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DEGRADATION OF ORGANIC, IRON, COLOR AND TURBIDITY FROM PEAT WATER

Mirna Apriani[1, 2], Ali Masduqi[2] and Wahyono Hadi[2]
[1]Study Program of Safety Engineering, PoliteknikPerkapalan Negeri Surabaya, Indonesia
(Shipbuilding Institute of Polytechnic Surabaya)
[2]Department of Environmental Engineering –Institut Teknologi Sepuluh Nopember Surabaya, Indonesia
E-Mail:mirnaapriani@gmail.com

ABSTRACT

This paper evaluates the Fenton process, involving oxidation and settling after coagulation and flocculation for the removal of organic, iron, color and turbidity from peat water. The experiment is to examine the operation condition which can result in the highest removal efficiency. The experimental variables studied include oxidation time, molar ratio of $[H_2O_2]/[Fe^{2+}]$, coagulation and flocculation pHs and settling time. The highest removal efficiency is resulted from operation condition of 60 minute oxidation and the coagulation pH of 8. The organic removal efficiency is around 33.40% to 46.86% for oxidation and 53% to 79.66% for settling. The highest removal of 37.92 mg/L organic is resulted from the $[H_2O_2]/[Fe^{2+}]$ molar ratio of 4.5. For organic concentration of 26.65 mg/L, the highest removal is resulted from the $[H_2O_2]/[Fe^{2+}]$ molar ratio of 3.5. The removal efficiency of iron, color and turbidity by settling process is 99% for all of the $[H_2O_2]/[Fe^{2+}]$ molar ratio. In oxidation process, the removal efficiency of iron, color and turbidity are 2% to 4%, 20% to 57%, and 17% to 42% respectively. The experiment results also show that the maximum effect of removing pollutant is occurring on settling process after coagulation and flocculation.

Keywords: fenton process, peat water, oxidation, coagulation, removal efficiency.

INTRODUCTION

Kalimantan is one of the Indonesian island which has a peatland [1,2]. Simpang Arja village, Rantau Badauh District of south Kalimantan, has not been included in the coverage area of regional water company. The scarcity of clean water sources caused peat water has been used as an alternative. Peat soil has a very high organic matter with the main component is humic acid, lignin and carbohydrate with acidic pH [3-7]. Humic acid causes brown and yellowish color in peat water [8]. Humic acid is humic substance as Natural Organic Matter/NOM [9,10]. NOM can cause the color, increase coagulant dose, disinfectant dose and cause harmfull disinfection by product in chemical disinfection process [9-11]. Peat contains high iron naturally [37].

Several experiments of peat water treatments had been carried out. Degradation of humic acid was conducted by chitosan-silica composite (CSC) as an adsorbent. The optimum dosage of CSC was 10g for humic acid degradation [5]. Adsorption process of humic acid from peat water was performed by pyrophyllite adsorbent. The optimum condition was achieved by process using dosage 5g and contact time 90 minute [8]. Combination of cationic surfactant modified zeolite, granular activated carbon and limestone as an adsorbent was conducted with optimum condition of pH 2-4 [6]. By using combination of upflow anaerobic filter and slow sand filter, only iron that meet the clean water standard [12]. By using pre-treatment powdered activated carbon/PAC followed by ultrafiltration membrane, the removal efficiency of 98.02% for color and 98.54% for organic were achieved [13]. By using combination of alum coagulant, peat and lime, the removal efficiency of 97.5% for color, 90% for organic and 98.5% for turbidity were achieved [14]. The dose of coagulant is linier with the removal efficiency for treating organic [9], color and turbidity [14]. Coagulant can cause a new problem of increasing the sludge production (Murray and Parsons 2004), so it is difficult for household application [14]. The adsorption and coagulation process were more expensive physical-chemical treatments [15,16]. The treatments using adsorption and coagulation are effective for color removal in many cases but causing the secondary waste [17,18].

LITERATURE REVIEW

Advanced oxidation process/AOP

Based on the result of existing experiment, this research was conducted by Advanced Oxidation Processes/AOP, namely Fenton process. AOP have been demonstrated to be innovative suitable technology for removing high organic matter [16,19,20,36] into a more simple form and harmless compound [21] by producing reactive oxidants, the hydroxyl radical [22]. Fenton process is a simple technology, effective at pH 2-4 [11,21,23], no special equipment is needed [24] using cheap chemicals [16,34], using non toxic matter and not producing residue [11,25,26].

