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The Effect of Calcium Oxide and Aluminum Sulfate on Iron, Manganese and Color Removal at Peat Water Treatment

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Abstract

The availability of clean water is a basic need for human life. Peat water is well-known as acidic water (low pH), high content of Fe^{2+} and Mn^{2+} and colored that make it hard to remove by conventional filtration method. Treatment in batch and continuous methods by using Calcium Oxide (CaO) and aluminum sulfate $Al_2(SO_4)_3 \cdot 18H_2O$ result in significance reduce of iron and manganese. The batch method in particular, able to reduce iron from 3.5 ppm to 0.1 ppm (97%), manganese from 0.59 ppm to null (100%) and color from 130 TCU to 1.7 TCU. Turbidity also reduced from 33.8 NTU to 1.9 NTU whereas pH increase from 3.19 to 6.8. The continuous method in different circumstances shows iron removal from 3.35 ppm to 0.05 ppm (98.6%), manganese from 0.5 ppm to null (100%) whilst pH raised from 3.19 to 7.16 and turbidity decrease from 31.8 NTU to 1.14 NTU. Both results fulfill the water quality standard required by Permenkes No. 416/Menkes/1990.

Keywords: Peat water, calcium oxide, aluminum sulfate

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INTRODUCTION

Indonesia has peatlands spread in three largest islands namely Sumatera, Kalimantan and Papua. Peatland in Sumatera occupies the largest area about 6,436,649 hectare whereas Kalimantan and Papua about 4,778,004 and 3,690,921 hectare, respectively. These areas provide peat water that can be treated and served as clean water to fulfill needs where public facility is not available [1].

Water from peatland usually comes with brownish yellow color, high content of iron and manganese as well as organic matter and acidity. This unhygienic low quality of peat water can cause illness such as vomiting, skin disease and others health problems. Despite its huge potential, peat water contains serious problem when it comes to water treatment process. Coagulant addition can be ineffective due to low pH (3-5) of peat water caused by high content of humic and fulvic acids hence a better water treatment is needed [2]. The color of peat water depends on the proportion of humic and fulvic acid within peatland. Peat water can be neutralized by adding alkaline, which makes its pH raised. Alkaline compound used in this work is calcium oxide whereas aluminum sulfate used as coagulant.

The proportion of calcium oxide and aluminum sulfate on peat water treatment highly affects the removal of iron and manganese and color of water. This factor applies not only in batch method but also in continuous method. Several methods had been conducted in peat water treatment process, some conventional technique proved quite effective result such as coagulation, flocculation and filtration [3]. Chemical substances was used in coagulation and flocculation process. The coagulant dosage and operational condition are crucial in obtaining good result and preventing side product from coagulant substance mixture [4].

The amount of calcium oxide used in peat water treatment determines the iron removal as well as color. Manganese can also be removed by addition of calcium oxide. Color can be reduced up to 96% as reported by some authors but it has side effect i.e. high total dissolve solid within the treated water [5,6]. Further process hence is necessary to obtain processed water suitable for daily purposes [7]. Treatment by using aluminum sulfate can be useful to bind particle's charge and reduced diffusion layer thickness around the particle. The process will lead to decrease of total dissolve solid within peat water. According to Kemmer [8], Jar test is a standard method for testing coagulation process. Water treatment process is considered successful if it can reduce the turbidity and other contaminants contains within the water.

In a sedimentation process, particles grows and binds each other to form larger particle and then precipitated physically. Filtration is important to separate colloid particles remains from previous process. This separation usually uses quartz sand. The suspended solid was removed when the treated water passing by quartz sand filter. Peat water treatment had been reported with focus effort on solving contaminant substances contained in the sample. The processing technology by using simple method and chemical agents as well as ultra-filtration techniques using membrane had been widely used [9].

