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Preliminary Study of Breakpoint Chlorination (BPC) at Tura Tea WWTP, Samarinda

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Abstract

Population migration and growth in Indonesia have led to an increase in domestic wastewater production, which can reduce environmental quality if not treated properly. The main problem in this study is the high concentration of ammonia in the effluent of Tura Tea WWTP, Samarinda, which is 96 mg/L, exceeding the quality standard of Environmental Ministry of Indonesia No. 11 of 2025, which is 50 mg/L. High ammonia mixed with high chlorine is toxic and has the potential to form disinfection by-products. This study aims to evaluate the performance of wastewater management facilities and develop an optimization approach to improve effluent quality to meet quality standards. The research methods included field data collection and laboratory analysis of key parameters (TSS, BOD, COD, pH, ammonia, and total coliform) at the inlet and outlet points. The optimization process was carried out using the breakpoint chlorination method with calcium hypochlorite ($Ca(OCl)_2$). The results showed that the optimal dose capable of effectively reducing organic pollutants was a chlorine dose of 200 mg/L, which produced a residual chlorine level of 3.55 mg/L with an ammonia removal efficiency of 80%, initially 96 mg/L to 19.2 mg/L. This study demonstrates that the chlorination-based disinfection process using calcium hypochlorite ($Ca(OCl)_2$) in the final treatment stage can improve WWTP performance and ensure that effluent meets domestic wastewater quality standards in Indonesia.

Keywords: *Ammonia, Breakpoint chlorination, Calcium hypochlorite, Chlorine, WWTP*

1. Introduction

Rapid population growth and urban sprawl in Indonesia have led to a significant increase in domestic wastewater production. One of the problems is that domestic wastewater is not managed properly and can pose a threat to the environment. One of the efforts to process domestic waste is by using Wastewater Treatment Plant (WWTP) technology [1]. In WWTPs, there are various treatments to reduce the pollutants present in domestic wastewater through different stages of physical, chemical, and biological processing [2]. The application of Wastewater Treatment Plant (WWTP) technology has been implemented at WWTP Tura Tea. Based on the evaluation results conducted by the Environmental Agency (DLH), secondary data from the measurement of inlet and outlet parameters at WWTP Tura Tea showed that the ammonia concentration at the inlet was 98 mg/L, and after going through the WWTP treatment process, the ammonia concentration at the outlet was 96 mg/L. This indicates that the treatment at WWTP Tura Tea is still not optimal and shows that the wastewater treatment plant is still experiencing difficulties in meeting the wastewater quality standards set out in the Environmental Ministry of Indonesia No. 11 of 2025, which is 50 mg/L for ammonia.

Several studies report that biological processes alone are often insufficient to remove nitrogen due to the efficiency of nitrification and short hydraulic retention time. The Breakpoint Chlorination (BPC) method as a determinant of the optimum dose to be used as a potential solution, however [3], its application in small-scale domestic wastewater treatment plants is still rarely explored in Indonesia. Research conducted by Putra [4] states that wastewater treatment plants that are not yet optimal in treating domestic wastewater need to be evaluated by adding a disinfection process using calcium hypochlorite with the determination of the optimal dose using the breakpoint chlorination (BPC) method. Research conducted by Mugwii also states that mixing for 30 minutes and a Cl_2-NH_4^+ weight ratio of 8:1 [5]. The Breakpoint Chlorination (BPC) process stage reduces ammonia from 2.7 mg/L to 0.02 mg/L-N while completely eliminating residual microorganisms. Technical notes indicate that the use of chlorine at a ratio of 9:1 to ammonia with a contact time of 30 minutes has been applied in several wastewater treatment plants in certain cities in the United States.

Therefore, this study was conducted to determine the optimum chlorine dose using the Breakpoint Chlorination (BPC) method for the efficiency of reducing ammonia parameters in domestic wastewater by testing the following optimum doses: 100 mg/L, 150 mg/L, 200 mg/L, 250 mg/L, 500 mg/L, and 750 mg/L. After conducting the experiment, the six types of treatment were tested for residual chlorine levels produced after the process to analyze the breakpoint at the dosage used in the application to the wastewater treatment plant.

