COMPARISON OF POLY ALUMINIUM CHLORIDE (PAC) AND ALUMINIUM SULPHATE COAGULANTS EFFICIENCY IN WASTE WATER TREATMENT PLANT

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ABSTRACT

Hospital waste water containing high organic compounds that can harm the environment if not done processing beforehand. One way to lower the price of contaminants contained in hospital wastewater is the process of physically-chemical treatment using coagulation process in the Waste Water Treatment Plant and the coagulation process requires coagulant optimally capable of reducing the organic content in the water treatment. The purpose of this research is to make the design of waste water treatment plant and compare the effectiveness of the use of poly aluminum chloride (PAC) and aluminum sulfate in water turbidity reduction of hospital waste at the Waste Water Treatment Plant design. So that at the Waste Water Treatment Plant produces effluents that comply with effluent hinted that diindentifikasikan in parameters such as BOD, COD and TSS. The WWTP design is Consist of equalization bath, bath coagulation, chlorination and sump. The study was conducted with the study of literature. Based on the research results with the use of a second dose of the coagulant optimum of 160 mg / l. The highest efficiency value to decrease BOD, COD, TSS and TDS looks at PAC coagulant aluminum sulfate compared with the percentage of 96.17%, while the PAC valued at 95% although if measured in terms of economical aluminum coagulants have more economic value namu in terms of environmental and safety the use of PAC is better than Alum. Therefore, in the coagulation process of hospital waste water is recommended to use coagulants PAC.

Keywords : *Aluminum Sulfate, Coagulant efficiency, Hospital waste water, Poly Aluminium chloride*

1. INTRODUCTION

Source of water pollution can be come from the hospital. Sources of hospital wastewater can be derived from bathrooms, kitchen rooms, the examination rooms, laboratories, operating rooms and other rooms containing hazardous materials and germs. Various kinds of toxicities such as pharmaceutical waste, radio-nuclides, solvents and disinfectants for medical purposes with a high concentration for laboratory activities (Siregar, 2008). Hospital waste as well as other waste containing organic and inorganic materials, which the containing level can be determined by testing waste water such as BOD, COD, pH, microbiological, TSS and others (Said, 2006). Water waste from hospitals is one source of water pollution potential because the hospital waste water is containing organic compounds , chemical compounds and pathogenic microorganisms that can cause disease to the surrounding community. Pursuant to Law No. 32 of 2009 in Indonesia about Protection and Management of the Environment, an activity is required to process and manage wastes produced by its activities, in order to conserve the environmental functions so the waste must be processed and managed with the applicable quality standards. Kep-MENLH / 12/1995 concerning effluent quality standards for hospital activities that requires every hospital must treat wastewater to a permitted standard (Anonim, 2009).

From the explanation above, those can be used as a guide for the hospital to process and manage the waste till get the environmental quality standards that applicable (Taurini, 2014) Hospitals need to build Wastewater Treatment Plant to produce safe effluent which can be disspossed to the environment that passed the quality standards. In this research, we make the WWTP so that the result processed can be disposed into environment. The main characteristics of the hospital's waste water is the content of coliform bacteria, because it has very high value. In addition to the high content of coliform bacteria, the characteristics that is high of the waste water are BOD, COD, and

TSS (Aziz, 2016). The objectives of this research are to are to design WWTP in hospital, determine the output waste from WWTP and can be used as a basis in the calculation of WWTP.

In order to improve the efficiency of water treatment plants, it is necessary to study the potential problems that may arise in every stage of the process water treatment consisting of raw water conditioning, coagulation-flocculation, sedimentation, filtration and disinfection (Hermana, 2010). This study focused on the coagulation-flocculation processes that require chemical additives or called coagulants (Fatnasari, 2010). Coagulant type often used is aluminum sulfate (aluminum) and poly aluminum chloride (PAC) (Wityasari, 2015). Coagulation is the addition of chemicals (coagulant) into the raw water with the aim of reducing the repulsion between colloidal particles, so that the particles can be joined into a floc-floc fine. While flocculation is a process of agglomeration or clumping of particles terdestabilisasi into floc size possible can be separated by sedimentation and filtration. Coagulation process could be hampered if the turbidity level is too low or too high (Rahimah, 2016).

The purpose of this study was to compare the effectiveness of the use of poly aluminum chloride (PAC) and aluminum sulfate in water turbidity reduction of hospital waste at the Waste Water Treatment Plant design, to determine the effectiveness of the reduction of coagulant PAC and alum when used in wastewater treatment hospital.