Fenton process

Fenton process produces hydroxyl radical (OH*) from reaction of Fe^{2+} and hydrogen peroxide [9-11,24,26-29]. Hydroxyl radical reacts with organic matter and Fe^{2+} become Fe^{3+} as coagulant by pH adjustment above 6. The pH adjustment will lead to coagulation process and stop oxidation process [11]. Fenton process can be described in the following reaction:

$Fe^{2+} + H_2O_2 \rightarrow OH^* + OH^- + Fe^{3+}$ [1]

$Organic + OH^* \rightarrow H_2O + product$ [2]

Fenton process has been used to treat humic acid in water treatment. About 90% of organic removal was achieved by fenton process to degrade the organic [9,11,27]. Fenton process have been reported that effectiveness to treat organic in wastewater and decolorizing [15,19,24,28,30-34,37].

All the previous research [9,11,15,19,24,27,28, 30-34,37] are adding Fe^{2+} and acid solution to the Fenton process. In this paper the Fe^{2+} for Fenton process came from the peat water. The peat water contains iron and acidic pH. Fenton process is effective in acidic pH condition. Fenton process in this research can utilize the acidic condition. Fenton process for peat water does not need to add any acid solution. The other advantage of using Fenton process for peat water treatment is utilizing the pollutant in peat water as catalyst. By using Fenton process to treat peat water, it can save chemical operational cost effectively.

MATERIALS AND METHODS

Materials

The experiment was performed using natural peat water. The characteristics of peat water are summarized in Table 1.

Table-1. Characteristics of peat water.

Parameter	Range value
Organic (mg/L	25.64 - 37.92
Iron (mg/L)	13.56 - 46.89
TSS (mg/L)	172 - 368
Color (TCU)	802 - 3390
Turbidity (NTU)	86 - 365
pH	3.4 - 3.6

METHODS

The aim of this work is to study the optimum condition for $[H_2O_2]/[Fe^{2+}]$ molar ratio, oxidation time, coagulation pH and settling time for treating peat water to achieve the highest removal efficiency. The parameters are organic, iron, color and turbidity.

Generally, the experiment procedure is adapted from [9-11] with slight modification. The complete procedure can be explained as follows:

(1) peat water sample in a batch reactor of 1 L beaker glass was added by H_2O_2 based on $[H_2O_2]/[Fe^{2+}]$ molar ratio : 3.5 ; 4 ; 4.5 ; 5

(2) stirred using jar test with 50 rpm under different condition of oxidation process: 90 minute and 60 minute.

(3) by stopping oxidation process, experiment was then carried out by adjusting pH to conduct coagulation process. NaOH was added in order to have pH of around 7 for oxidation time 90 minute and pH of 8 for oxidation time 60 minute.

(4) After pH adjustment, the sample was stirred using jar test with 200 rpm with 1 minute to coagulate.

(5) After 1 minute, the sample was stirred with 30 rpm with 15 minute to flocculate.

(6) The sample was then settled in 15, 30 and 60 minute and analyzed each parameter (organic, iron, turbidity and color).

Raw peat water and treated peat water were analyzed for organic, iron (Fe^{2+}), pH, color and turbidity according to the standard method.

RESULTS AND DISCUSSIONS

This experiment is to study the removal efficiency of peat water treatment in terms of organic, iron, color and turbidity parameters. The experiment is to examine the operation condition that can result in the highest removal efficiency.

Figure-1 to 8 show that Fenton Process is divided by the line 90 minute to indicate that the oxidation process is on the left of lines 90 minute and the settling process in on the right of line 90 minute. The oxidation process occurs in two variations of the experiment i.e 90 minute and 60 minute. The starting point of the 90 minute oxidation process was described at point 0 minute on the X axis and the starting point of the 60 minute oxidation process was described at the point 30 minute on the X axis. On the right side of the line 90 minute describe the settling process with experiment variation of 15, 30 and 60 minute.

The best outcome is based on the results that can give the highest removal efficiency. Selecting the best $[H_2O_2]/[Fe^{2+}]$ molar ratio is determined by using the smallest value based on the economic considerations. The smaller ratio value has also meant the smaller amount of H_2O_2 to be added. The determination of settling time is based on the shortest settling time which can result in the highest removal efficiency.

