with COD concentrations reaching 30,000 mg/l and a pH between 3 and 4. Whereas, combined wastewater from other processes has relatively lower COD concentrations ranging between 600 and 1500 mg/l [8]. If untreated properly, wastewater from the nata de coco industry poses a high risk of environmental pollution, especially water pollution.

The regulatory guidelines for wastewater quality in coconut processing industries and associated activities are outlined in Attachment XVII of the Minister of Environment Regulation of the Republic of Indonesia, Number 5 of 2014. These regulations establish the upper limits for various water quality parameters, including Chemical Oxygen Demand (COD) at 150 mg/L, Biochemical Oxygen Demand (BOD) at 75 mg/L, Total Suspended Solids (TSS) at 100 mg/L, and pH levels between 6 and 9 [9]. Commonly, biological and physicochemical processes were applied to treat wastewater with high COD quality [10]. Determining appropriate wastewater treatment methods according to the content of various chemicals needs to be carefully considered.

Various methods, including trickling filters, activated sludge, anaerobic treatment, SBR, ultrafiltration, and MBR, are previously reported as alternative methods to treat wastewater containing organic pollutants (COD). Following treatment through trickling filters, wastewater originating from the organic paint and dye industry consistently achieves a COD removal effectiveness ranging from 60% to 70% [11]. Employing a sequencing batch reactor (SBR), synthetic textile wastewater containing 500 mg/L of COD and 5000 mg/L of TDS undergoes treatment, resulting in COD removal efficiencies of 80.71% and 59.44% [12]. Additionally, extended aeration-activated sludge, utilized in the pulp and paper industry for wastewater treatment, exhibits an average BOD removal effectiveness of 74.6%. This method can significantly reduce COD and TSS by 83% and 90%, respectively [13].

Active sludge is used in canned fish wastewater treatment and can remove organic matter, such as DOC, by 88.0% [14]. Synthetic vinasse, a chemical compound present in sugar industry wastewater, undergoes anaerobic treatment using the UASB reactor, achieving COD removal and methane production efficiencies of approximately 80.45% and 56%, respectively [15].

Based on the analysis, it is evident that activated sludge and Upflow Anaerobic Sludge Blanket (UASB) anaerobic treatments are optimal for the removal of high concentrations of Chemical Oxygen Demand (COD). However, anaerobic wastewater treatment methods, including the UASB reactor, exhibit certain drawbacks compared to activated sludge processes. These disadvantages are: (1) the generation of offensive odors from anaerobic reactors, (2) the inherent instability of these reactors, and (3) challenges in handling variations in high load rates, which complicate the management of advanced reactors such as UASB [16].

Additionally, wastewater treatment employing activated sludge is advantageous as it does not necessitate extensive space and can yield high-quality treated water at moderate operational and maintenance costs [17]. In this research, the team selected the activated sludge method for wastewater treatment. The primary aim of this study is to evaluate the efficacy of industrial wastewater treatment systems utilizing conventional activated sludge techniques. A secondary objective is to establish a correlation between the quantity of organic matter (COD load) and the efficiency of COD removal.

This will help engineers design better wastewater treatment plants, especially when they are figuring out how big an aeration tank they need.

2. RESEARCH METHODOLOGY

2.1 Study location

The study was conducted at the nata de coco factory of PT Kara Santan Pratama, situated in Gunung Putri, Bogor Regency, West Java. The research was carried out by the investigator from February 2019 to June 2023.

2.2 Water quality analysis

The analyst will conduct COD analysis using the HACH DR2800 spectrophotometer instrument and the COD Reactor, Hanna Instruments HI 839800.

2.3 Wastewater treatment process for nata de coco industry

In the conventional activated sludge process utilized for treating industrial wastewater from nata de coco production, the system comprises three main tanks: the primary settling tank, the aeration tank, and the final settling tank. A critical component of this process is the extensive recirculation of biomass from the final settling tank back to the aeration tank. This method relies on specialized equipment referred to as Return Activated Sludge (RAS), which transfers settled activated sludge from the final settling tank back to the influent of the aeration tank. This mechanism results in an average sludge retention time that is extended relative to its hydraulic retention time [18]. Microorganisms can efficiently oxidize organic molecules in a very short amount of time due to their significant biomass recirculation [19].

The wastewater holding tank collects wastewater from the production process. This tank regulates the wastewater flow rate and includes a coarse screen to separate large debris. After pumping from the holding tank, the wastewater first undergoes oil separation in a designated tank before being directed to an equalization tank. From there, it is pumped into the primary settling tank, which then transfers the wastewater to the aeration tank for aeration with atmospheric air. Subsequently, the wastewater is conveyed from the aeration tank to an intermediate holding tank for additional chemical and physical treatments prior to entering the final settling tank. The primary role of the settling tank is to reduce suspended solids, facilitated by gravity that aids the effluent's flow from the primary settling tank to the aeration tank. The aeration process involves injecting air into the wastewater, enabling the microorganisms in the aeration tank to break down the organic substances. These microorganisms use the energy obtained from the decomposition of organic materials to support their growth and metabolic processes. Thus, a significant amount of biomass will grow and develop in the aeration tank. The bacteria in this biomass will break down the pollutants in the wastewater.

The mixture of biomass and wastewater in the aeration tank is typically referred to as mixed liquor-suspended solids (MLSS). Water from the aeration tank flows into the final settling tank, where activated sludge, rich in microorganisms, settles and is subsequently recirculated to the aeration tank inlet using either an airlift pump or a sludge circulation pump. The wastewater then enters the final settling tank, where settling or separation of the treated wastewater from the activated sludge occurs.