Neutralization and coagulation able to decompose color of water, the speed used in Jar-test is 100 rpm for 1-2 minutes to achieve homogeneous mixtures follow by slow stirring for another 10 minutes [8]. The main components within peat water are fulvic and humic acids and color forming substance i.e. humin. To evaluate the structure and soil condition, test must be carried out through geomorphology and stratigraphy. Geomorphology includes lowland and low bumpy hills whilst stratigraphy comprise of various rock types arrangement [10].

MATERIALS AND METHODS

Methods

In this experiment both batch method and continuous at 0.8 L/sec were conducted, which took place at Talang Keramat village, Banyuasin, South Sumatera. Continuous method required several additional equipment such as pumping and piping system. Small to large barrels also needed as reactor vessels. The schematic diagram of the process is shown on Figure 1.

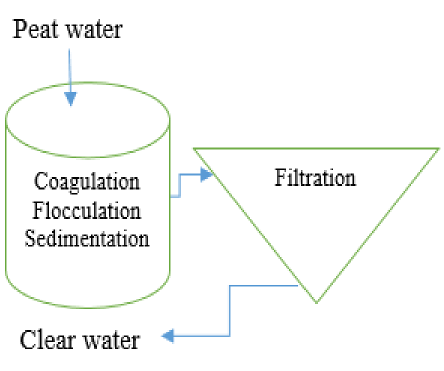


Figure 1. Schematic diagram of Batch process

Prior entering flask for batch process, peat water was checked and analyzed. The Jar test conducted during neutralization and coagulation at stirring speed 100 rpm for 1 minute follow by low stirring (30 rpm) for 4 minutes. The flocculation process carried out in slower speed of stirring to stimulate flocs formation. Sedimentation step conducted later on for 8 minutes to precipitate colloidal particles follow by filtration step.

In the continuous process, system equipped with pumping and piping system and barrel to collect the result. Peat water neutralization initially carried out by adding calcium oxide 10%. This process aimed to increase pH of the peat water. The next process was coagulation using aluminum sulfate 1%. The concentration of the coagulant was set to 25 ppm. The resulting suspension streamed into flocculation stage and sedimentation, which then end at filtration stage. Quartz sand used in this final process. Physical and chemical properties was evaluated on the water treatment result. In Figure 2, the continuous system of peat water treatment was depicted.

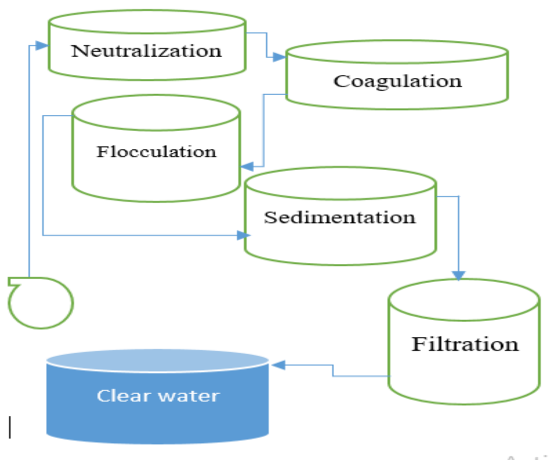


Figure 2. Continuous process schematic diagram

Water from batch method was analyzed in the laboratory whereas continuous system was evaluated at 2880 liter/hour capacity. The continuous system installation located at Talang Keramat RT 16 RW 03 Talang Kelapa sub-district, District of Banyuasin South Sumatera Province having coordinate 2°53’35”S 104°45’16”E as seen in Figure 3.

RESULTS AND DISCUSSION

Batch Process

Preliminary test on physical properties of peat water displayed on Table 1. The water shows low pH and high turbidity. Jar-test conducted subsequently by using aluminum sulfate.