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Organic removal

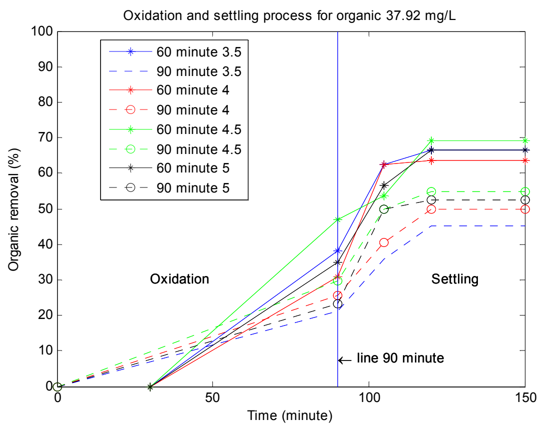

Figure-1. Removal efficiency of organic under different conditions of the molar ratio $[H_2O_2]/[Fe^{2+}]$, oxidation time and settling time (conditions : initial organic 37.92 mg/L).

Figure-1 shows the comparison between the oxidation process of 90 minute and 60 minute with the variation of molar ratio of $[H_2O_2]/[Fe^{2+}]$ and settling time. The removal efficiency of oxidation process is lower than settling process. The highest removal efficiency (46.84% for oxidation; 53.53% for 15 minute settling, for 30 and 60 minute settling is 69.12%) of 37.92 mg/L organic parameter was recorded at oxidation time 60 minute, and the $[H_2O_2]/[Fe^{2+}]$ molar ratio 4.5.

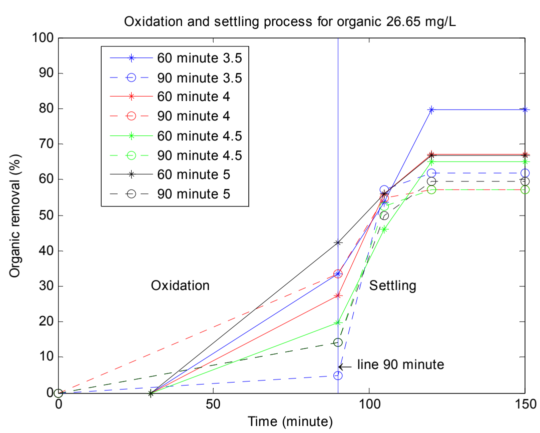

Figure-2. Removal efficiency of organic under different conditions of the $[H_2O_2]/[Fe^{2+}]$ molar ratio, oxidation time and settling time (conditions: initial organic 26.65 mg/L).

The result of the removal of organic concentration of 26.65 mg/L is presented in Figure-2. The highest removal efficiency (33.40% for oxidation; 53.58% for 15 minute settling, 79.66% for 30 and 60 minute settling) was obtained from oxidation time of 60 minute, and the $[H_2O_2]/[Fe^{2+}]$ molar ratio of 3.5.

Iron removal

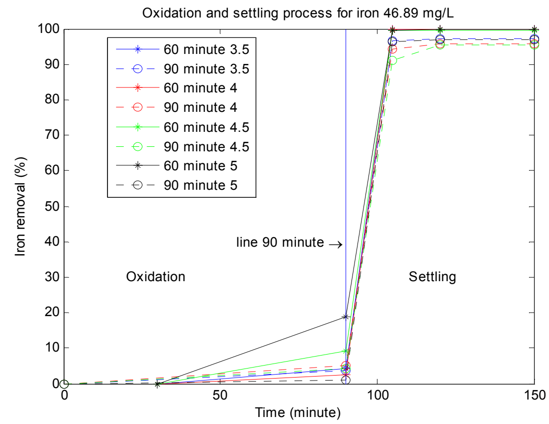

Figure-3. Removal efficiency of iron under different conditions of the $[H_2O_2]/[Fe^{2+}]$ molar ratio, oxidation time and settling time (conditions: initial iron 46.89 mg/L).

As shown in Figure-3 the iron removal using 60 minute oxidation reached around 99% in settling process. The highest removal efficiency for iron removal is using the 60 minute oxidation time, the $[H_2O_2]/[Fe^{2+}]$ molar ratio is 3.5. The removal efficiency is 99.81% for settling process and 2.56% for oxidation process.