2. Literature Review

Domestic wastewater can be divided into two types: grey water and black water. Grey water comes from rinsing water, chemical compounds resulting from the use of detergents, shampoos, toothpaste, and household cleaning products. Meanwhile, black water is organic waste that comes from biological materials such as feces, food scraps, and vegetables, which can generally be degraded naturally by microorganisms [6]. Domestic wastewater requires treatment with a wastewater treatment system, commonly referred to as a wastewater treatment plant (WWTP), so that domestic waste originating from black water and grey water can be safely disposed of into the environment and water bodies [1]. Areas with domestic wastewater treatment systems that do not fully treat the water before discharging it into water bodies cause the water to settle and potentially reduce water quality along the watershed. Domestic wastewater can be monitored or tested before being discharged into water bodies by comparing the results of IPAL treatment in the inlet and outlet tanks. The inlet and outlet test results are compared with the regulations in Environmental Ministry of Indonesia No. 11 of 2025, Annex I, concerning domestic wastewater quality standards [7].

Based on Environmental Ministry of Indonesia No. 11 of 2025, Annex I, the quality standards for domestic wastewater include the main parameters of pH, BOD, COD, TSS, ammonia, and fecal coliform. Domestic wastewater treatment plants (WWTPs) generally have problems with high concentrations of ammonia on the surface of wastewater [2]. High levels of ammonia can be toxic in water because it contributes to eutrophication, which can slowly cause a decrease in dissolved oxygen levels in the water. An ammonia concentration of 1 mg/L in water will cause a decrease in dissolved oxygen levels [7]. Ammonia is toxic to the human body in amounts exceeding what the body can detoxify. This is quite dangerous if people frequently consume fish caught in waters contaminated with ammonia, as it can cause ammonia to accumulate in the body and, in the long term, have an undesirable impact on health [3]. The maximum threshold value for ammonia allowed in domestic effluent is 50 mg/L for communal systems and 10 mg/L for individual systems. Table 1 lists the domestic wastewater quality standards according to Environmental Ministry of Indonesia No. 11 of 2025, Annex I.

Tabel 1. Domestic Wastewater Effluent Quality Standards

Parameter	Unit	Maximum Level	
		Individual	Community
Acidity Level (Ph*)	-	6-9	6-9
BOD	mg/L	150	30
COD	mg/L	300	100
TSS	mg/L	100	30
Ammonia (NH_3-N)	mg/L	50	10
Fecal Coliform	MPN/100 mL	1.000	-

An important parameter as an indicator of organic pollution levels is ammonia (NH_3) concentration. Ammonia is a nitrogen compound that serves as a nutrient for aquatic organisms, but high concentrations of ammonia can be toxic to aquatic biota. Apriliana et al. state that ammonia toxicity can inhibit the growth of aquatic organisms and cause death due to oxygen depletion in the blood, changes in pH, and enzymatic imbalances [8]. Based on Helwandi's statement, excessive ammonia in water comes from anthropogenic activities such as the disposal of domestic wastewater, feces, urine, and detergents, and can cause eutrophication, which reduces surface water quality [9]. The study by Mayuli states that high levels of ammonia in the human body can cause shortness of breath, chest pain, coughing up blood, and pneumonia [3]. Ammonia can enter the human body through the respiratory and digestive systems. Inhaling ammonia vapor can cause irritation to the eyes, skin, and respiratory tract [5]. This ammonia problem needs to be addressed by finding an effective solution. There are five wastewater treatment technologies that can effectively remove ammonia, namely biological processes, breakpoint chlorination (BPC), reverse osmosis (RO) membrane filtration, ion exchange (IE) processes, and ammonia stripping processes. Biological processes and breakpoint chlorination are two of the most efficient technologies for ammonia removal, with relatively high effectiveness and relatively low costs.