The chlorination tank channels the treated clear water (supernatant) from the top of the settling tank into the public sewer. Meanwhile, the settled activated sludge from the bottom of the final settling tank is reintroduced into the inlet of the aeration tank to degrade the pollutants in the wastewater. To maintain optimal operation, the quantity of recycled sludge is adjusted to ensure an ideal Mixed Liquor Suspended Solids (MLSS) concentration. Excess sludge from both the primary and final settling tanks is accumulated in a sludge holding or thickening tank to achieve the necessary MLSS levels. Subsequently, the sedimented sludge is transferred to a sludge drying tank, and the filtrate is redirected to the wastewater holding tank. Figure 1 illustrates the treatment process for industrial wastewater from nata de coco utilizing the activated sludge method. Figure 2 illustrates a layout employing the activated sludge process.

The factor that influences the performance of the wastewater treatment process is the hydraulic retention time (HRT) in the aeration tank [20]. HRT is calculated by dividing the tank volume by the influent wastewater flow rate. Other influential variables in wastewater include the concentration of organic matter (BOD and COD), ammonia concentration, oxygen or air supply, and temperature effects.

The following subsections describe design variables commonly used in wastewater treatment processes involving activated sludge systems. Monitoring COD parameters, daily wastewater flow rate, and pH are prioritized because analyzing BOD concentration levels in the laboratory is time-consuming.

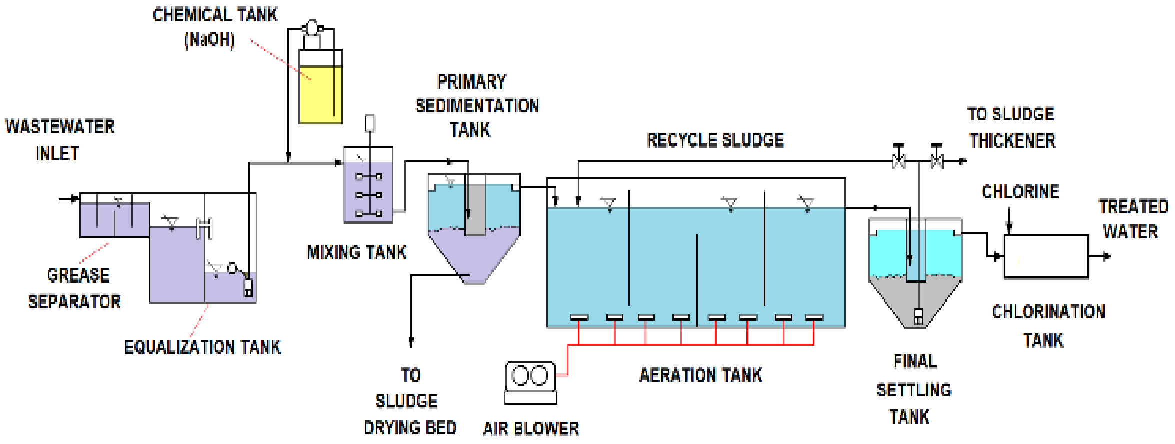

Figure 1. The flow diagram of the industrial wastewater treatment process for nata de coco using the activated sludge method

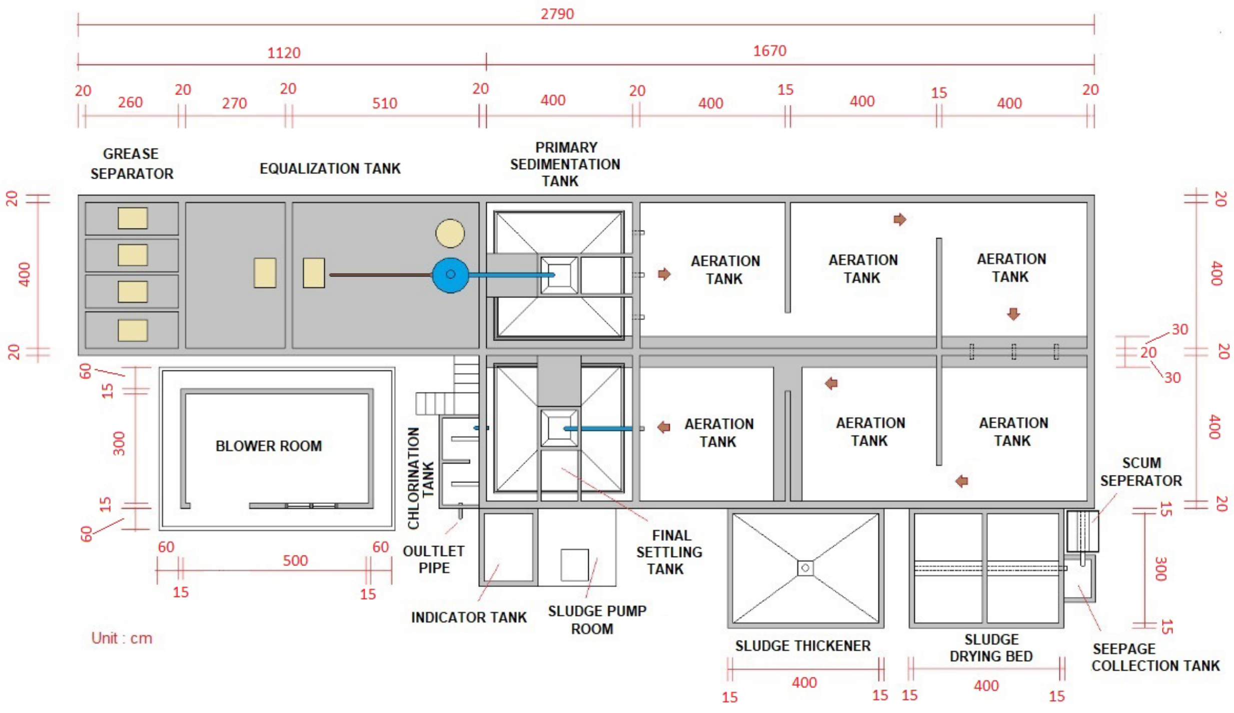

Figure 2. Layout of wastewater treatment facilities in the nata de coco industry

Table 1. WWTP technical specifications

Item	Unit	Initial Sedimentation Tank	Aeration Tank	Final Sedimentation Tank
Length	cm	400	1,200	400
Width	cm	400	800	400
Effective depth	cm	300	350	300
Free Space Height	cm	50	50	50
Material	-	Reinforced concrete K300	Reinforced concrete	Reinforced concrete K300
Number	-	1	1	1
Effective Volume	m^3	48	383	48
Information	-	-	6 rooms @ (4m × 4m × 3,5m), series flow	-

