JURNAL ILMU LINGKUNGAN
Volume 21 Issue 3 (2023) : 659-666 ISSN 1829-890

The Effect of Cone Area Variations on the Continuous Discharges Flow (CDF) Method Sedimentation Unit as a New Method for Raw Water Turbidity Removal

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ABSTRAK

Luas cone pada unit sedimentasi metode continuous discharges flow (CDF) dapat mempengaruhi luas bidang pengaruh dan kecepatan aliran CDF terhadap partikel flok yang disisihkan di zona pengendapan. Penelitian ini menganalisis pengaruh variasi luas cone terhadap penyisihan kekeruhan air baku Sungai Batang Kuranji Kota Padang dengan kekeruhan saat sampling 25,385-26,164 NTU, pH 7,1-7,3, suhu 26,5-26,8°C. Reaktor dirancang pada debit 240 Liter/jam, yang terdiri dari unit koagulasi terjunan, unit flokulasi baffle, unit sedimentasi metode CDF dengan nilai CDF 6%, serta 3 variasi diameter cone (cm) atau luas cone (%) terhadap luas permukaan bak sedimentasi, yaitu 10 cm (13%), 15 cm (30%) dan 20 cm (52%) sebanyak 4 unit cone setiap variasi. Hasil penelitian menunjukkan, luas cone berbanding terbalik terhadap efisiensi penyisihan kekeruhan, semakin kecil luas cone maka efisiensi penyisihan kekeruhan semakin meningkat. Efisiensi penyisihan kekeruhan pada luas cone 13% adalah 83,455%, sedangkan pada luas cone 30% dan 52% berturut-turut adalah 82,270% dan 81,425%. Penyisihan tertinggi tercapai pada luas cone 13% dengan efisiensi 83,455% dari 26,164 NTU menjadi 4,169 NTU. Nilai kolerasi Rank Spearman -0,898 menyatakan hubungan yang sangat kuat dan berbanding terbalik dari variasi luas cone terhadap efisiensi penyisihan kekeruhan. Penambahan luas cone menurunkan kecepatan aliran, bilangan reynold (NRe) dan bilangan froude (NFr). Pada luas cone 13%, nilai NRe 95,085 dan NFr 2,833x10^{-4}.

Kata kunci: Luas cone, sedimentasi metode CDF, Penyisihan kekeruhan, Bilangan froude (NFr), Bilangan reynold (NRe)

ABSTRACT

The area of the cone in the continuous discharge flow (CDF) sedimentation unit can affect the area of influence and the flow velocity of the CDF on the floc particles set aside in the settling zone. This study analyzed the effect of variations in cone area on the turbidity removal of raw water from the Sungai Batang Kuranji, Kota Padang, with turbidity at sampling 25.385-26.164 NTU, pH 7.1-7.3, temperature 26.5-26.8°C. The reactor was designed at a discharge of 240 Liters/hour, consisting of a waterfall coagulation unit, a baffle flocculation unit, a CDF method sedimentation unit with a CDF value of 6%, and 3 variations of cone diameter (cm) or cone area (%) to the surface area of the sedimentation tank, namely 10 cm (13%), 15 cm (30%) and 20 cm (52%) as many as 4 cone units for each variation. The results showed that the cone area is inversely proportional to the turbidity removal efficiency, the smaller the cone area, the more turbidity removal efficiency. The turbidity removal efficiency for a cone area of 13% was 83.455%, while for a cone area of 30% and 52%, respectively, was 82.270% and 81.425%. The highest allowance was achieved at a cone area of 13% with an efficiency of 83.455% from 26.164 NTU to 4.169 NTU. The Rank Spearman correlation value of -0.898 indicates a very strong and inverse relationship from variations in cone area to turbidity removal efficiency. The addition of the cone area decreases the flow velocity, Reynolds number (NRe), and Froude number (NFr). At a cone area of 13%, the value of NRe is 95.085 and NFr is 2.833x10^{-4}.