One of the solutions to prevent ammonia content in wastewater is to carry out a chemical process such as chlorination. Chlorination is a water treatment process carried out by adding chlorine to water that has undergone a previous treatment process with the aim of killing germs and oxidizing chemicals in the water. This method uses a disinfectant containing chlorine, namely calcium hypochlorite [$Ca(OCI)_2$], which has the ability to oxidize ammonia compounds and pathogenic microorganisms [10]. Calcium hypochlorite [$Ca(OCI)_2$] is used as a disinfectant because it is cheaper and more soluble in water. Chlorine added to wastewater reacts with ammonia to form chloramines (monochloramine and dichloramine) at the beginning of ammonia (NH_3) removal until the ammonia is almost completely removed and produces N_2 (nitrogen) gas, which is safe [4]. Excessive use of chlorine can cause the formation of trihalomethanes (THMs), which are carcinogenic and mutagenic, so these compounds must be removed. To eliminate the formation of trihalomethane (THM), the breakpoint chlorination (BPC) method is required before using calcium hypochlorite [$Ca(OCI)_2$] to determine the optimum dose of chlorine to be used in wastewater [11]. The optimum dose of calcium hypochlorite is determined by the breakpoint chlorination (BPC) method, which is the breakpoint where all ammonia has been completely oxidized into nitrogen gas (N_2). and still has free chlorine residue at a safe level as a disinfectant. The breakpoint is important because it ensures the achievement of the main objectives, namely the complete oxidation of ammonium compounds and the thorough killing of pathogenic bacteria [3].

Breakpoint chlorination (BPC) is the amount of chlorine needed to oxidize organic matter (ammonia) and other oxidizable substances and kill microorganisms if there is still active chlorine remaining at that concentration. The relationship between the chlorine addition dose and the active chlorine residue forms a chlorination graph. The reaction that occurs from the start of chlorine addition can be divided into four reaction stages as shown in Figure 1. The Breakpoint Chlorination graph is as follows:

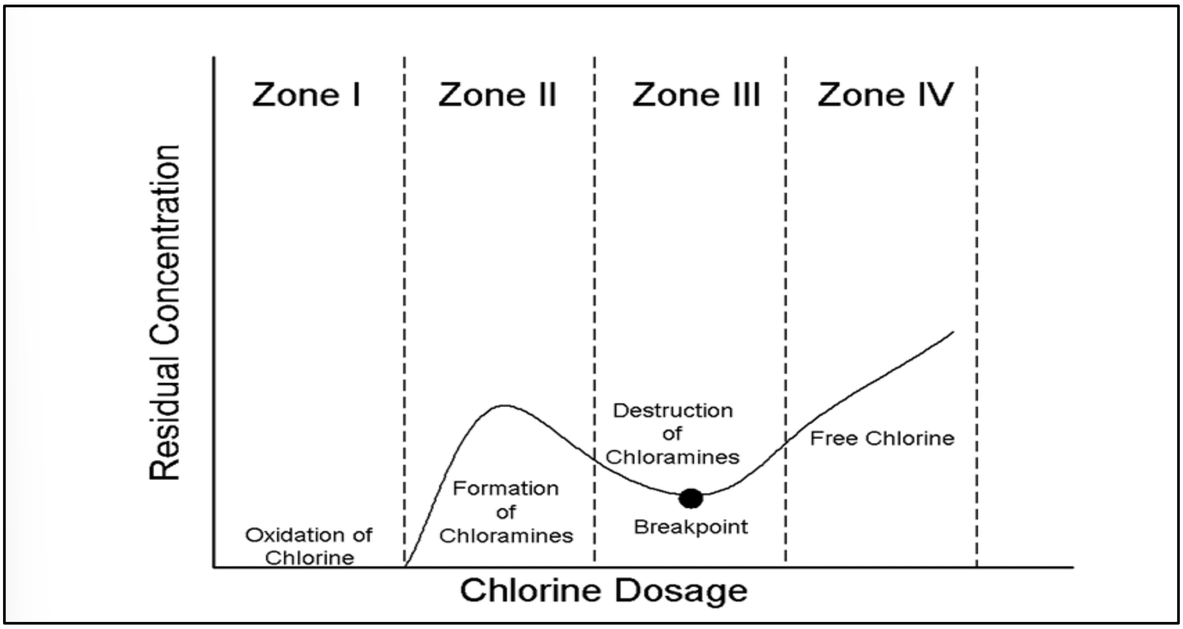

Fig 1. Breakpoint Chlorination Graph

Stage 1: Chlorine Oxidation

According to Sugiatnto [12], at this stage chlorine is broken down by reducing compounds and no chlorine residue is yet visible. Substances that can oxidize chlorine:

$2Fe^{2+} + Cl_2 \rightarrow 2Fe^{3+} + 2Cl^-$ .... (1)

$Mn^{2+} + Cl_2 \rightarrow Mn^{4+} + 2Cl^-$ .... (2)