Table 2. Technical specifications of WWTP supporting facilities

Item	Unit	Air Blower	Air Diffuser	Sludge Circulation Pump
Type	-	Root Blower	Fine Bubbles Difucer	HCP or equivalent
Merk	-	Shoufu	-	-
Capacity	m^3/minute	8.77	250 mm	0,1 - 0,22
Material	-	-	Single membrane plastic	Stainless Steel
Total head	mm aqua	3500 - 4000	-	8
Electrical power	-	8,6 Kw, 380 Volt, 3 phase, 50 Hz	-	0,5 kW, 220 Volt
Revolutions Per Minute	RPM	1500	-	-
Number	unit	2(Alternating operations)	96 units The aeration tank is divided into 6 rooms and each room is equipped with 16 diffusers	2 units (1 operating unit and 1 spare unit)
Equipment	-	silencer, ball valve, and check valve		Outlet Diameter: 2“

2.4 Performance test period

The investigation was conducted between February 2019 and March 2023. During the seeding period of February to March 2019, we started the microbial growth process inside the wastewater treatment plant's (WWTP) aeration tank.

After the wastewater treatment process stabilized, periodic analysis of the COD (chemical oxygen demand) concentrations at the inlet and outlet was conducted until June 2023.

2.5 Technical specifications of nata de coco industrial activated sludge WWTP

The wastewater treatment facility utilizing the activated sludge process comprises a primary settling tank, an aeration tank, and a final settling tank. Table 1 presents the technical specifications of the wastewater treatment plant (WWTP). Additionally, the WWTP includes supporting facilities such as air blowers, air diffusers, and sludge circulation pumps, with their specifications detailed in Table 2.

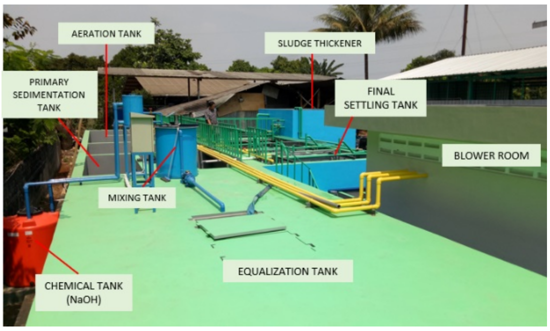

Figure 3. Wastewater treatment facilities for nata de coco

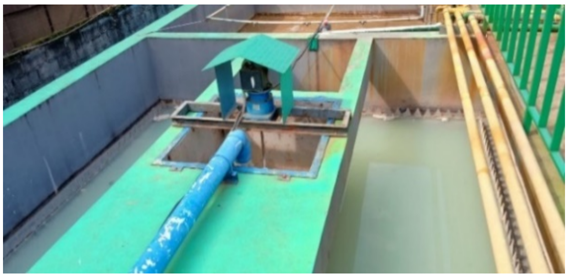

Figure 4. Primary settling tank

Figure 5. Aeration tank

Figure 6. Final settling tank

Figures 3 to 6 depict the layout of the activated sludge wastewater treatment facility designed to treat industrial effluent from the nata de coco industry.

2.6 Organic load (COD loading rate or volumetric loading)

The COD load is determined by dividing the mass of COD in the influent wastewater by the volume of the reactor or aeration tank [21, 22]. The formula for Organic Loading is given by:

$$\text{Organik Loading} = \frac{Q \times So}{V} \ \text{kg/m}^3.\text{day} \qquad (1)$$

where,

- Q: influent wastewater flow rate (m^3/day)
- So: COD concentration in the influent wastewater (kg/m^3)
- V: reactor volume (m^3)

In standard activated sludge processes, the organic load (COD load) typically falls within the range of 0.3 to 0.8 kg/m^3.day.

3. FINDING AND DISCUSSION

3.1 Fluctuation of wastewater flow rate February-April 2019

To ascertain the amount of wastewater treated in the activated sludge wastewater treatment unit changes in wastewater flow were measured.

This measurement was conducted with a flow rate measuring device during the operational phase of the installation. The data illustrate the variation in wastewater flow rates from February to April 2019, as shown in Figure 7. Analysis of these data reveals substantial fluctuations in the inflow to the wastewater treatment plant (WWTP), ranging from 43 to 133 m³/day, with an average flow rate of 80.78 m³/day.