Keywords: Cone area, CDF sedimentation method, Turbidity removal, Froude number (NFr), Reynolds number (NRe)

Citation: Ridwan., Afrianita, R., Putri, A. M., dan Anggika, R. (2023). The Effect of Cone Area Variations on the Continuous Discharges Flow (CDF) Method Sedimentation Unit as a New Method for Raw Water Turbidity Removal. Jurnal Ilmu Lingkungan, 21(3), 659-666, doi:10.14710/jil.21.3.659-666

1. Introduction

Clean water treatment processes are generally affected by turbidity (Xu et al., 2006). Turbidity is one of the physical properties of water. Turbidity is caused by a condition when all solid substances are in the form of sand, silt, and clay or suspended particles in water and can be living (biotic) components such as phytoplankton (Crittenden et al., 2012). The presence of turbidity in the waters causes sunlight to not enter the water so the process of photosynthesis is disrupted which disrupts other vegetation in the water (Effendi, 2003).

In general, a complete clean water treatment plant consists of coagulation, flocculation, sedimentation, and filtration processes (Kawamura, S. 1991). Sedimentation is a solid-liquid separation by utilizing gravitational settling to remove suspended solids (Reynolds & Richards, 1996). The condition of particle deposition in the sedimentation tank is influenced by one of them being laminar flow conditions, so that it can set aside 65-70% of total suspended solids (Gurjar et al., 2017). Increasing the efficiency of particle settling in conventional sedimentation tanks is generally done by increasing the dimensions of the tanks. Limited land in the field is an inhibiting factor, so modifications are needed to maximize the efficiency of settling sedimentation tanks (Husaeni et al., 2012). Some of these modifications are the sedimentation method of settlers, sedimentation of the solid contact method, and sludge blanked clarifiers (Crittenden et al, 2012), as well as the sedimentation of the continuous discharge flow (CDF) method as a new method (Ridwan et al, 2020).

Ridwan et al, (2022), modified the sedimentation unit by engineering continuous and controlled flow rates in the sedimentation unit deposition zone called the continuous discharges flow (CDF) sedimentation method. The CDF method sedimentation unit works like the leaking tank phenomenon. The effect of leakage in the form of a point is converted into a field called a cone with a conical or pyramidal shape. The point in question is the bottom of the cone which is connected to the drainpipe and valve as a regulator of the amount of exhaust flow in the CDF channel, while the field is the area of the cone mouth (Novembri, 2019).

In the Novembri study (2019), turbidity removal in the raw water of the Sungai Batang Kuranji was carried out in the CDF method sedimentation using a cone area of 30% of the surface area of the sedimentation tank with the shape of the sedimentation building being rectangular. The 30% cone area is the ratio of the total area of 4 cones with a diameter of 15 cm compared to the surface area of the sedimentation area, which is 0.24 m^2. Novembri research (2019), resulted in a turbidity removal rate of 82.38% with a CDF value of 6% from a reactor discharge of 240 L/hour at a detention time of 1 hour which is relatively shorter than the design criteria, namely 2-4 hours (Hudson, 1981).

The CDF value is a continuous and controlled control of the amount of exhaust flow discharge by adjusting the size of the CDF valve opening (Ridwan et al, 2021). The sedimentation turbidity removal rate of the CDF method has exceeded the conventional sedimentation efficiency, which is 70% (Husaeni et al., 2012), and is in the sedimentation efficiency interval modified with tube settlers, which is 82-97%, (Gurjar & Bhorkar, 2017). Based on these results, the engineering of sedimentation structures using the CDF method can be an alternative to removing raw water turbidity which can be continuously refined.