Stage 2: Formation of Chloramine Compounds

At this stage, a reaction will occur between ammonia and chlorine to form chloramine, as well as between organic compounds and chlorine to form chloro-organic compounds. The reaction that forms chloramine can be seen from the reaction below [13]:

$NH_3 + HOCl \rightarrow NH_2Cl + H_2O$ (monochloramine)..(3)

$NH_2Cl + HOCl \rightarrow NHCl_2 + H_2Cl$ (dichloramine).. (4)

$NHCl_2 + HOCl \rightarrow NCl_3 + H_2Cl$ (trichloramine)..(5)

Stage 3: Formation of Nitrogen Gas (N_2)

Chlorine demand is the amount of chlorine that needs to be added to reach the breakpoint. Nitrogen gas is formed based on the following reaction [7]:

$NH_4^+ + HOCl \rightarrow NH_2Cl + H_2O + H^+$..(6)

$2NH_2Cl + HOCl \rightarrow N_2 + 3HCl + H_2O$..(7)

The usefulness of breakpoint chlorination in reducing ammonia content can be seen in the following reaction:

$2NH_3 + 3HOCl \rightarrow N_2 + 3H_2O + 3HCl$..(8)

At this stage, BPC (breakpoint chlorination) also occurs. BPC is the amount of chlorine required so that:

1. All oxidizable substances are oxidized.
2. Ammonia disappears as N_2 gas.
3. There is still dissolved active chlorine residue, the concentration of which is considered necessary for the eradication of germs during the distribution process [14].

Stage 4: Free Chlorine

This is the area that has passed the break point and all ammonia substances have been converted into N_2 gas which escapes from the solution as bubbles, but a small amount of chloramine remains. At this stage, any additional chlorine dosage begins to function to eliminate germs and reduce ammonia parameters [6]. The factors that influence the success of the breakpoint chlorination (BPC) method are:

1. Initial ammonia concentration (NH_3-N). If chlorine usage increases almost proportionally to the initial [NH3-N], then the higher the ammonia, the greater the Cl_2/calcium hypochlorite dosage required to reach the breakpoint [15].
2. Ammonia/nitrite ratio (A/N) and the presence of nitrite (NO_2^-). Nitrite reacts more quickly with chlorine than ammonia. The presence of nitrite in wastewater can increase the initial chlorine demand and change the form of disinfection by-products. The relationship between ammonia and nitrite (A/N) determines which dominates the BPC curve. If the influence of ammonia is more dominant than nitrite, then the chlorine dose is much lower than with high nitrite and low ammonia [5].
3. pH has an effect on changing the proportion of HOCl (hypochlorous acid), which is more reactive, to OCl- (hypochlorite ion), which is less reactive. At a slightly alkaline neutral pH (6–8), the HOCl fraction is large enough that the oxidation reaction of ammonia is

more efficient, and the chlorine requirement at the optimum pH (6–8) is usually lower. If the pH is too high (>8.5), the efficiency of ammonia reduction requires a larger dose due to pH adjustment. The general recommendation is to target a pH of 6.5–7.5 for BPC [5].

4. Contact time affects the gradual transformation process ($NH_3 \rightarrow NH_2Cl \rightarrow NHCl_2 \rightarrow N_2$), which requires time. A contact time of 30 minutes is often used to ensure that the breakpoint is fully achieved under practical conditions (depending on stirring rate, mass transfer, and concentration) [11].
5. The content of dissolved organic matter that reacts with chlorine can reduce the chlorine available to react with ammonia and increase chlorine demand. This indicates that high levels of organic matter can increase the risk of forming byproducts such as (THMs, HAAs, halonitriles such as DCAN). Therefore, BPC is more effective when the organic matter content in wastewater has been reduced or is more effective when performed after organic matter removal stages such as (coagulation-filtration or biological processes) [16].
6. The type and form of chlorine used can affect the breakpoint chlorination process. Types of chlorine include chlorine gas (Cl_2), sodium hypochlorite (NaOCl), calcium hypochlorite [$Ca(OCl)_2$], sodium dichloroisocyanurate (NaDCC), and chloramine (monochloramine, NH_2Cl). These types of chlorine have advantages and disadvantages for wastewater treatment. Calcium hypochlorite [$Ca(OCl)_2$] is most effective when used with an active chlorine content of 60-70%. Its advantages are that it is easy to use and stable [15]
7. Temperature can affect the BPC process because it can accelerate the reaction rate and shorten the contact time. The optimum temperature in the BPC process under ambient operating conditions is around (20-30°C) [16].