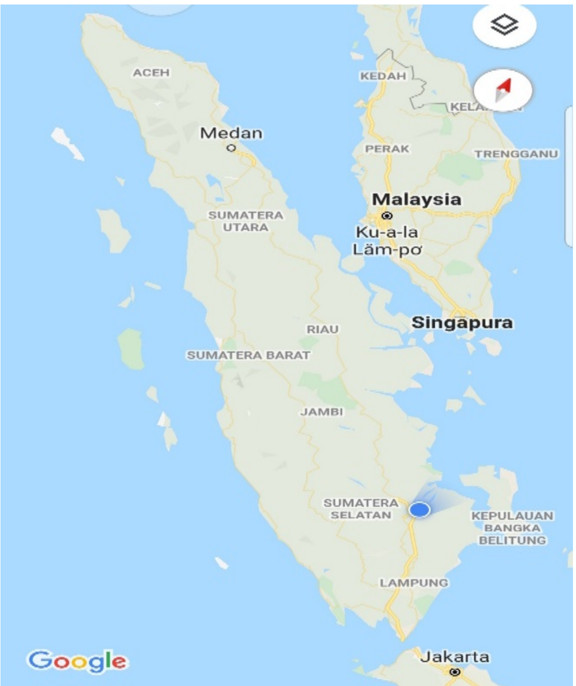


Figure 3. Research location at Talang Keramat, Banyuasin, South Sumatera

In batch process, calcium oxide and aluminum sulfate was added once whereas in continuous process, the addition carried out continually in a controlled dosage. Controlling the calcium oxide and aluminum sulfate in continuous process is important since it administer gravitationally using a stop valve.

Table 1. Preliminary analysis result on peat water

Parameter	Value	Permenkes, No. 416, 1990
Turbidity (NTU)	33.8	5
pH	3.14	6.5 – 8.5
CND ((µS/cm)	407	1500
Color (TCU)	130	15
TDS (ppm)	209	1000
Fe (ppm)	3.5	0.3
Mn (ppm)	0.59	0.1

Table 2 shows Jar-test result with aluminum sulfate dosage range from 22 ppm to 28 ppm. Jar-test by using aluminum sulfate 1% obtained the optimum aluminum sulfate at 25 ppm. The infectivity of aluminum sulfate caused by low pH of the peat water. Addition of alkali is necessary to increase pH at the initial process.

Table 2. Jar-test analysis result by using aluminum sulfate

Parameter	Alum dosage (ppm)			
	22	24	26	28
Turbidity (NTU)	18.9	18.3	21.7	21.8
pH	3.21	3.19	3.16	3.16
CND ((µS/cm)	315	310	305	305
Color (TCU)	28	24	24	15
TDS (ppm)	129	126	110	105
Fe (ppm)	2.5	2.4	2.3	2.3
Mn (ppm)	0.35	0.31	0.3	0.27

Table 3 shows the calcium oxide dosage carried out in the Jar-test using concentration varied from 60 to 120 ppm.

Table 3. Jar-test result by using calcium oxide

Parameter	CaO dosage (ppm)			
	50	80	100	120
Turbidity (NTU)	4.2	1.88	1.9	3.4
pH	5.94	6.59	6.68	7.05
CND (µS/cm)	2170	2933	3250	3485
TDS (ppm)	1570	1667	1698	1783
Color (TCU)	5	2	1	1
Fe (ppm)	1	0.05	0.05	0.01
Mn (ppm)	0	0	0	0

The optimum dosage of calcium oxide obtained by the Jar-test is 100 ppm. In this concentration, the iron, manganese and color is decreased as well as the turbidity. At above 100 ppm dosage, increased of turbidity was detected. The pH of peat water analyzed at dosage below 100 ppm did not meet the regulation requirement but at above 80 ppm, the peat water pH fulfilled the regulation standard. Problem arise when treatment of peat water by using calcium oxide conducted result in increase of conductivity and total dissolved solid. Jar-test concluded the in effectivity of calcium oxide treatment due to above reason.

Further experiment was carried out using combined treatment of calcium oxide and aluminum sulfate. The calcium oxide was varied while aluminum sulfate used at 25 ppm dosage. Aluminum sulfated is considered able to stabilize and reduce conductivity as well as total dissolved solid in the peat water. Table 4 shows analysis result of peat water treatment using calcium oxide and aluminum sulfate.