The continuous and controlled discharge rate at the sedimentation unit can affect the hydraulic conditions of the flow in the form of the Reynolds number (NRe) and Froude number (NFr). NRe and NFr that are not by the design criteria cause the performance of the sedimentation unit to be not optimal, thereby reducing the efficiency of turbidity removal (Huisman, 1977). Based on SNI 6774:2008 concerning Procedures for Planning Package Units for Water Treatment Installations, NRe must be less than 2000 and NFr must be greater than 10^{-5}. According to Huisman (1977), NFr must be greater than 10^{-5} so as not to cause the flow to become stationary, so that the processing effectiveness decreases. NFr ≥ 1 is also not recommended because it can cause high water turbulence that can break up the floc that has formed. Likewise with NRe, if NRe ≥ 2000 it will cause the flow to become turbulent so that the previously formed flocs will break and it becomes difficult to settle in the settling zone of the sedimentation unit. According to Van der Walt (2008), flow conditions must be considered to obtain an effective settling velocity. The settling of solid particles and their removal efficiency depends on the flow conditions.

According to previous research, at a cone area of 30%, the CDF flow velocity value is 0.000056 m/s for exhaust flow or a CDF value of 6% (Novembri, 2019). The use of cones aims to expand the influence of the CDF flow itself on the cross-sectional area of the sedimentation tank. Any variations or changes in the area of the cone identified will affect the area of influence and the flow velocity of the CDF on suspended floc particles and particles that tend to float in the deposition zone to be set aside. This change in CDF flow velocity is due to the velocity function (v) being tied to the cone area (A) and flow rate (Q) or equal to (Q/A) which itself also affects the hydraulic conditions of CDF flow as represented by the NRe and NFr numbers. Based on this, to determine the effect of the cone area on the efficiency of turbidity removal in the sedimentation unit of the CDF method, this study varied the area of the cone to improve the performance of the sedimentation unit of the CDF method so that the maximum cone area was obtained from previous studies, namely 15 cm in diameter or with an area of 30% of the surface area of the sedimentation tank (Novembri, 2019).

The objectives of this study include determining the efficiency of turbidity removal in the sedimentation unit using the CDF method with 3 variations of cone diameter, namely 10 cm (13%), 15 cm (30%), and 20 cm (52%) in diameter, analyzing the effect of cone area variations. on turbidity removal efficiency, Reynolds number, and Froude number in the sedimentation unit CDF method, determining the optimum cone area for turbidity removal in this study.

2. Material and Method

The study was conducted to determine the effect of variations in diameter (cm) or cone area on the surface area of the sedimentation tank (%), namely diameter (Ø) 10 cm or cone area 13% of the surface area of the sedimentation tank, (Ø) 15 cm or cone area 30% of the surface area of the sedimentation tank and (Ø) 20 cm or 52% of the cone area of the surface area of the sedimentation tank against the raw water turbidity allowance. The CDF value used is 6% of the total reactor inflow, which is 240 L/hour. The coagulant used is Aluminum Sulphate (Alum) with raw water from the Sungai Batang Kuranji, Padang City with the procedure for determining the optimum coagulant dose based on the results of the jar test (SNI 19-6449:2000).

Table 1. Data on the Quality of the Sungai Batang Kuranji

No.	Parameter	Unit	Water Quality Test Results	
			1st Sampling	2nd Sampling
1.	Turbidity	NTU	26.164	25.385
2.	pH	-	7.3	7.1
3.	Temperature	°C	26.5	26.8

The research was carried out on a reactor designed based on SNI 6774-2008 and consisting of a hydraulic coagulation unit in the form of a waterfall, baffle channel flocculation, and a sedimentation process using the CDF method with 3 cone area variations and a flow rate of 240 L/hour.

Removal efficiency is the decrease in the turbidity value of the treated water to the initial turbidity value with the formula below, (Hudson, 1981)

$$E = \frac{C_o - C_i}{C_o} x100\% \quad (1)$$

Analysis of variations in cone area in the CDF sedimentation reactor method for the efficiency of raw water turbidity removal was analyzed using the correlation coefficient and the significance of Rank Spearman analysis (Sujarweni, 2014). Spearman's Rank correlation coefficient illustrates the direction and value of the relationship between variations in cone area and turbidity removal efficiency. The significance value explains whether or not there is a significant relationship in each cone area variation to the turbidity removal efficiency.