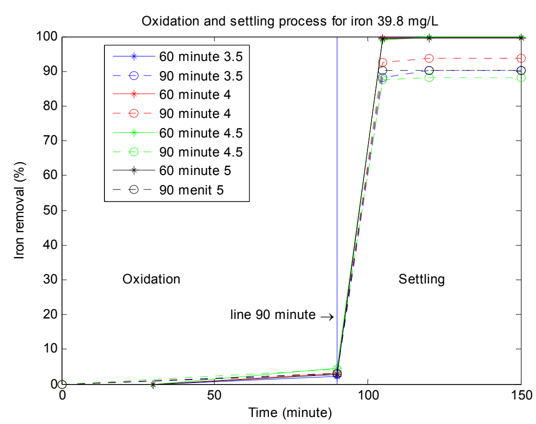

Figure-4. Removal efficiency of iron under different conditions of the $[H_2O_2]/[Fe^{2+}]$ molar ratio, oxidation time and settling time (conditions: initial iron 39.8 mg/L.

Figure-4 shows degradation of iron is dominated by the settling process. The removal efficiency is around 99% starting from 15 minute settling process, 4% in oxidation process by using 60 minute oxidation time for all $[H_2O_2]/[Fe^{2+}]$ molar ratio.

Color removal

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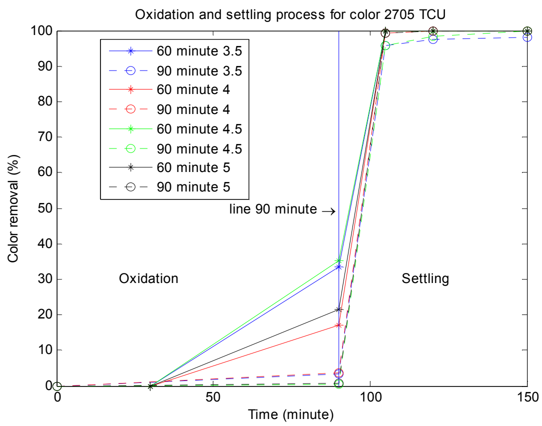

Figure-5. Removal efficiency of color under different conditions of the $[H_2O_2]/[Fe^{2+}]$ molar ratio, oxidation time and settling time (conditions : initial color 2705 TCU).

The peat water has brown color with the initial color of 2705 TCU. The removal of color using 60 minute oxidation time is greater than 90 minute oxidation time. The removal efficiency of 60 minute oxidation time is around 20% to 35%, while the 90 minute oxidation time resulted onlyaround 3%. From settling process after coagulation the color removal efficiency reached 95% to 99% starting from 15 minute settling time for all oxidation time variation. The highest removal efficiency is using the 60 minute oxidation time (Figure-5).

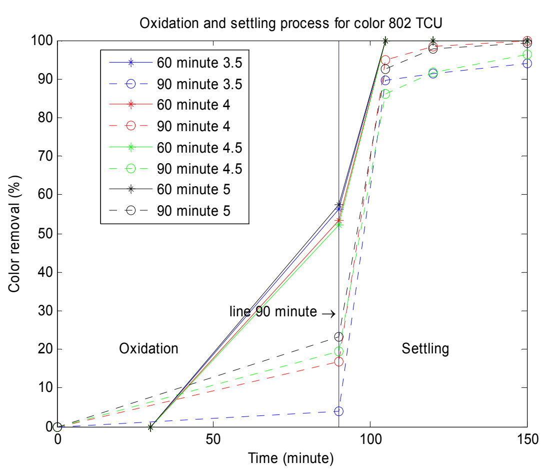

Figure-6. Removal efficiency of color under different conditions of the $[H_2O_2]/[Fe^{2+}]$ molar ratio, oxidation time and settling time (conditions : initial color 802 TCU).

The highest removal efficiency of 802 TCU color reached when the oxidation timeof the process using 60 minute. The removal efficiency is around 52% to 57%. From settling process the color removal can reached around 99% in 60 minute oxidation time and around 95% to 99% in 90 minute oxidation time (Figure-6).

Turbidity removal

The effect of oxidation and settling process of turbidity was tested under different oxidation time and $[H_2O_2]/[Fe^{2+}]$ molar ratio. As reported in Figure-7, the oxidation process remove turbidity around 23% to 34% for 60 minute and 20% to 27% for 90 minute. From coagulation process, the removal efficiency is around 99% starting from 15 minute settling for 60 minute oxidation process and all $[H_2O_2]/[Fe^{2+}]$ molar ratio. The removal efficiency is around 93% to 99% starting from 15 minute settling for 90 minute oxidation and all $[H_2O_2]/[Fe^{2+}]$ molar ratio.