The advantage of the breakpoint chlorination method is its ability to combine the chemical oxidation and disinfection processes in one stage, thereby increasing the efficiency of wastewater treatment. However, research discussing the optimum chlorine dosage with the breakpoint chlorination (BPC) method for the efficiency of ammonia reduction in domestic wastewater is still limited. The breakpoint chlorination (BPC) process is an oxidation stage that produces a series of intermediate compounds in the form of chloramines (NH_2Cl, NHCl2, and NCl_3). The initial stage of chlorine reacts with ammonia to form mochloramine (NH_2Cl), then undergoes further oxidation to form dichloramine ($NHCl_2$) and trichloramine (NCl_3). If the chlorine dose continues to increase until it reaches a certain stoichiometric ratio ($Cl/N \approx 7.6 – 9.0$ by mass) all ammonia will be completely oxidized to nitrogen gas N_2, and this is called the breakpoint. At this stage, reactive species such as hydroxyl radicals (HO) and chlorine radicals (Cl) are formed which have a role in the further oxidation process of ammonia and dissolved organic compounds [5]. Factors affecting the success of the breakpoint chlorination method breakpoint chlorination (BPC) Therefore, further research is needed to determine the optimum chlorine dosage that is effective and safe to apply in community-based domestic wastewater treatment systems.

3. Method

The research location was at the Tura Tea Wastewater Treatment Plant (IPAL) located on Pakang Road, RT 28, Handil Bakti Village, Palaran District, Samarinda City, East Kalimantan, with coordinates 0°35'18"'S 117°09'48"'E. The Tura Tea wastewater treatment plant was built in 2013 and began operating in 2015 until now. The Tura Tea IPAL built by local residents measures 10 × 5 × 2.5 meters and serves 23 households in the area of Jalan Pakang, RT 28, Handil Bakti Village, Palaran District, Samarinda City. Based on an interview with the RT 28 representative, there are 6 households not served by the Tura Tea IPAL, as the Tura Tea IPAL was constructed before these 6 houses (which are considered new houses). Observations revealed that the Tura Tea IPAL appears to be poorly maintained, as the surrounding area is overgrown with weeds, shrubs, banana trees, trees, and moss, as shown in Figure 2. The top of the Tura Tea IPAL is covered with items such as motorcycles, boats, and piles of trash. Local residents stated that there was no maintenance, upkeep, or special attention given to the Tura Tea IPAL by the residents served by the IPAL.

Fig 2. Location and Condition of the Tura Tea Wastewater Treatment Plant in Palaran District, Handil Bakti Village

3.1. Sample Collection

Domestic wastewater samples in this study were taken at only one point, namely at the outlet (after treatment). Samples were taken using the grab sampling method, namely using a 20-liter jerry can. The water sample were promptly transported to the Environmental Technology

Laboratory, stored in sealed containers at room temperature, and analyzed within 24 hours of collection. The water samples were collected for the purpose of performing the breakpoint chlorination method. Domestic wastewater quality parameters were analyzed by the Environmental Agency (DLH) by taking wastewater samples at two points, namely the inlet (before treatment) and the outlet (after treatment). The water quality parameters analyzed included TSS, BOD, COD, pH, ammonia, and total coliform. The analysis was conducted based on the Indonesian National Standard (SNI) for ammonia measurement using SNI 06-6989.2005. pH measurement was conducted using a digital pH meter (HANNA HI-98107).

3.2. Experimental Design

Optimal dose testing was carried out using the Breakpoint Chlorination (BPC) method, employing calcium hypochlorite [$Ca(OCl)_2$] as the disinfectant. Chlorine doses applied in the experiment were 100 mg/L, 150 mg/L, 200 mg/L, 250 mg/L, 500 mg/L, and 750 mg/L [17]. The mixing process was performed using a magnetic stirrer at speed of 1500 rpm for 30 minutes. Subsequently, the samples were analyzed to determine the optimum chlorine dose and the corresponding free chlorine residual. The optimum dose was found to reduce ammonia concentration by up to 80%, while producing a minimal amount of residual chlorine [18]. According to the Regulation of the Environmental Ministry of Indonesia No. 11 of 2025, the permissible limit for chlorine residue in domestic wastewater effluent in 1 mg/L. Therefore, the selected dose is considered optimal, as it achieves effective ammonia reduction while maintaining chlorine residue below the regulatory threshold. Breakpoint determination was conducted using the iodometric titration method, which aims to minimize the releases of hazardous substances, including residual chlorine and disinfection by-products (DBPs), into the environment.