Table 2. Reactor Design Capacity 240 L/Hour

Design Parameters	Design Results	Design Criteria
Coagulation Unit		
Velocity gradient (/s)	795.99	> 750
Length (m)	0.092	-
Width(m)	0.046	-
Water depth (m)	0.08	-
Waterfall (m)	0.29	-
Detention time (s)	5	1-5
Flocculation Unit		
Detention time (minutes)	30	30-45
Velocity gradient (/s)	60-10	60-5
Velocity (m/s)	0.0013	≤ 9
Number of stages	6	6-10
Dimensions of each stage		
Length (m)	0.22	-
Width(m)	0.22	-
Water depth (m)	0.4	-
Sedimentation Unit		
Overflow rate (m^3/m/hour)	0.22	< 11
Surface load (m^3/m/hour)	1	0.8-2.5
Length (m)	0.54	-
Width(m)	0.44	-
Water depth (m)	1	1-5
Renolds number	78.81	< 2000
Bilangan Froudes	2.35 x 10^{-4}	> 10^{-5}
Detention time (hour)	1	1-3.5
Flow velocity (m/s)	0.00278	≤ 9
Number of collecting channels	2	-
Number of V-notch	22	-
Number of CDF cones	4	-
CDF cone diameter (m)	0.15	-
Variation of cone area to surface area of the sedimentation basin	10% 30% 52%	- - -

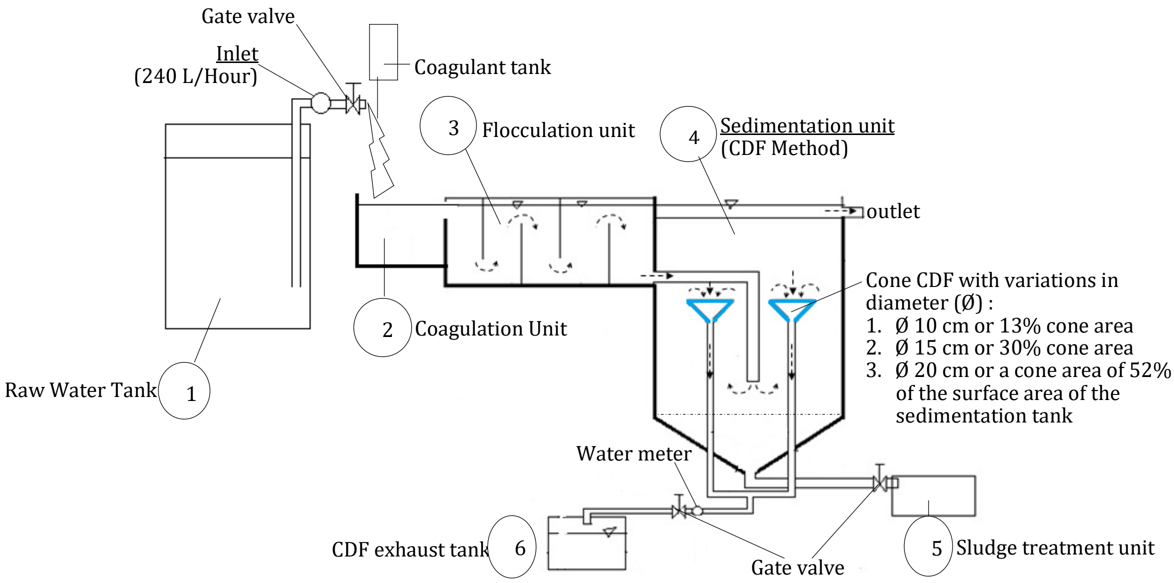

Figure 1. Part of sedimentation unit reactor CDF method with 3 cone area variation

Table 3. Interpretation of Correlation Values

Value	Interpretation
0,00 – 0,19	Very weak
0,20 – 0,39	Weak
0,40 – 0,59	Moderate
0,60 – 0,79	Strong
0,80 – 1,00	Very strong

The correlation coefficient and significance numbers are grouped into 5 levels, namely: very weak, weak, moderate, strong, and very strong as in Table 3. The Spearman Rank correlation coefficient is called significant if the significance value obtained is equal to or less than 0.05 (Sujarweni, 2014) and the Rank Spearman correlation value is between minus 1 to 1. If the value obtained is 0, it means that there is no relationship between the independent and dependent variables, while at a positive value of 1, it can be concluded that there is a positive relationship between the independent variables and the dependent variable. bound, and conversely for a negative value of 1, that is, there is a negative relationship between the independent variable and the dependent variable.