Wastewater Treatment Plant (WWTP) is a structure that is designed to dispose of biological and chemical waste from the water thus allowing the water to be reused at other activities. The main purpose of wastewater treatment is to decompose the content of pollutants in the water, especially organic compounds, suspended solids, pathogens and organic compounds that can not be decomposed by microorganisms found in nature (Hidayah, 2010). For treating wastewater parameters, processing units that will be applied consists of several treatment plant (Isyuniarto,). Based on the selection it has been done, then in WWTP will be used unit-of processing unit as follows :

a. Equalization

The use of equalization tank aims to generate a uniform flow so that the processing units in the installations be able to avoid shock loading. Form of equalization tank that will be used are rectangular. During the equalization stirring to prevent the precipitation of solid and odor. Biological oxidation due to the agitation in the tank, according to Metcalf & Eddy (2004), can reduce the concentration of 10-20% total COD, TDS and TSS by 15-20%.

b. Coagulation and Floculation

Coagulation - flocculation is a means for the separation of suspended solids (SS) and colloidal particles. SS is a product of natural minerals such as clay, silt, and so on, or derived from organic (decomposition of plant or animal). The colloid is SS with a smaller size, these particles can not settle naturally, has a diameter of less than 1 mm and the cause of the color and turbidity. Coagulation is defined as a process of destabilization of colloidal particles and suspended particles, including bacteria and viruses through neutralizing the charge elektrinya to reduce the repulsive force among particles refused, and the materials used for neutralization called coagulants (nuryani, 2016). While flocculation is defined as the process of merging partikelpartikel unstable after the coagulation process through the mixing process (stirring) is slow to form clumps or flocks that can be deposited or filtered on the subsequent processing (Wulandari, 2012)

Coagulant

Coagulant used for the study were Alum and PAC. Alum and PAC capability will be compared to decrease the turbidity of the water (Nur, 2016). The characteristics coagulant alum and PAC will be described below.

b.1 Tawas or alum, $Al_2(SO_4)_3.14H_2O$ (in the form of rocks, powders, liquids)

The density of alum is 480 kg / m^3, with a moisture content of 11-17%. Alum dosage can be reduced by: a decrease in the turbidity of raw water, direct filtration for turbidity <50 NTU, the addition of the polymer, and the optimum pH adjustment (6.0 - 8.0). Alum is dissolved in water with high levels of 3-7% (5% on average) for affixing. Application of maximum levels of 12 -15%. Aluminium suflat require alkalinity (such as calcium bicarbonate) in water to form floc:

$$Al_2(SO_4)_3.18H2O+3Ca(HCO_3)_2 \longrightarrow 2Al(OH)_3 + CaSO_4 + 18H_2O + 6C \quad (1)$$

$$CaSO_4 + Na_2CO_3 \longrightarrow CaCO_3 + Na_2SO_4 \quad (2)$$

When the natural alkalinity less, necessary to add Ca (OH) 2:

$Al_2(SO_4)_3.18H_2O+3Ca(OH)_2 \rightarrow 2Al(OH)_3 + 3CaSO_4 + 18H_2O$ (3)

Another alternative is the addition $NaCO_3$ relatively more expensive(16). Two important factor in the coagulation process, especially during coagulant addition is a factor pH and coagulant dose. Coagulants and pH optimum dose should be determined by tests in the laboratory. Alum optimal pH range is between 5.5 - 6.5 with adequate coagulation process can rangenya between pH 5.0 - 8.0 pada some conditions (Cornwell, 1998).

b.2 PAC

PAC is a polymer aluminum which is a new type of coagulant as a result of research and development of water treatment technologies. As the element is essentially aluminum and aluminum is associated with other elements to form repeating units in a molecule chains long enough. Thus the PAC combines neutralization and bridging capabilities particles - coagulation of colloidal particles that lasted more efficient. PAC has a long polymer chain, a high positive electrical charge and has a large molecular weight, the PAC has a high coefficient so as to minimize floc in the clarified water even in excessive doses. PAC faster formed floc than coagulant unusual, because the PAC has a positive electrical charge so high that PAC can easily neutralize the electrical charge on the surface of colloidal and can cope with and reduce the force repel electrostatically between particles as small as possible, thus allowing the particles - colloidal particles are approaching each other (covalent attractive forces of attraction) and forming clots / yamg larger mass. The positive aspect is the use of PAC to PAC pH range is 6 - 9. Power PAC better coagulation and floc generated comparatively less besar.Konsumsi PAC so that the cost of water purification is smaller per unit time. As a direct result of the purification process is shorter overall water purification capacity (from an existing installation) will increase. While the negative aspects of the use of PAC is a PAC liquid storage conditions require maximum temperature of 40°C (Kawamura, 2000).