Table 4. Jar-test using calcium oxide and 25 ppm aluminum sulfate

Parameter	Calcium oxide / Alum (ppm)			
	50/25	80/25	100/25	120/25
Turbidity(NTU)	6.1	1.3	1.9	2.4
pH	5.0	6.3	6.8	7
CND (μS/cm)	406	402	401	401
TDS (ppm)	201	200	200	200
Color (TCU)	15	5	1.7	1.7
Fe (ppm)	0.4	0.1	0.1	0.1
Mn (ppm)	0.1	0	0	0

The Jar-test analysis for combined administration of calcium oxide and aluminum sulfate shows decrease of iron, manganese, color, turbidity, conductivity and TDS. Peat water pH fulfilled the regulation standard after treated with calcium oxide 100 ppm and aluminum sulfate 25 ppm. Batch process at this stage required optimum dosage of alum at 25 ppm whereas calcium oxide at 100 ppm. Batch process is basis for continuous process conducted further. Continuous process designed to has 2880 liter/hour capacity. The decrease of iron, manganese and color in the batch process is depicted in Figure 4 and 5 where the optimum point of dosage system can be seen.

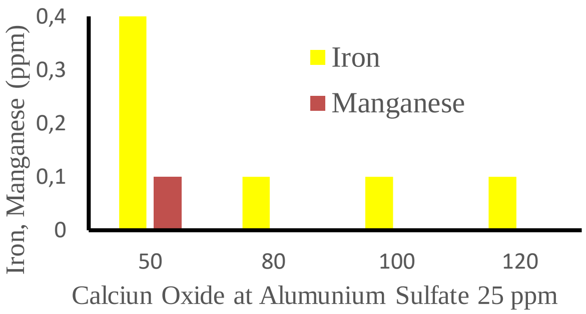


Figure 4. The diagram of iron and manganese decrease in batch

As seen in Figure 4, the ratio of Calcium oxide/Alum of 80/25 produce the best result of the quality of peat water. When we increase the ratio concentration, the turbidity also increase. It can be effected from the calcium oxide, which is not in a complete reaction with the suspended solid. The rest calcium oxide become a sediment in the peat water.

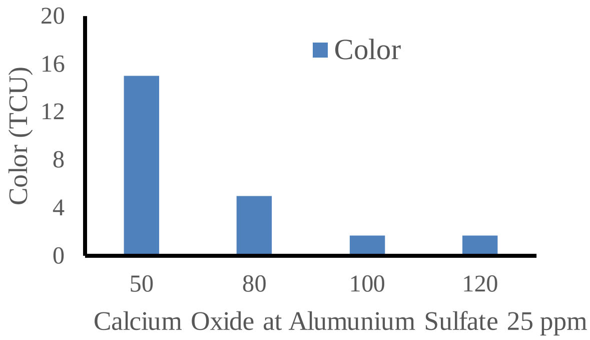


Figure 5. The diagram of color decrease in batch process

The Figure 5 show removal of color in line with the increasing of concentration of Calcium oxide/Alum. This shows that calcium oxide/alum reacts perfectly with suspended solid. In addition, color removal proves that the color contained in peat water is an organic color that does not require additional chemicals to remove it.

Continuous Process

In the preliminary step of continuous process, peat water was neutralize by adding calcium oxide. This step aimed to increase pH of peat water followed by coagulation process to stabilize colloidal particles within the water. Table 5 shows a slight change on the physical and chemical properties of the peat water.

Table 5. Examination result of the peat water on continuous process

Parameter	Value	Permenkes, No. 416, 1990
Turbidity (NTU)	31.8	5
pH	3.19	6.5-8.5
CND ((μS/cm)	410	1500
Color (TCU)	130	15
TDS (ppm)	210	1000
Fe (ppm)	3.35	0.3
Mn (ppm)	0.5	0.1

The continuous process was set at 2880 liter/hour capacity. Calcium oxide and aluminum sulfate must be added continuously in a constant rate. In this treatment method, neutralization and coagulation steps must be proceed cautiously. The flocculation process must be encouraged otherwise the treatment process was failed.