3. Results and Discussion

3.1. Coagulant Dosage

The jar test is a required method in determining the optimum coagulant dose. The coagulant used in this study was an alum. Alum coagulant is one of the coagulants that are easily available in the market at an economical price, so it is suitable for use to remove turbidity from raw water that has low turbidity (< 50 NTU). The optimum dose of alum coagulant was determined using a jar test with variations in coagulant doses, namely 10 mg/L, 20 mg/L, 30 mg/L, 40 mg/L, 50 mg/L, and 60 mg/L. Then the ranges were reduced by 8 mg/L, 10 mg/L, 12 mg/L, 14 mg/L, 16 mg/L and 18 mg/L. Optimum dose selection was determined based on the size of the flocs formed, the time of floc settling, and turbidity. water measured after the jar test (Pratiwi & Annisa, 2017).

Based on the tests that have been carried out, the optimum coagulant results for the raw water of the Batang Kuranji River are at a dose of 16 mg/L for the first and second samples of raw water. The final turbidity value in the jar test results for the first raw water sample was 3.027 NTU with a turbidity removal efficiency of 88.431% and for the second sample, raw water was 2.833 NTU with a turbidity removal efficiency of 88.840%. The results of the jar test measurements in determining the optimum dose in the first and second sampling can be seen in Table 4, Table 5, Table 6, and Table 7.

Table 4. The optimum dosage of Tawas Phase I coagulant in the first sampling

Dosage (ppm)	Initial data		Floc Size	Settling Time	Final Data	
	pH	Turbidity (NTU)			pH	Turbidity (NTU)
10	7.3	26.164	++	06.33.94	7.2	5.426
20			+++	06.13.53	7.2	4.042
30			++	07.05.62	7.2	4.856
40			+	08.46.02	7.2	5.597
50			+	07.21.39	7.1	6.184
60			++	06.52.58	7.1	6.533

Table 5. The optimum Dose of Alum Phase II Coagulant in the First Sampling

Dosage (ppm)	Initial data		Floc Size	Settling Time	Final Data	
	pH	Turbidity (NTU)			pH	Turbidity (NTU)
8	7.3	26.164	+	06.42.16	7.2	5.865
10			++	07.16.68	7.2	4.810
12			++	06.54.13	7.0	3.951
14			+++	07.07.18	7.1	3.739
16			+++	06.28.07	7.1	3.027
18			++	06.37.58	7.0	3.311

Table 6. The optimum Dose of Alum Phase I Coagulant in the Second Sampling

Dosage (ppm)	Initial data		Floc Size	Settling Time	Final Data	
	pH	Turbidity (NTU)			pH	Turbidity (NTU)
10	7.1	25.385	++	06.41.64	7.0	5.213
20			+++	06.16.38	6.9	3.801
30			++	07.14.04	6.9	4.596
40			+	08.38.39	6.8	5.339
50			++	07.08.42	6.8	5.825
60			++	06.58.87	6.8	6.242

Table 7. The optimum Doses of Phase II Alum Coagulant in the Second Sampling

Dosage (ppm)	Initial data		Floc Size	Settling Time	Final Data	
	pH	Turbidity (NTU)			pH	Turbidity (NTU)
8	7,1	25,385	+	06.49.50	7.0	5.523
10			++	07.20.69	6.9	4.662
12			++	06.37.02	7.0	3.713
14			+++	07.33.44	6.9	3.489
16			+++	06.35.84	7.0	2.833
18			++	06.51.31	6.8	3.146