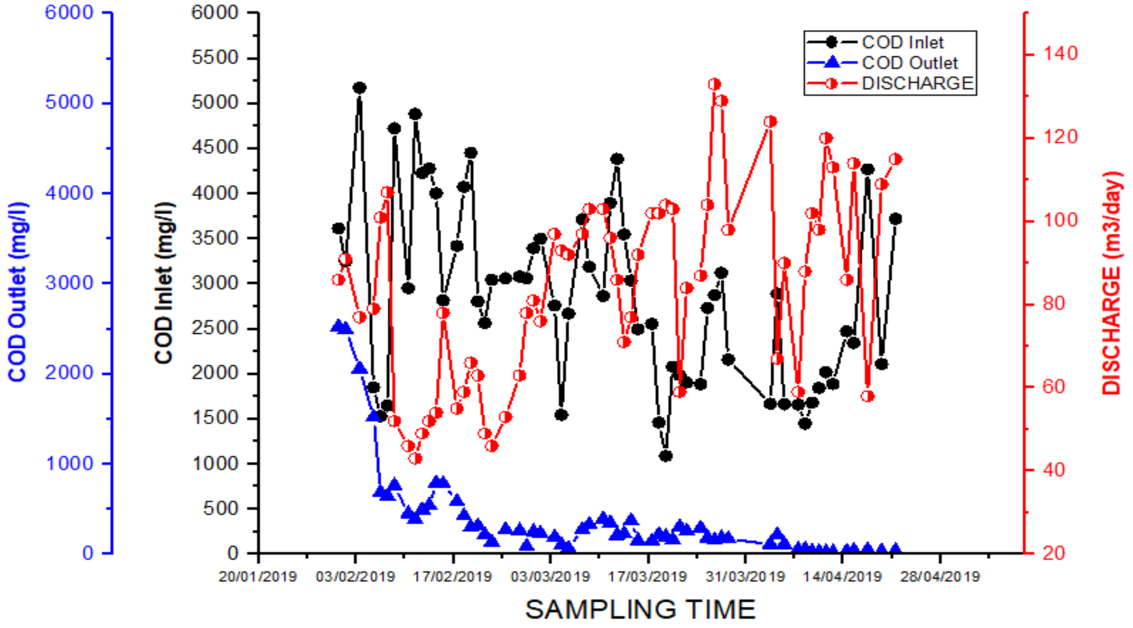

Figure 7. COD Inlet, COD Outlet, and discharge of wastewater in the seeding period (February-April 2019)

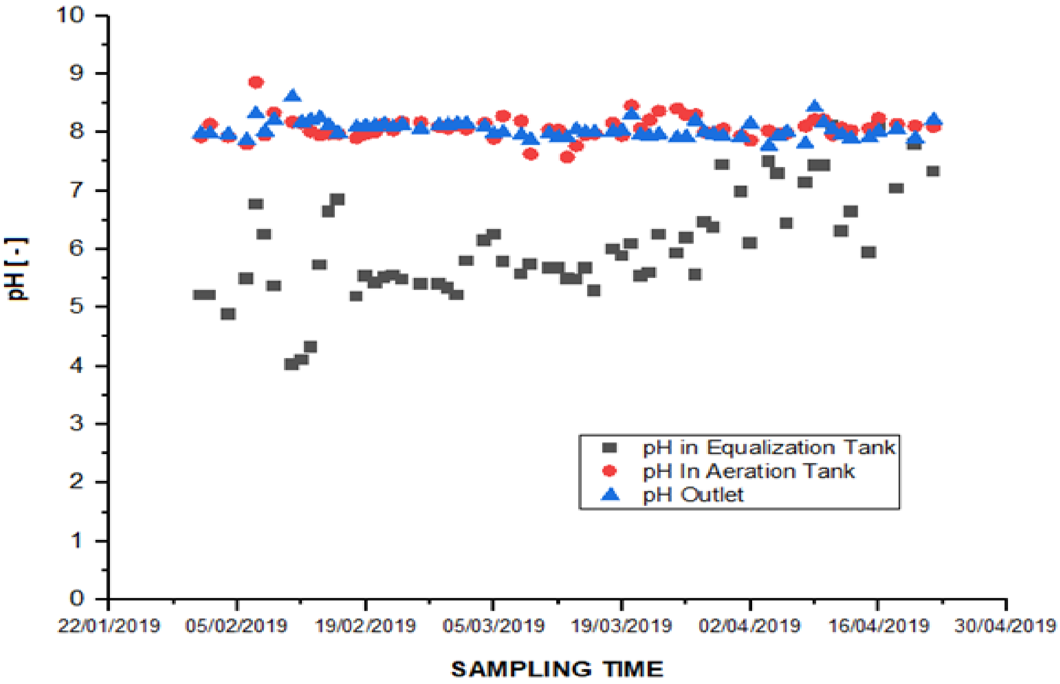

Figure 8. Graph of wastewater pH in the equalization tank, aeration tank inlet pH, and IPAL outlet pH (February-April 2019)

Figure 7 also shows significant fluctuations in the COD concentration entering the wastewater treatment plant (WWTP). Under a 200 m^3/day design capacity, the activated sludge wastewater treatment unit is intended to handle BOD concentrations of 1,250 mg/L and COD concentrations between 2,500 and 3,000 mg/l. After chlorination, processed wastewater from the activated sludge process should have a BOD content of no more than 75 mg/l and a COD concentration of no more than 150 mg/l.

3.2 pH in February at WWTP from February to April 2019

Washing wastewater from nata de coco, rinse water, and tray washing wastewater are treated in the activated sludge WWTP. Meanwhile, a relatively small amount of harvest wastewater, with a COD concentration of up to 30,000 mg/l and a pH between 3 and 4, is not treated in the activated sludge WWTP [4]. The period from February to April 2019, marks the start-up phase of microbial growth within the aeration tank (seeding process). The WWTP collects wastewater in a holding tank, directs it to a grease separator tank, and then directs the overflow into an equalization tank. The wastewater, with a low pH ranging from approximately 4 to 5, requires a gradual introduction of NaOH solution before it enters into both the grease separator tank and the primary settling tank. Following the addition of NaOH, the pH of the wastewater entering the primary settling tank rises to about 8.

The pH of the wastewater in the equalization tank continues to fluctuate, according to the findings of the WWTP launch process from February to April 2019. It was caused by the different wastewater sources that were entering the equalization tank not mixed uniformly. The wastewater would be mixed uniformly under the additional NaOH as pH control solution in the mixing tank. Nevertheless, the pH of the wastewater leaving the WWTP and the pH of the wastewater entering the aeration tank are both roughly 8.

Figure 8 depicts the pH trends of the wastewater in the equalization tank, at the inlet of the aeration tank, and at the outlet of the WWTP.

To stop the fermentation process, the pH is raised using the activated sludge method. A low pH forces the Nata de Coco fermentation process to continue in the equalization tank, forming jelly-like materials from the sediment. The ideal pH 4 environment for the bacterium Acetobacter xylinum to create nata de coco is what causes this process to occur [23].