PAC is not cloudy when its use is excessive, while the primary coagulant (such as aluminum sulfate, ferric chloride and ferrous sulfate) when excessive doses for the water to be murky, as a result of excessive floc. Then the usage of PAC in the field of water purification is more practical. PAC faster formed floc than usual coagulant. PAC is a class of Aluminium Chloride, which are known in complex organic chemical compounds with hydroxyl ions (OH) and ion - aluminum ion standard chlorination different as polynuclear form. The general formula PAC is $(Al_2(OH)nCl6\text{-}n)m$. PAC is used as coagulant and flocculant in a water treatment process.

Applications PAC is basically divided into two parts, namely:

- In the processing of surface water for the purposes of clean water, drinking water and water for industrial processes (taps, paper industry, textile industry, steel industry, wood industry, etc.).
- In industrial liquid waste processing, among others: the pulp and paper industry, textile industry, sugar industry, food industry, and others - others.

Characterictics of the PAC:

a. Freezing point = -18 ° C,
b. Boiling point = 178 ° C,
c. Empirical formula = $(Al_2$ (OH) 6-n) m with 1 $<$n $<$5 and m $<$10 and
d. Specific gravity = 1.19 (20 ° C).

Mechanism Process Coagulation–Flocculation :

1. The addition of coagulant

As known, in a colloidal solution there is always a second force opposing forces, namely the attractive force and van der Waals repulsion commonly called zeta potential. At the same distance, a repulsive force - reject always greater than gravity – interesting (Al-Lyla, 1998). This is what causes clumping of the particles will not occur. To overcome these necessary chemicals called coagulants.

2. Destabilization Colloidal Particles

In water colloidal particles are electrically charged similar (same negative) repel each other so it can not attract each other - attract and particles remain in place, this is called a stable condition (Ervy, 2010). Condition stable particles that do not allow the formation of floc. If in the water are rendered positively charged metal ions, the positive charge can reduce the repulsion between the members of colloids (Repulsion force) and can lead to the inclusion in prespitat hydroxide colloids. So that there will be conditions destabilization of the particles. Condition Unstable colloidal particles allows the formation of floc in order to precipitate.

3. Flocculation Process

Colloids unstable tends to clot. Clotting speed determined by the number of collisions and collisions between particles - colloidal particles. In this flocculation process, collisions between the particles can occur in several ways, namely:

a. Collisions result zigzag motion of particles randomly.

The collision caused by the movement of zig-zag randomly particles known as flocculation perikenetik called brown motion which resulted in merger between flocks.

b. The collision due to the influence of media movement

The collision due to the influence of media movement known as flokulasiortokinetik. The velocity gradient media movement mengakibatkanpartikel-particles brought media will have different speeds, causing collisions between particles (floc). Medium speed difference is actually a determinant factor in the process of flocculation (Asmadi, 2012).

The process of coagulation and flocculation optimum influenced many variables - variables are complex, while the variables that influence are:

1. Water Quality

Coagulant needs depending on turbidity. High turbidity can cause coagulation process becomes more effective, but the addition of coagulant is not always correlate linearly with the turbidity (Kodoatie, 2013). Likewise, the decline in the colors <5 Pt Co is very difficult with the coagulation process because it requires a high dose, but a decrease in color up to ± 15 PtCo easier.

1. Quantity and Characteristics of Water

Non-uniform particle size is much easier to coagulated. This is because the active site more easily form on small particles, while large particles accelerate the deposition. The combination of these two types of particles causes the more easily the coagulation process.

3. Effect of pH

Selection of the proper pH will result in coagulant dose used to obtain the optimum effluent is small. It is caused by the chemical nature of coagulant which is highly dependent on pH. Limits on pH value occurs due to the type of coagulant used coagulant in water and reaction to determine the concentration of the coagulant used. Operating errors in determining pH range will lead to wastage of chemicals and result in a lower quality in wastewater treatment effluent. If using Fe 3+ coagulant coagulation pH range is 5.0 to 8.5 However the general pH 7.5.