Table 8. Analysis of the Effect of Cone Area Variations on the Efficiency of Turbidity Removal at a Production Debit of 240 L/hour

Time to (t) (minute)	Cone Area Variation (%)	Initial Turbidity (NTU)	Experiment Results in 1			Experiment Results ini 2			Average (%)
			Final Turbidity (NTU)	Removal Efficiency (%)	Average Removal Efficiency (%)	Final Turbidity (NTU)	Removal Efficiency (%)	Average Removal Efficiency (%)	
5	13	26.164	4.549	82.614	83.510	4.537	82.659	83.400	83.455
10			4.423	83.095		4.426	83.084		
15			4.350	83.374		4.435	83.049		
20			4.308	83.535		4.416	83.122		
25			4.285	83.623		4.364	83.321		
30			4.259	83.722		4.331	83.447		
35			4.246	83.772		4.310	83.527		
40			4.277	83.653		4.228	83.840		
45			4.235	83.814		4.217	83.882		
50			4.213	83.898		4.169	84.066		
5	30	26.164	4.721	81.956	82.199	4.732	81.914	82.341	82.270
10			4.712	81.991		4.724	81.945		
15			4.704	82.021		4.745	81.864		
20			4.718	81.968		4.691	82.071		
25			4.677	82.124		4.652	82.220		
30			4.682	82.105		4.593	82.445		
35			4.671	82.147		4.568	82.541		
40			4.589	82.461		4.541	82.644		
45			4.533	82.675		4.487	82.850		
50			4.567	82.545		4.469	82.919		
5	52	25.385	4.937	80.552	81.398	4.957	80.473	81.451	81.425
10			4.908	80.666		4.868	80.823		
15			4.882	80.768		4.736	81.343		
20			4.713	81.434		4.801	81.087		
25			4.678	81.572		4.768	81.217		
30			4.703	81.473		4.677	81.576		
35			4.654	81.666		4.597	81.891		
40			4.612	81.832		4.549	82.080		
45			4.581	81.954		4.575	81.978		
50			4.552	82.068		4.559	82.041		

3.2. Analysis of Effect of Cone Area Variation on Turbidity Removal Efficiency

The results showed that there was a decrease in raw water turbidity after passing through the processing unit, namely coagulation, flocculation, and sedimentation units using the CDF method. Allowance for raw water turbidity expressed as a percentage is the amount of turbidity that can be set aside by the processing unit for the wide variation of cones carried out in this experiment. Experiments were carried out in duplo with data collection time at 5-minute intervals, and the data obtained are presented in Table 8.

In Table 8, the highest average removal efficiency occurs at a cone area of 13%, namely 83.455%, where for the first experiment with an average efficiency of 83.510%, namely removing raw water turbidity from 26.164 NTU to 4.213 NTU, while in the second experiment, the average efficiency was an average of 83.400% with the ability to remove raw water turbidity from 26.164 NTU to 4.169 NTU. Allowance occurs continuously during the live water treatment reactor with a total of 10 times the data. According to Husaeni et al (2012), the efficiency of turbidity removal in conventional sedimentation units reaches 70% and when compared with the results of this study, efforts to improve the turbidity removal performance of the CDF method sedimentation units show good performance. According to the Regulation of the Minister of Health of the Republic of Indonesia, Number 492 of 2010 the limit for the level of turbidity for drinking water is 5 NTU.

The results of water treatment in the research for each cone area variation have met the established quality standards and the turbidity value of the processed water will be even smaller if the reactor is equipped with a filtration unit (Kawamura, 2008). Table 8 explains, the smaller the cone area, the higher the level of turbidity removal. The cone area of 30% represents no modification treatment to the sedimentation unit of the previous CDF method or is said to be the same as the Novembri study (2019). According to Novembri (2019), the efficiency of sedimentation turbidity removal by the CDF method with a CDF value of 6% reaches 82.38% with raw water turbidity of 23.613 NTU. This efficiency is also not much different from the study on the sedimentation unit with a cone area of 30%, which is 82.270% with raw water turbidity of 26.164 NTU. The addition of cone area in this study reduced the efficiency of turbidity removal, where at 13% cone area it reached 83.455%, at 30% cone area it reached 82.270% and at 52% cone area it reached 81.425%. These results also show that the effect of the value of the CDF flow velocity is more dominant when compared to the effect of the area of the CDF field itself. The maximum turbidity removal in this study was a 13% cone area of 83.455%.