3.3 COD removal from February to April 2019

An efficient treatment of organic-laden wastewater using biological systems is achievable when the Biochemical Oxygen Demand (BOD)/Chemical Oxygen Demand (COD) ratio exceeds 0.6. Conversely, if the BOD/COD ratio falls between 0.3 and 0.6, the pace of the biological treatment process diminishes, necessitating a longer period for the microorganisms to adapt to the degradation process [24]. Typically, wastewater from the nata de coco industry displays a BOD/COD ratio of 0.4 to 0.8, introducing certain challenges to the treatment process. During the WWTP performance test, the COD concentration in the wastewater fluctuated between 1460 and 5175 mg/L. It corresponded to a BOD: COD ratio of approximately 0.34.

When the BOD/COD ratio is less than 0.5, the organic contaminant is not easily broken down biologically and needs to be pretreated before entering the biological treatment system. Additionally, appropriate biological treatment technologies can be chosen for the post-treatment of wastewater [25].

Microbial growth within the activated sludge system was initiated in February 2019. The industrial wastewater from nata de coco production was characterized by high Chemical Oxygen Demand (COD) concentrations, while the total phosphorus (P) concentration remained relatively low. By April 2019, wastewater quality assessments indicated a total phosphorus content of 0.23 ng/L, a COD concentration of 997 mg/L, and an ammonia level of 0.52 mg/L. During the initial performance test in February 2019, a nutrient and microbial solution—consisting of a blend of sugar, tapioca, NPK fertilizer, sulfur, urea, and EM4—was introduced to the aeration tank at a rate of 320–400 liters per day (equivalent to 8–10 jerry cans of 40 liters each). The purpose was to enhance the N and P compositions in the wastewater to promote optimal microbial growth. The C: N:P ratio in the activated sludge process is 100:5:1 [26]. According to Figures 8 and 9, the COD concentration in the wastewater varied greatly, ranging from 1,530 to 4,725 mg/l on average. These results were obtained from the WWTP performance test conducted in February 2019.

At the outset of the performance test, the COD concentration in the treated wastewater at the WWTP outlet was high but showed a gradual decrease over time. Before February 10th, 2019, the variability in COD removal was significant, likely due to the system not yet having achieved steady-state conditions. Achieving a steady state in a biological system typically requires an extended operational period. The treated wastewater displayed an average COD concentration of 759.8 mg/L, with individual measurements ranging from 85 to 2525 mg/L. The average COD removal efficiency was 75.5%, with fluctuations between 23.23% and 97.22%. Furthermore, the flow rate of the wastewater varied from 43 to 133 m^3/day, averaging 80.78 m^3/day. By the end of February 2019, the COD removal efficiency had stabilized, consistently exceeding 90%. During the microbial seeding phase, the average COD removal efficiency was recorded at 75.4%, with an average COD load of 0.56 kg COD/m^3 of aeration tank volume per day. After this seeding period, the efficiency of COD removal remained relatively constant, prompting a reduction in the daily addition of nutrients and microbes to between 120 and 160 liters, or 3 to 4 jerry cans of 40 liters each.

Figure 6 illustrates the outcomes of the performance test for the wastewater treatment plant (WWTP) conducted from March to April 2019. During this period, the influent wastewater flow rate to the WWTP varied, with an average of 95.7 m^3/day and a range from 58 to 133 m^3/day. The influent wastewater entering the activated sludge WWTP exhibited an average Chemical Oxygen Demand (COD) concentration of 3387.5 mg/L, with values ranging from 1090 to 4385 mg/L. In comparison, the treated wastewater (outlet) demonstrated an average COD concentration of 163.1 mg/L, varying from 21 to 390 mg/L. The average COD removal efficiency achieved was 95.7%, with variations between 82.11% and 98.98%. The data indicate that, on average, 0.56 kg of COD per m^3 of aeration tank volume per day was processed by the activated sludge WWTP, with the daily load ranging from 0.37 to 1.04 kg COD/m^3. This operational parameter led to an average COD removal efficiency of 95.7%. The results highlight the exceptional performance of the activated sludge WWTP, particularly in terms of COD removal efficiency.

From Figure 9, it can also be seen that during the period from February to March 2019, when the activated sludge process was already stable, although the inflow flow rate and COD concentration to the wastewater treatment plant (WWTP) fluctuated, the treated wastewater COD concentration already met the wastewater quality standards, which are less than 150 mg/l.

In order to facilitate a comparison of COD, BOD, TSS, and pH concentrations before and after treatment, sampling was carried out on April 1, 2019.

The COD concentration in the wastewater (COD Inlet), as shown in the table, was 2141 mg/l. Following treatment in the activated sludge WWTP, it dropped to 98 mg/l. Following treatment, the BOD concentration decreased from 722 mg/l at the inlet to 30 mg/l, and the TSS concentration dropped from 250 mg/l at the inlet to 13 mg/l. Originally, the wastewater exhibited a pH of 5.18, which increased to 8.11 following treatment. According to Regulation Number 5 of 2014 issued by the Minister of Environment and Forestry of the Republic of Indonesia, which sets forth the Wastewater Quality Standards, Annex XVII outlines the quality criteria for wastewater resulting from coconut processing activities. The treated water now complies with these established quality standards, which stipulate maximum allowable levels for Chemical Oxygen Demand (COD) at 150 mg/L, Biochemical Oxygen Demand (BOD) at 75 mg/L, Total Suspended Solids (TSS) at 100 mg/L, and pH between 6 and 9. These standards are critical benchmarks for evaluating the quality of wastewater discharged from the nata de coco industry into aquatic bodies or public sewers. The visual characteristics of the wastewater prior to treatment, within the aeration tank, and after treatment are depicted in Figure 7.