4. Speed Time Round and Round

Rotation speed is closely connected with the process of mixing the coagulant into the water, the process of destabilization of the particle and displacement as well as the incorporation of precipitates formed into a floc-floc. Stirring time was also highly influential as it relates to the time it takes precipitates collide with each other which is sufficient to form a floc with the best quality.

5. Temperature

Low temperatures have an adverse effect on the efficiency of all processes. The contact time in the coagulation flocculation facility should be set. The lower the temperature the longer the contact time of need because it affects the formation of floc-floc in order to quickly settle in sedimentation basin.

c. Sedimentation

In the sedimentation tank types horizontal removed particles is dependent upon over flow rate (Vo), in this type there are several assumptions:

1. Particles and velocity vectors are distributed on a cross-section of the tank, as a function of the inlet zone.
2. Transfer the liquid will looking down on the length of the tank.
3. Particles below will be removed from the tank (Basuki, 2004).

d. Ozonation

Ozone is produced when oxygen (O_2) molecules are dissociated by an energy source into oxygen atomsand subsequently collide with an oxygen molecule toform an unstable gas, ozone (O_3), which is used to disinfect wastewater. Most wastewater treatment plants generate ozone by imposing a high voltage alternating current (6 to 20 kilovolts) across a dielectric discharge gap that contains an oxygen-bearing gas. Ozone is generated onsite because it is unstable and decomposes to elemental oxygen in a short amount of time after generation. Ozone is a very strong oxidant and virucide only next to OH radicals .

The mechanisms of disinfection using ozone include:

a. Direct oxidation/destruction of the cell wall with leakage of cellular constituents outside of the cell.
b. Reactions with radical by-products of ozone decomposition.

c. Damage to the constituents of the nucleic acids (purines and pyrimidines).
d. Breakage of carbon-nitrogen bonds leading to depolymerization.

When ozone decomposes in water, the free radicals hydrogen peroxy (HO2) and hydroxyl (OH) that are formed have great oxidizing capacity and play an active role in the disinfection process. It is generally believed that the bacteria are destroyed because of protoplasmic oxidation resulting in cell wall disintegration (cell lysis) (Effendy, 2016).