The degree of correlation between the cone area in the CDF sedimentation unit and the efficiency of raw water turbidity removal can be measured statistically using the SPSS application. The statistical analysis used is Rank Spearman analysis. The value of the correlation and its significance can be seen in Table 9.

Table 9. Correlation and Significance of Cone Area Variations on the Efficiency of Raw Water Turbidity Removal

			Cone Area Variation	Turbidity Removal Efficiency
Spearman's rho	Cone Area Variation	*Correlation Coefficient*	1.000	-0.898**
		Sig. (2-tailed)	.	0.000
		N	60	60
	Turbidity Removal Efficiency	*Correlation Coefficient*	-0.898**	1.000
		Sig. (2-tailed)	0.000	.
		N	60	60

Based on Table 9, it can be seen that the level of correlation between the two variables shows a value of -0.898. Based on Table 4, these values show a very strong correlation. A negative value on the correlation coefficient indicates that the wider the cone, the smaller the efficiency of raw water turbidity removal, and vice versa. The significance value obtained is 0.000 ≤ 0.05 which means that there is a significant relationship between the two variables.

3.3. Analysis of the Effect of Cone Area on the Reynolds Number (NRe) and Froude Number (NFr)

The increase in the cone area of the sedimentation unit using the CDF method with a CDF value of 6% affects the hydraulic conditions of the flow in the form of the Reynolds number (NRe) and Froude number (NFr). The principle of using CDF in this sedimentation unit is to open a valve connected to the pipe as a CDF channel on 4 cones in the settling zone. The presence of the CDF valve opening causes the exhaust flow in the settling zone to downward towards the cone which can remove floc particles suspended in the water. This makes the particle settling rate greater so that floc particles can settle in the sludge zone and some of them are carried along with the flow of wastewater that comes out through the cone. Modification of the cone area in the CDF sedimentation unit is expected not to cause turbulence so that the flocs formed do not break and can settle completely and speed up the rate of settling. Based on the calculations that have been done, the velocity values for the cone area variations from the CDF sedimentation method can be seen in Table 10.

Table 10. Velocity Values for Each Cone Area Variation

Cone Area Variation (%)	Nilai CDF (%)	Qinlet (L/hour)	Flow (m/s)
13			0.0004066
30	6	240	0.0003370
52			0.0003134

Based on Table 10, there is an increase in downward flow velocity with a reduction in cone area in the CDF method sedimentation unit with a CDF value of 6%, affecting the flow conditions in the form of the Reynolds number (NRe) and Froude number (NFr). Based on the calculations that have been done, the NRe and NFr values for each cone area do not cause turbulence so that the formed floc does not break and can settle or be removed perfectly as presented in Table 11 below.

Table 11. Reynolds Number (NRe) and Froude (NFr) Values for Each Cone Area Variation

Cone Area Variation (%)	NRe Value Criteria SNI6774.2008	NRe	NFr Value Criteria SNI 6774.2008	NFr
13		95.085		2,8
30	< 2000	7.81	> 10^{-5}	2,3
52		73.289		2,1

Based on Table 11, it can be seen that the area of the cone affects the value of the Reynolds number and Froude number. The smaller the cone area, the higher the Reynolds number and Froude number due to the increase in flow velocity as the cone area decreases in the sedimentation unit of the CDF method. This is to Ramli's research (2017), which shows the NRe value in a fluid increases in direct proportion to the increase in flow velocity. NRe and NFr are one of the most important hydraulic criteria in designing sedimentation units. NRe and NFr that do not meet the criteria cause the performance of the sedimentation unit to be not optimal, thereby reducing the efficiency of turbidity removal. Based on SNI 6774.2008 concerning Procedures for Planning Units for Water Treatment Installation Packages, this value already meets the criteria. Based on SNI 6774.2008, NRe must be less than 2000 and NFr must be greater than 10^{-5}. The relationship between cone area, flow velocity, NFr, and NRe can be seen in Figure 2.