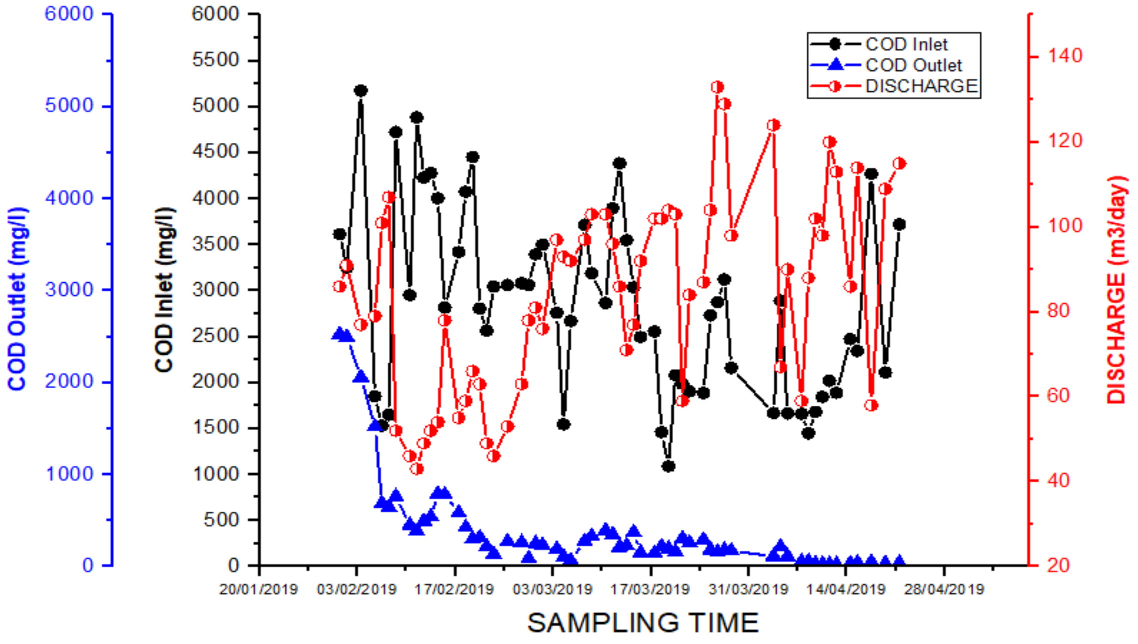

Figure 9. COD Inlet, COD Outlet, and removal efficiency in the seeding period (February-April 2019)

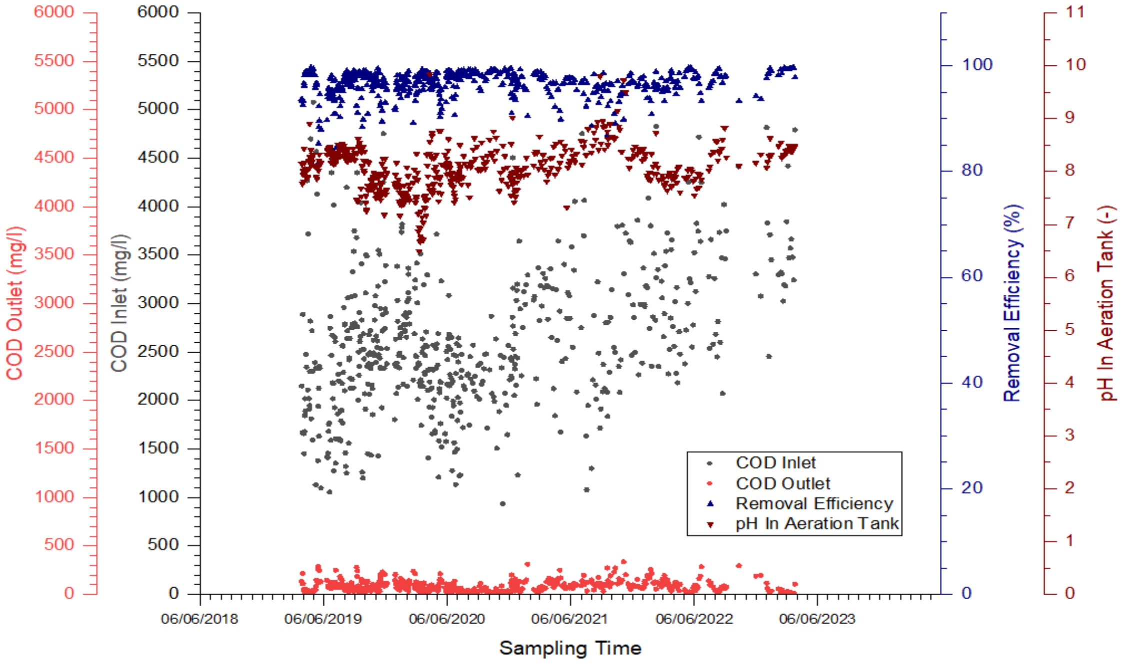

Figure 10. COD concentration, pH in aeration tank, and removal efficiency (April 2019-June 2023)