2. RESEARCH METHOD

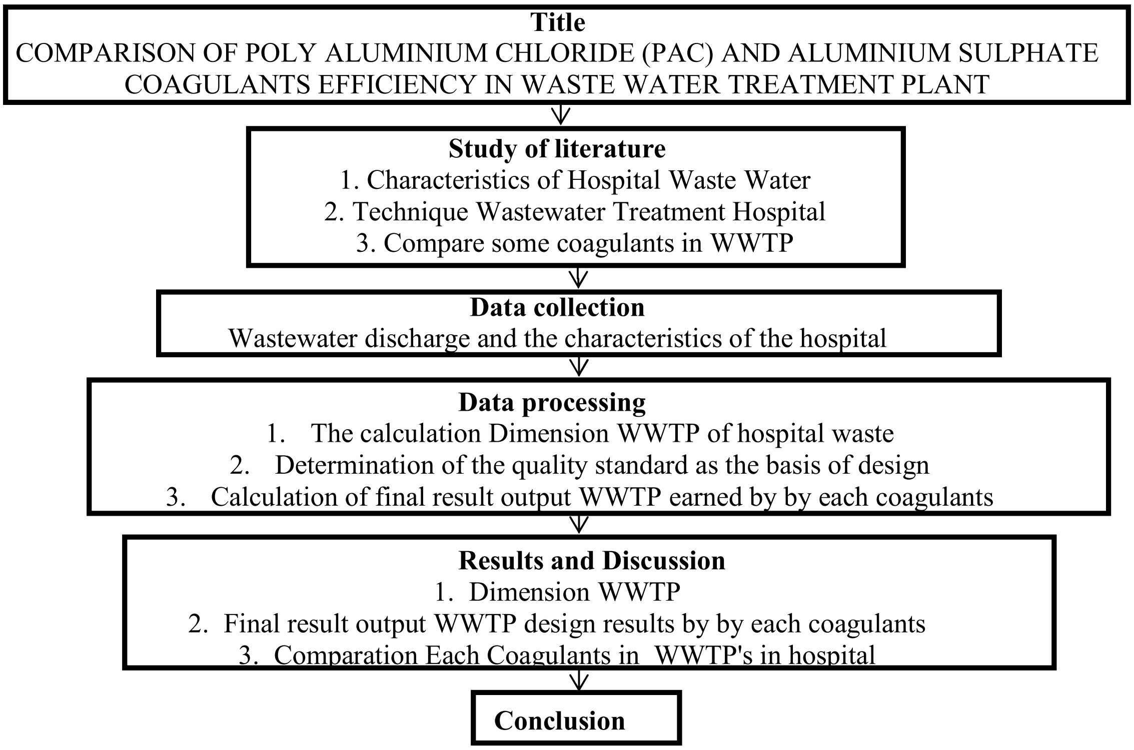

FIGURE 1. Research Procedure

3. RESULT AND DISCUSSION

3. 1Design Wastewater Hospital

To treat wastewater hospital it is necessary to design that fits inside the hospital waste water treatment, the processing units used is composed of pre-treatment unit such as equalization bath, flocculation and coagulation treatment unit ozonation unit. In the treatment of coagulation and flocculation done a physical operation which aims to eliminate floating and dissolved solids in wastewater and wastewater preparing to enter the further treatment stages, namely treatment ozonation bath. In this ozonation bath will acts in killing bacteria present in the water and to eliminate most of the organic content in wastewater.

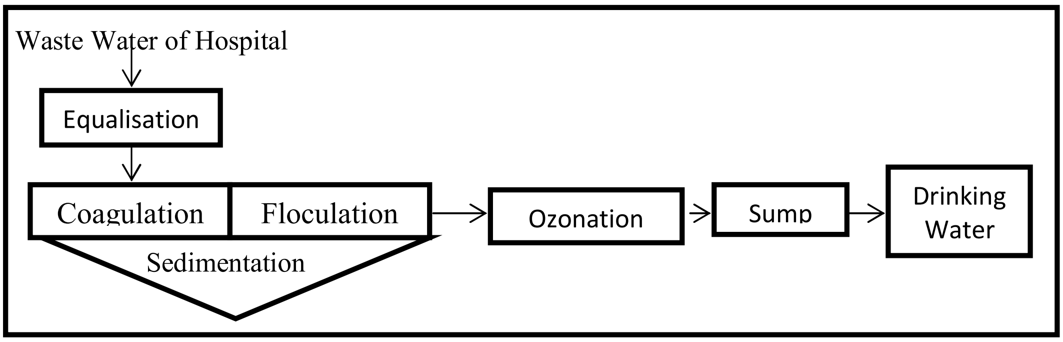

FIGURE 2. Block Diagram WWTP Hospital

3.2 Calculation of Dimension WWTP

In this planning, hospital waste flow of water obtained as follows: 28 m^3 / day. It refers of literature, including the text book Decentralised Wastewater Treatment in Developing Countries and Treatment and Reuse Fourth Edition by Metcalf and Eddy [13] both in obtaining design criteria of planning and calculating the dimensions of the WWTP

3.2.1. Equalization Tank

The use of equalization tank aims to generate a uniform flow so that the processing units in the installations be able to avoid shock loading. Form of equalization tank that will be used are rectangular. During the equalization stirring to prevent the precipitation of solid and odor. Biological oxidation due to the agitation in the tank, according to Metcalf & Eddy[13]. Over Flow Rate 28 (m^3/day.m^2)

3.2.2. Coagulation and Floculation

In the process of coagulation and flocculation, the water will be very role, because the chemical must be mixed with water. Stirring / Agitation process will very quickly and uniform dispersion of compounds in water, the coagulation process occurs with rapid stirring, effective and economics cost [24]. In this case the process of coagulation and flocculation chemical and physical reactions will occur precipitation: Aluminum Hydroxide (Alum) and PAC.