3.5. Data Analysis and Efficiency Calculation

The calculation of residual chlorine to create a breakpoint chlorination graph uses the formula:

$$Concentrition\ (mg/L) \ = \frac{(A-B)\times N\times FP\times 35453}{V} \quad (1)$$

Explanation:

A : mL of titration $Na_2S_2O_3$ 0,1 N for Samples
B : mL of titration $Na_2S_2O_3$ 0,1 N for Blanko (+/-)
N : Normality of Titrate Solution $Na_2S_2O_3$ 0,1 N
V : Volume Samples (100 mL)
FP : Dilution factor

Calculate each dose that has been titrated with the calculation procedure before the addition of KI (mL) as A, and after the addition of starch (mL) as B. The dilution factor used is 1, the volume of wastewater at the time of testing is 100 mL, and the normality of the $Na_2S_2O_3$ titrant solution is 0.1 N. The titration data for each chlorine dose was plotted in a graph showing the relationship between the chlorine dose and the residual chlorine concentration to determine the chlorination breakpoint. The optimum dose was obtained from the point where the addition of chlorine no longer resulted in a significant increase in free chlorine residue.

Calculation of chlorine efficiency in reducing ammonia parameters by calculating Removal using the following formula:

Basic Removal Efficiency

$$Removal\ \ Efficiency\ (\%) = \frac{C_i - C_f}{C_i} \times 100 \quad (2)$$

Explanation:

$C_{i.}$: Initial concentration (mg/L) before chlorination process
C_f : Initial concentration (mg/L) after chlorination process
% : Removal efficiency results

Removal efficiency is used to measure the success of the chlorination process, after determining the optimum chlorine dose and ensuring that the final quality meets quality standards. The breakpoint chlorination (BPC) method, in ammonia removal efficiency, is one of the main indicators of achieving the optimum chlorine dosage or breakpoint. A high efficiency value of 99% indicates that the chlorination process has been completely broken down to form N_2.

4. Results and Discussion

4.1 Water Quality Analysis at of the Tura Tea Wastewater Treatment Plant

Based on secondary data from July 2025 obtained from the Samarinda City Environmental Agency, the water at the Tura Tea wastewater treatment plant outlet was tested using the quality standards of Environment and Forestry Ministry of Indonesia Number 68 of 2016 in July 2025. Meanwhile, the design reference in this case refers to the latest quality standards, namely Environmental Ministry of Indonesia No. 11 of 2025. Test results are presented in Table 2.

Tabel 2. Tura Tea Wastewater Treatment Plant Inlet and Outlet Test Results

No	Parameter	Unit	Quality Standard	Test Results***		% Removal	Test Method	Result
				Inlet	*Outlet*			
A.			**Physics**					
1	TSS	mg/L	100*	267	78	70,79	SNI 6989 3:2019	Compliant
B.			**Inorganic Chemistry**					

1	pH	-	6,0 – 9,0*	7,13	7,25	-	SNI 6989 11:2019	Compliant
2	BOD	mg/L	150*	65	41	36,92	SNI 6989 72:2019	Compliant
3	COD	mg/L	300*	249	155	37,75	SNI 6989 2:2019	Compliant
4	Ammonia (NH_3-N)	mg/L	50*	98	96	2,04	SNI 06-6989 30:2005	Does not meet
C.			Organic Chemistry					
1	Oils dan Fats	mg/L	1**	1	0,2	80	IK – 7.2.40 (Spektrofotometri IR)	Compliant
D.			Microbiology					
1	Total Coliform	count/ 100 mL	3000**	5400	2200	59,25	SM 9221 A,B,C, 23rd Ed, 2017	Compliant