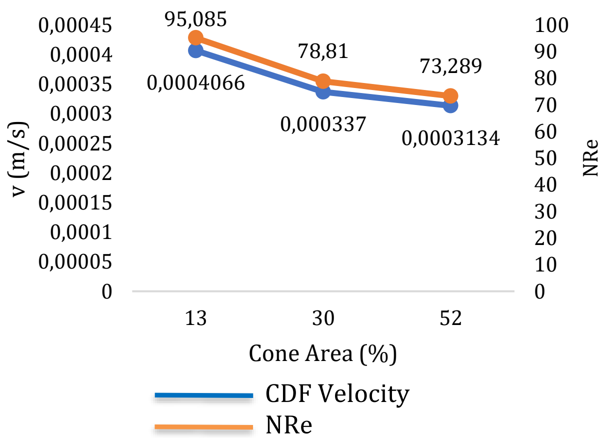

Figure 2. Flow Velocity and NRe Values for Each Cone Area Variation

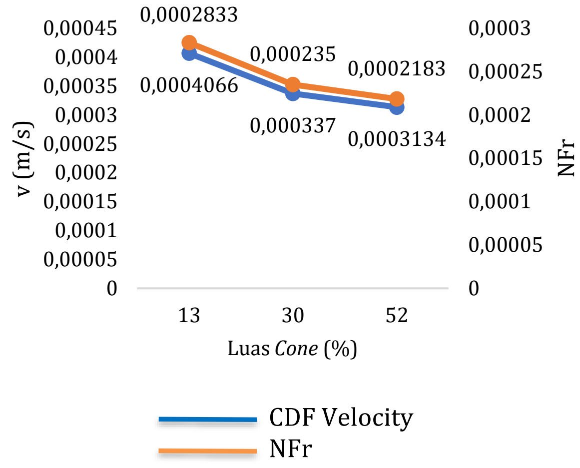

Figure 3. Flow Velocity and NFr Values for Each Cone Area Variation

Based on Figures 2 and 3, it can be seen that the relationship between cone area is inversely proportional to flow velocity, NRe, and NFr. According to Huisman (1977), the NFr value should not reach a stagnant or quiescent flow state. The stagnant flow condition causes stagnant areas in the sedimentation unit which causes a decrease in efficiency. The flow will reach stagnation if the NFr value is below 10^{-5}, therefore the NFr value must remain above 10^{-5}. In addition, according to Crittenden et al (2012), a small NFr of 10^{-5} can cause a back-mixing mechanism. This causes the trajectory of the flock's deposition to change randomly and can be carried to the outlet zone. Based on SNI 6774.2008 concerning Procedures for Planning Unit Packages for Water Treatment Installation, this value meets the criteria where the Reynolds number is less than 2000 and the Froude number is greater than 10^{-5}.

4. Conclusion

The average turbidity removal efficiency of the processed water from the sedimentation unit using the CDF method with variations in diameter (cm) or cone area (%) on the surface of the sedimentation tank is 10 cm (13%), 15 cm (30%) and 20 cm (52%) were 83.455%, 82.270%, and 81.425%. The effect of the cone area is inversely related to the turbidity removal efficiency and Reynolds number (NRe) and Froude (NFr), the smaller the cone area, the greater the removal efficiency and NRe and NFr. The highest turbidity removal efficiency occurs at a cone diameter of 10 cm or a cone area of 13% of the sedimentation basin area with an average efficiency of 83.455%.

Nomenclature

E	turbidity removal efficiency	%
Co	Initial turbidity	NTU
Ci	Final turbidity	NTU

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