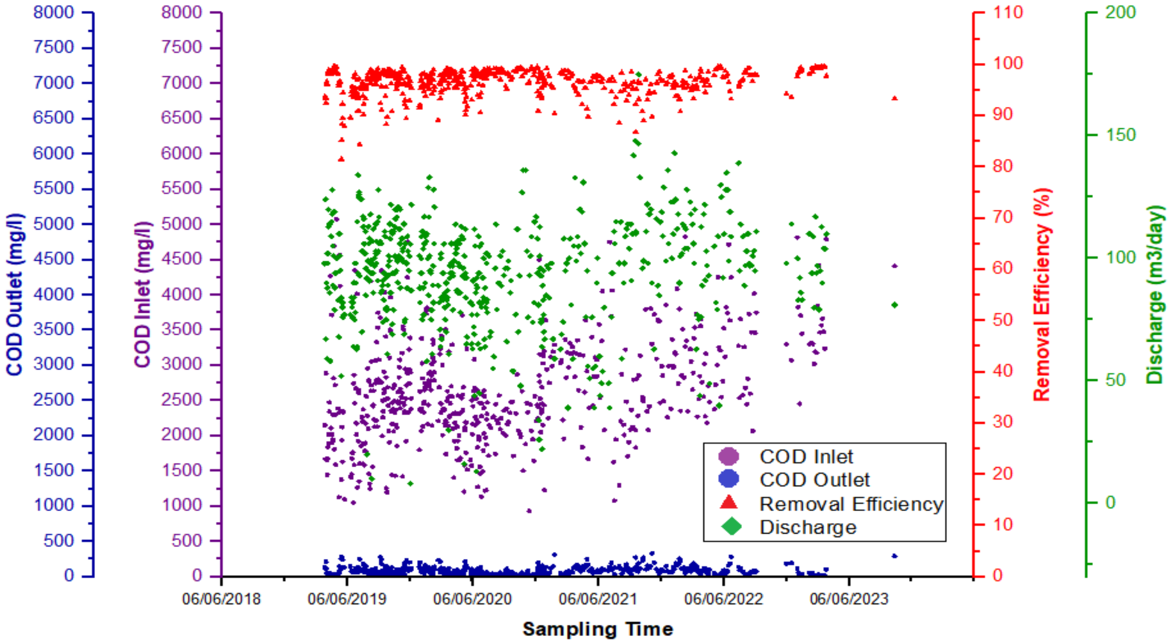

Figure 11. COD Inlet, COD Outlet, wastewater discharge, and removal efficiency (April 2019-June 2023)

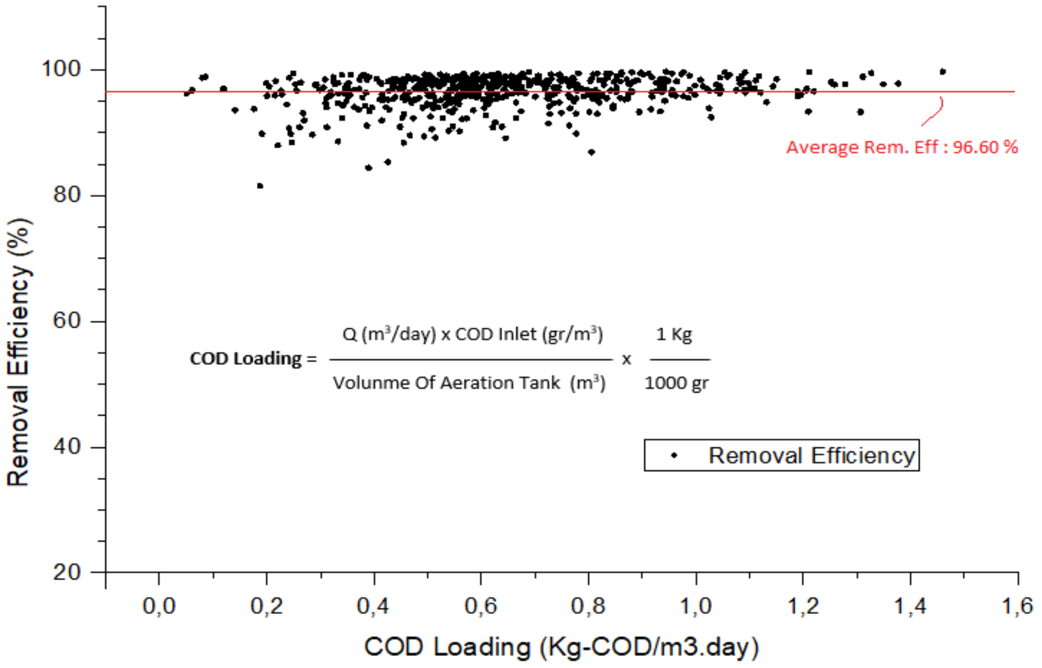

Figure 12. COD loading versus removal efficiency (April 2019-June 2023)

3.4 COD removal from April 2019 to June 2023

Until June 2023, the effectiveness of the activated sludge wastewater treatment process was evaluated through continuous monitoring of daily flow rates, COD concentrations at both the inlet and outlet, and pH levels in the sedimentation tank, as illustrated in Figures 10 and 11. Figure 10 shows the variability in influent COD levels in the wastewater on specific dates, May 6, 2019, and November 17, 2020, with values ranging from 933 to 5,080 mg/L and an average concentration of 2,550.97 mg/L. Post-treatment, the COD concentrations in the effluent varied from 10 to 336 mg/L, averaging 84.91 mg/L at the outlet. The pH in the Aeration Tank maintained an average of 8.03, fluctuating between 6.5 and 9.85. Consequently, the average COD removal efficiency achieved was 96.6%, with the effectiveness ranging from 81.5% to 99.68%.

The elimination of COD is not constant during the course of the sampling period observations indicate that both operational conditions and the characteristics of the wastewater exert a substantial influence on the wastewater treatment system. The concentration of influent wastewater often correlates directly with the concentration of MLSS in the aeration tank. Air injection primarily impacts the removal of COD from wastewater by accelerating the biological treatment process in the aeration tank.

Figures 10 and 11 demonstrate that despite significant fluctuations in the COD concentration and wastewater flow rate entering the wastewater treatment plant (WWTP), monitoring indicates that the WWTP operates efficiently.

Figure 12 illustrates the correlation between COD loading and removal efficiency. Analysis of the WWTP's performance from April 2019 to June 2023 reveals that with COD loading varying from 0.05 to 1.46 kg-COD/m³.day (averaging 0.64 kg COD/m³.day), the average COD removal efficiency was maintained at 96.6%. This represents an improvement in COD removal efficiency compared to the initial seeding phase, achieved after three years of operation under higher organic (COD) loads. The enhanced performance can likely be attributed to the microbial community's adaptation to the wastewater characteristics.