Analysis based on data obtained using quality standards regulated by Environmental Ministry of Indonesia No. 11 of 2025 concerning Wastewater Quality Standards and Wastewater Treatment Technology Standards for Domestic Wastewater shows parameter The TSS at the inlet concentration was 267 mg/L, after processing the concentration decreased to 78 mg/L removal efficiency 70,79%. The pH parameter had an inlet and outlet concentration of 7.13 – 7.25. The BOD and COD parameters at the inlet and outlet tanks had a BOD concentration of 65 mg/L – 41 mg/L removal efficiency 36,92%, and COD of 249 mg/L – 155 mg/L removal efficiency 37,75%. The oil and fat parameters tested had a concentration at the inlet and outlet of 1 mg/L – 0.2 mg/L removal efficiency 80%. In the ammonia parameter after testing the inlet and outlet, a concentration of 98 mg/L – 96 mg/L was obtained, which still exceeded the quality standard. This indicates that the removal reduction efficiency at the Tura Tea WWTP is not optimal in reducing ammonia levels. Therefore, further processing was carried out in the form of disinfection using calcium hypochlorite [$Ca(OCl)_2$]. The optimum dose of calcium hypochlorite [$Ca(OCl)_2$] will be determined using the breakpoint chlorination (BPC) method to find the optimum dose to reduce ammonia concentration and not produce excessive chlorine residual.

4.2 Ammonia Reduction Efficiency

The results of testing using the BPC method produced changes in wastewater. An increase in efficiency in removing ammonia by adding chlorine doses up to an optimum point of 200 mg/L resulted in an efficiency of 80% after breakpoint chlorination occurred, chlorine efficiency decreased due to the formation of excessive chlorine residues and the formation of chloramine reactions. This event is in accordance with the breakpoint chlorination characteristic graph, where the optimum point is reached when all ammonia has been oxidized into nitrogen gas (N_2) and free chlorine residues are stable.

Based on the results of research conducted at a dose of 200 mg/L, the measured free chlorine residual level was 3.55 mg/L, which is still below the maximum limit set by the WHO (5 mg/L). This indicates that the dose is effective in reducing ammonia and safe in terms of disinfectant residue. According to Mugwili, the optimal dose ratio between chlorine and ammonia to achieve the breakpoint chlorination point ranges from 8:1 to 10:1, so the results of this study are consistent with previous studies [12].

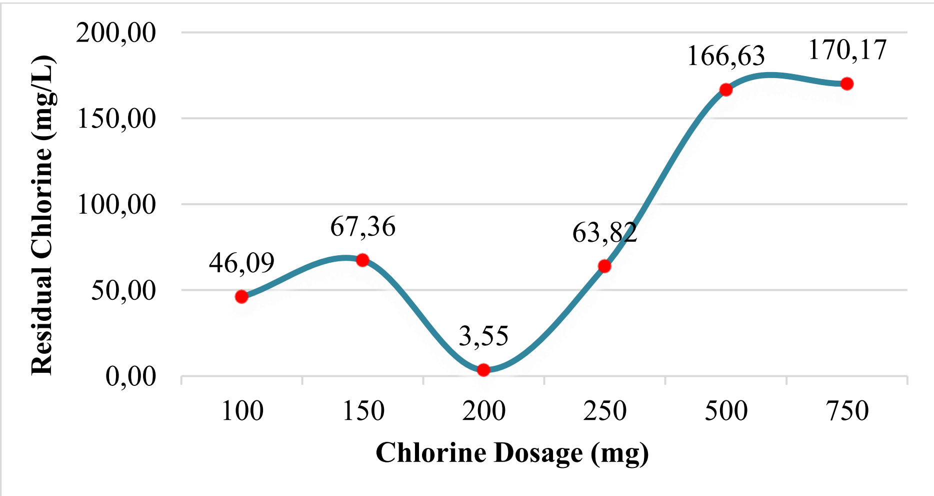

Fig 3. Result Breakpoint Chlorination Curve

4.3 Discussion

From **Figure 3, w**hen chlorine is added to wastewater, there is a reaction between chlorine with H+ ions and OH- radicals in the water:

$Cl_2 + H_2O \rightarrow HOCl + H^+ + Cl^-$……....(3)

$Ca(OCl)_2 + 2\ H_2O \rightarrow Ca\ (OH)_2$……..(4)

$HOCl + H_2O \rightarrow H_3O^+ + OCl^-$……..(5)

$OCl^- \rightarrow Cl^- + O$……...(6)

According to Fauzi, chloride ion (Cl-) is an inactive ion, while Cl_2, HOCl, and OCl are active ingredients. The most efficient bacteria-killing agent comes from Hypochlorous Acid (HOCl) which does not decompose [17]. On the other hand, chlorine can react with other chemical compounds that can be oxidized, for example ammonia. Ammonia (NH_3) in water will react with chlorine (hypochlorous acid) and form monochloramine, dichloramine, and trichloramine (Figure 3).