Solid particles formed by iron, manganese and other contaminants are expected to precipitate during sedimentation step. The turbidity of the output assumed will be decreased to ≤ 5 NTU. This number is required to ease the operation of filter media.

The sedimentation step is not the only factor in reducing turbidity. Previous steps must contribute in removing particles that causes turbid water. Result shows, there is significant decrease in iron, manganese and color. The final result can be seen from filtration product, which was affected by every previous process had been conducted. In addition to iron, manganese and color, the pH also must be considered on the treatment result. The Health Ministry regulation year 1990 required standard value for these variables. The complete results are listed in Table 6.

Table 6. Analysis result of continuous process peat water treatment on the final filtration stage

Parameter	Calcium oxide / Alum (ppm)			
	50/25	80/25	100/25	120/25
Turbidity(NTU)	4.15	1.14	1.14	1.25
pH	4.58	6.36	7.16	7.18
CND (µS/cm)	406	401	400	405
TDS (ppm)	200	200	200	202
Color (TCU)	15	1.0	0.5	0.5
Fe (ppm)	0.5	0.05	0.05	0.05
Mn (ppm)	0.1	0.0	0.0	0.0

Based on analysis result, the optimum dosage of calcium oxide was obtained i.e. 100 ppm. At this optimum condition, peat water pH had fulfill the standard requirement as well as the removal of iron, manganese, color and turbidity. The removal of iron and manganese is depicted on Figure 6. The result shows that iron and manganese had reduced as expected by 98.6% for iron and 100% for manganese whereas color decreased by 99.6%. Figure 7 gives a drastic decrease of color almost. In addition, the whole step and findings are described in the Table 7.

The treatment of peat water sample taken from Talang Keramat area, which has 31-35 NTU turbidity still does not fulfill the standard requirement value. The problem lies on the high content of suspended and colloidal particles. Turbidity of peat water decreases as pH increases.

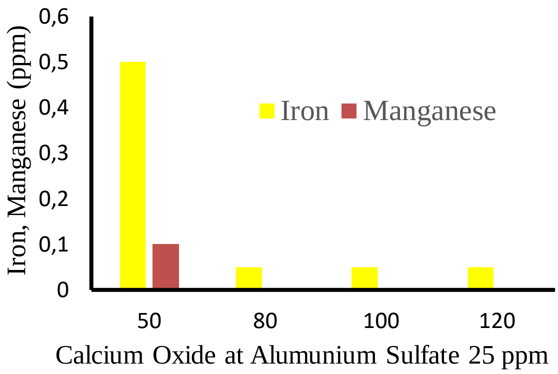


Figure 6. The decrease of iron and manganese on the continuous process

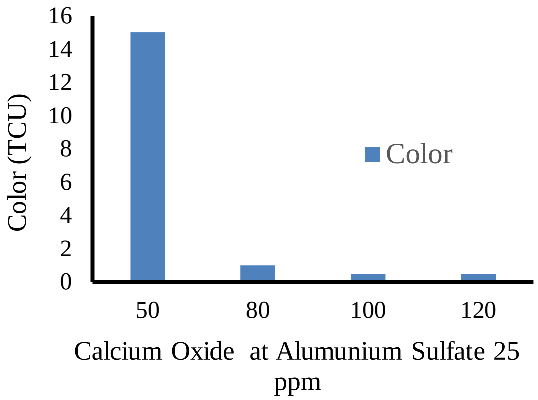
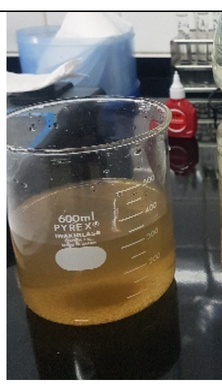
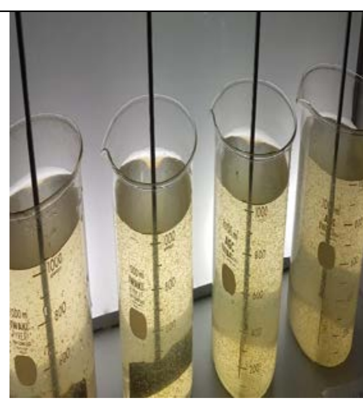