In the activated sludge process, adaptation time is a critical factor in how well COD (chemical oxygen demand) is removed. During the activated sludge process, organic matter in wastewater is broken down by bacteria. Adaptation time is the amount of time these bacteria take to adjust to their new surroundings, which may include different wastewater compositions [27, 28].

Over time, the bacterial populations within the activated sludge adapt to the organic matter present in the wastewater. This adaptation enhances bacterial activity in breaking down organic matter, which in turn, increases the efficiency of COD removal [29]. The period of adaptation facilitates the proliferation and development of diverse bacterial species proficient in decomposing various forms of organic matter. Such microbial diversity bolsters the resilience of the activated sludge system against fluctuations in wastewater composition, thereby improving COD removal efficiency [28].

The activated sludge process offers the advantage of faster processing compared to the anaerobic process. In this process, aerobic bacteria exhibit a higher growth rate, allowing for the use of a smaller treatment reactor. However, aeration is necessary, which requires energy. On the other hand, the anaerobic process demands less energy than the activated sludge process, but its processing rate is slower, necessitating a larger reactor volume [29].

The decision between an activated sludge process and an anaerobic process hinge on various factors, such as the type of waste, treatment objectives, operational expenses, and environmental regulations. The activated sludge process is better suited for wastewater treatment in areas with limited land availability, whereas the anaerobic process might be more appropriate in the absence of land constraints.

Operators of wastewater treatment plants can modify the organic load entering the wastewater treatment system by knowing the link between COD load and removal efficiency. The activated sludge method is more effective at breaking down organic matter in wastewater when it gives bacteria more time to adjust to fluctuations in organic load.

Additionally, when designing the activated sludge wastewater treatment plant, it is easier to determine the volume requirements for the aeration tank when using data or graphs that show the relationship between organic load (COD) and removal efficiency, especially when treating nata de coco wastewater.

3.5 Environmental implication and economic advantage

The biological degradation of an organic contaminant in an activated sludge method is undeniably effective in treating nata de coco industrial wastewater, especially in the COD degradation process. Removing COD from organic-contained wastewater affects the reduction of organic load to the environment water body minimizing pollution and the associated harmful effects on water bodies. Many organic contaminants can be harmful to aquatic organisms. By lowering COD levels, the concentration of these potentially dangerous substances is also reduced, creating safer environments for aquatic life. Reducing the organic load to the environment may also increase the dissolved oxygen in the water and prevent the hypoxic or anoxic conditions in the water that endanger the aquatic ecosystem. The nata de coco wastewater may contribute about 50 kg-COD/day if it is untreated. By using the biological degradation process in an activated sludge treatment system, the COD is successfully degraded to the permissible COD discharge level. It has a positive impact on the organic load reduction in the environment.

From April 2019 to June 2023, the average daily wastewater discharge was approximately 93.70 m³ (Figure 11). Within the 383 m³ capacity of the aeration tank (Table 1), the hydraulic retention time (HRT) is calculated to be 4.88 days, resulting in a COD removal efficiency of 96.6%. In contrast, a conventional anaerobic system studied by Azzahrani et al. [30] in 2016 reported a COD removal efficiency of 90.2% with a much longer HRT of 20 days. This comparison indicates that a reactor in a conventional anaerobic process would need to be four times larger than that used in an activated sludge system to achieve similar efficiencies. Moreover, additional post-treatment steps are necessary in the conventional anaerobic system to compensate for its lower COD removal efficiency relative to the activated sludge system.

The activated sludge system provides a potential advantage to be widely applied in the organic-contained wastewater treatment system due to its technical and economic advantages.

4. CONCLUSION

From February 1st to April 23, 2019, the standard activated sludge process, with a design capacity of 100 m^3/day, treats wastewater with a BOD/COD ratio of approximately 0.34. making the wastewater relatively difficult to biologically degrade. To maximize wastewater treatment, the pH must be raised to approximately 8 by adding a NaOH solution.

Following the treatment of wastewater with an initial average COD load of 0.56 kg COD/m³/day, which achieved a COD removal efficiency of 95.7% in April 2019, there was an observed enhancement in the average COD removal efficiency to 96.6% by June 2023. This improvement was noted despite an increase in the COD load to a range of 0.2–1.3 kg COD/m³.day, averaging 0.64 kg COD/m³.day during the period. The likely driver of this increased efficiency is the microbial adaptation to the wastewater conditions.

From April 2019 to June 2023, it appears that there is no clear connection between fluctuations in wastewater flow rate and the effectiveness of COD removal. The presence of an adaptation period allows for the growth and development of various types of bacteria that are efficient at breaking down substances; thus, increasing bacterial diversity can enhance COD removal efficiency.

The monitoring of WWTP performance reveals a correlation between the organic load (COD) and removal efficiency, facilitating the rapid calculation of aeration tank volume in the design of activated sludge WWTP. The activated sludge system offers significant potential for broad application in treating organic-contained wastewater, thanks to its technical and economic benefits.

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NOMENCLATURE

Q	Flowrate, m^3. day^{-1}
V	Volume, m^3
pH	Potential Hydrogen, dimensionless
S0	Concentration, kg.m^{-3}
COD	Chemical Oxygen Demand, mg.l^{-1}
BOD	Biochemical Oxygen Demand, mg.l^{-1}
TSS	Total Suspended Solid, mg.l^{-1}
TDS	Total Dissolved Solid, mg.l^{-1}
HRT	Hydraulic Retention Time, hour
MLSS	Mixed Liquor-Suspended Solids, mg.l^{-1}
NaOH	Natrium Hydroxide, mg.l^{-1}

Abbreviations

WWTP	Wastewater Treatment Plant
UASB	Upflow Anaerobic Sludge Blanket
SBR	Sequencing Batch Reactor
N	Natrium
P	Phosphor
K	Kalium