$NH_3 + HOCl \rightarrow NH_2Cl + H_2O$ pH ≥ 7 ....(7)

$NH_2Cl + HOCl \rightarrow NHCl_2 + H_2O$ ≤ pH ≤ 6 ....(8)

$NHCl_2 + HOCl \rightarrow NCl_3 + H_2O$ pH ≤ 3 ....(9)

If the wastewater contains a lot of ammonia (NH_3), then NH_2Cl is quite stable, and if NH_2Cl has excess chlorine, it will break down and form N_2 gas.

$2NH_2Cl + HOCl \leftrightarrow N_2 + {}_3HCl + H_2O$ ....(10)

According to Paramerta, monochloramine can form more quickly than chloramine and trichloramine, therefore contact time is very important [11]. The possibility of monochloramine being oxidized is quite small compared to chlorine because monochloramine reacts slowly to organic substances so it can reduce the number of THMs formed. Chlorine present in water as chloramine is called bound available chlorine. $Cl_2 + OCl^- + HOCl$ is called free available chlorine. Active chlorine in solution is obtained from free available chlorine plus bound available chlorine. Hypochlorous acid (HOCl) and hypochlorite (OCl) are substances that kill microorganisms. Chlorine added to water will react with inorganic and organic compounds which then function as disinfectants. Hypochlorous acid (HOCl) is a disinfectant compound that is more reactive than OCl^-. Pathogenic microorganisms such as bacteria experience death because chlorine can break down the chemical structure of enzymes, even destroying them. When chlorine comes into contact with microorganism enzymes, hydrogen atoms will change into chlorine ions. This changes or even breaks the chemical bonds in the enzyme. This shows that chlorine at the optimal dose effectively reduces ammonia and produces minimal residual chlorine. The graph above shows the relationship between residual active chlorine in the Tura Tea wastewater treatment plant sample water after being treated with chlorine at doses of 100 mg/L, 150 mg/L, 200 mg/L, 250 mg/L, 500 mg/L, and 750 mg/L and a contact time of 30 minutes. Based on the graph above, the breakpoint is at 90% calcium hypochlorite with a dose of 200 mg/L, which leaves the smallest amount of free chlorine, namely 3.55 mg/L.

The ammonia removal efficiency of 80% obtained in this study is higher compared to the results of Putra, which only reached 65% at a dose of 150 mg/L [4]. The difference is due to the type of domestic wastewater and the contact time used. After applying the optimum dose of 200 mg/L, the ammonia concentration was reduced by 19.2 mg/L from an initial 96 mg/L, which meets the quality standard in the Regulation of the Environmental Ministry of Indonesia No. 11 of 2025 for communal WWTP systems (50 mg/L). The breakpoint chlorination method proves to be an effective solution to improve the performance of domestic WWTPs. The results of this study indicate that the chlorination process in domestic wastewater can significantly reduce ammonia without producing excessive chlorine residuals. The application of this breakpoint chlorination method has the potential to be adapted in communal wastewater treatment systems by considering optimal dosing and operational costs. Thus, integrating the chlorination process into existing systems can be a strategic step toward achieving effluent quality that meets environmental standards [19].

5. Conclusion

This study demonstrated that applying the Breakpoint Chlorination (BPC) method using calcium hypochlorite [$Ca(OCl)_2$] effectively reduced ammonia levels in domestic wastewater, achieving an 80% reduction from 96 mg/L to 19,2 mg/L at an optimum doses 200 mg/L, with residual chlorine concentration of 3,55 mg/L – still within the WHO limit of 5 mg/L. The findings highlight the BPC method's potential to enhance ammonia removal efficiency in communal-scale wastewater treatments system, contributing to improved effluent quality that complies with the Environmental Ministry of Indonesia No. 11 of 2025. Moreover, the study confirms that chemical oxidation and disinfection are complementary strategies for optimizing treatment performance, while recommending further research on disinfection by-product formation under sustainable conditions.

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