Figure 7. The decrease of color on the continuous process

FAt pH 6.5, the decrease of turbidity falls down to number as required by regulated standard value. Total dissolve solid (TDS) is proportional to the conductivity of peat water. TDS and conductivity corresponds to the addition of inorganic compound i.e. calcium oxide. This inorganic compound can be suspended by adding aluminum sulfate a.k.a. alum. Alum is known to binds and de-stabilize colloidal particles. Some authors reported that increasing pH in the preliminary treatment is a common procedure (Budijono, 2016).

Addition of calcium oxide increase the peat water pH along with decrease of turbidity. The pH increase is part of neutralization process that is necessary for the follow up steps i.e. removing color and organic compound by means of coagulation and flocculation. These two follow up processes need to initiate by adding calcium oxide to increase pH of the peat water sample. Calcium oxide reacts to form hydroxide compound, which causing pH raised. Organic compounds within the peat water comes from high content of humic and fulvic acid (Suherman, 2013).

Table 7. Result of treatment by continuous and batch processes

No	Image of raw peat water	Treated water by sedimentation and filtration	Remark
1			Water from sedimentation and filtration process, condition and result: calcium oxide 80 ppm, alum 25 ppm, iron 0.05 ppm, manganese 0 ppm, pH 6.36 and turbidity 1.24 NTU
2			Water from sedimentation and filtration process, condition and result: calcium oxide 100 ppm, alum 25 ppm, iron 0.05 ppm, manganese 0 ppm, pH 7.16 and turbidity 1.14 NTU
3			Jar-test condition and result: calcium oxide 80 ppm, alum 25 ppm Fe 0.5 ppm, Mn 0 Turbidity 1.3 NTU pH 6.3 Calcium oxide 100 ppm, Alum 25 ppm Fe 0.1 ppm, Mn 0 Turbidity 1.9 NTU pH 6.8

Color within peat water from Talang Keramat scale at 130 TCU and can be removed by dosing calcium oxide, which also increase its pH. The relationship between color removal and pH suggest that increasing the peat water pH apparently lower the color of water. This finding had been reported by another author whom found out that color can be decrease until 99% as the peat water pH increases by 125%.

The color of water could be an indication of dissolved organic compound. Preliminary test also suggest that iron and manganese has strong correlation with the color. Iron and manganese removal was followed by color obliteration by increasing peat water by adding calcium oxide. This method is economically advantage compare to other methods (Malakootian, 2010). A conventional method can be done by administration of coagulant. Iron and manganese can also be adsorbed and precipitated by calcium oxide along with stabilize colloidal particles.

CONCLUSION

The effort on peat water treatment at Talang Keramat by using batch and continuous methods was successfully decreased iron and manganese. Peat water from Talang Keramat has iron and manganese content at 3.5-3.9 ppm and 0.5-0.59 ppm, color by 130-190 TCU, pH 3.2 and turbidity at 30-35 NTU which is higher than clean water standard requirement according to Ministry of Health regulation No. 416/IX/1990. Treatments by batch and continuous methods using dosage of calcium oxide 100 ppm and aluminum sulfate 25 ppm were able to reduce iron by 97% by batch method and 98.6% by continuous method whereas manganese reduced by 100% by both methods. Aluminum sulfate without other treatment cannot reduce turbidity hence need to combine with calcium oxide addition. By this method, turbidity reduce from 31-33 NTU to 1.9 NTU in batch method whilst continuous process able to reduce down to 1.14 NTU.

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