A. Alum

*Concentration Of Alum : 160 ppm
*Power of stirrer motor : 3,05 Watt
*Flow rate Alum : 0,088 kg/h
*Solution Alum : 5%
*Flow rate water : 1,672 kg/h
*Total volume : 1,76 m^3

A. PAC

*Concentration Of PAC : 160 ppm
*Power of stirrer motor : 3,05 Watt
*Flow rate PAC : 0,088 kg/h
*Solution PAC : 5%
*Flow rate water : 1,672 kg/h
*Total volume : 1,76 m^3

3.2.3. Sedimentation

*Number of Weir Loading : 1
*Weir Loading : 140 m^3/d.m
*Over Flow Rate : 28 m^3/hari.m^2
*Scour Velocity : 12,53 cm/s
*Horizontal Velocity : 0,78 cm/s
*The slope of the Wall Channels : 0,00097

3.2.4. Ozonation

Type Ozonizer : Plasma ozonizer PSTA BATAN
*Power : 48,61 Watt
*Flow rate ozon : 1,94 mg/det
*Voltage : 25 kV/1,5 kHz
*Ozon Concentration : 0,12 ppm
*Cost Ozone Requirements once : Rp 131,47

Generally calculation of dimensions in the planning of these is shown in Table 1 :

Table 1. Design WWTP Hospital

Unit	Dimension			Residence time (h)	Power (watt)
	Length (m)	Wide (m)	Head (m)		
Equalisation	1	0,5	3,3	1,54	-
Coagulation	1,21	1,21	1,51	4	3,05
Floculation	1,21	1,21	1,51	4	3,05
Sedimentation	5	0,2	3,5	3	-
Chlorination	0,92	0,92	1,22	0,67	25
Sump	3,03	3,03	3,33	24	-

3.3 Calculation Result Output WWTP

In this planning, hospital waste flow of water obtained as follows: 28 m^3 / day so that calculation Result WWTP refers to parameters of efficiency reduction of some of the literature includes text book Decentralised Wastewater Treatment in Developing Countries and Treatment and Reuse Fourth Edition by Metcalf and Eddy [13]. After calculation, we can obtain mass balance from design WWTP at Table 2 and Table 3 (the units in mg/L)

Table 2. Mass Balance and Effisiency Design WWTP using Alum

Section	Parameter				
	BOD (mg/L)	COD (mg/L)	TDS (mg/L)	TSS (mg/L)	Bacteria (mg/L)
Influent	64,9	228,4	458	45	6300
Equalization	0%	0%	15%	15%	0%
	64,9	228,4	389,3	38,25	6300
Coagulation and	96,17%	96,17%	96,17%	96,17%	60%
Floculation	2,49	8,75	14,91	1,46	2205
Ozonation	96,7%	97%	86,1%	86,4%	100%
	0,09	0,26	2,07	0,19	0
Sump	0,09	0,26	2,07	0,19	0
Effluent by design	0,09	0,26	2,07	0,19	0
Outlet of Hospital	7,1	21,67	116	2	620

Table 3. Mass Balance and Effisiency Design WWTP using PAC

Section	Parameter				
	BOD (mg/L)	COD (mg/L)	TDS (mg/L)	TSS (mg/L)	Bacteria (mg/L)
Influent	64,9	228,4	458	45	6300
Equalization	0%	0%	15%	15%	0%
	64,9	228,4	389,3	38,25	6300
Coagulation and Floculation	95%	95%	95%	95%	60%
	3,24	11,42	19,46	1,91	2205
Ozonation	96,7%	97%	86,1%	86,4%	100%
	0,11	0,34	2,7	0,25	0
Sump	0,11	0,34	2,7	0,25	0
Effluent by design	0,11	0,34	2,7	0,25	0
Outlet of Hospital	7,1	21,67	116	2	620
*Quality of Drinking Water Standard	30**	12**	500*	500**	0*

*based on PERMENKES RI No.492/MENKES/PER/IV/2010

**based on PP RI No.82 on 2010

3.4 Comparation Coagualants

Calculation of material requirements and costs coagulant $Al_2(SO_4)_3$ and $FeCl_3$ to 5% concentration in wastewater treatment are as follows:

1. **Alum**

Alum solution of 5% = 50 g / 1 liter water
Water discharge = 28000 L / day
Optimum dose = 160 ppm
Price Alum = IDR 1,500, - / kg
The use of a coagulant per hour: 4.48 kg / day
Usage fees coagulant daily: Rp. 6720

2. **PAC**

PAC solution of 5% = 50 g / 1 liter water
Water discharge = 28000L / day
Optimum dose = 160 ppm
Price Tawas = Rp.5000, - / kg
The use of a coagulant per hour: 4.48 kg / day
Usage fees coagulant daily: Rp. 22,400

CONCLUSION

The study concluded that use of PAC more effective than alum although alum is cheaper than PAC. However, further research is needed on the effect of a coagulant to the decline in total organic matter and other content.

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