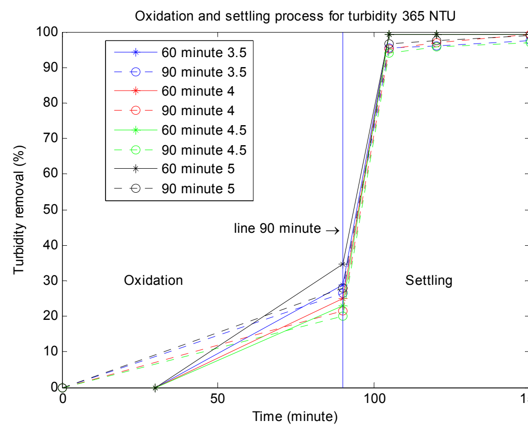

Figure-7. Removal efficiency of turbidity under different conditions of the $[H_2O_2]/[Fe^{2+}]$ molar ratio, oxidation time and settling time (conditions : initial turbidity 365 NTU).

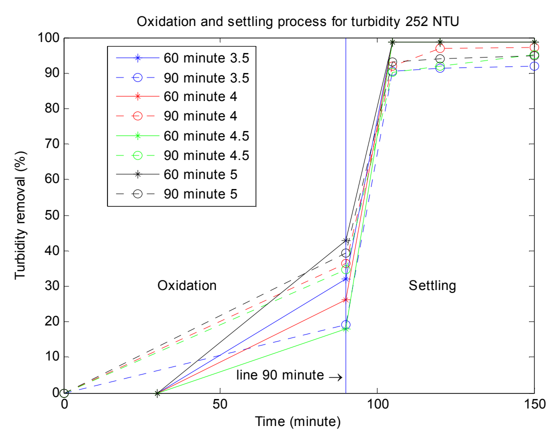

Figure-8. Removal efficiency of turbidity under different conditions of the $[H_2O_2]/[Fe^{2+}]$ molar ratio, oxidation time and settling time (conditions : initial turbidity 252 NTU).

The result of removing turbidity of 252 NTU in peat water has been reported in Figure-8. As shown in Figure-8 the highest turbidity removal efficiency is around 17% to 42% for oxidation process and 98% for coagulation process of 60 minute oxidation time. Oxidation process of 90 minute resulted in the removal efficiency of 19% to 39% and 90% to 97% for coagulation process.

Experiment was performed with some variations of oxidation time of 90 minute and 60 minute, with a different pH conditions, namely at a pH of 7 for 90 minute and a pH of 8 for the oxidation time of 60 minute. From figure-1 to8 it can be seen that the removal of all experiment parameters in settling process after coagulation were greater than oxidation process.

Results of experiments on peat water with organic concentration of 37.92 mg/L reached the highest removal efficiency by 60 minute oxidation time, 60 minute settling time and the molar ratio $[H_2O_2]/[Fe^{2+}]$ of 4.5. For organic concentration of 26.65 mg/L, the best result is using operation condition of 60 minute oxidation, the molar ratio of $[H_2O_2]/[Fe^{2+}]$ of 3.5 and the settling time of 30 minute.

Iron reacted with H_2O_2 in oxidation process resulted in the iron removal of around 2% to 4% and around 99% in settling process. For color and turbidity removal, the best condition is using 60 minute oxidation, the removal efficiency reached 99% after settling process using all of the $[H_2O_2]/[Fe^{2+}]$ molar ratio.

Mechanism of process that occurs in an organic removal using Fenton oxidation is based on the equation [1]: Fe^{2+} in the peat water reacts with H_2O_2 added generating OH* and Fe^{3+}. Then OH* formed react with organics as seen in equation [2] so organically transformed into CO_2 and H_2O [9-11,16,19,24,28,29]. Fenton oxidation process occurs in the peat water pH of 3.4 to 3.57. This peat water pH conditions have to be in optimum condition in order to be effective oxidation [21] thus no longer required for pH adjustment.

To stop the oxidation process, a variation adjustment of pH 7 and 8 was performed. The oxidation process produces Fe^{3+} which can function as a coagulant [28]. Fe^{3+} formed reacts with H_2O to form $Fe(OH)_3$ which can settle on a particular pH [35]. Selection of pH 7 to stop the oxidation process is based on the requirements of clean water. The selection of pH 8 was based on the nature of the iron which has a low solubility value for iron concentrations of 46.89 mg/L. From the experimental data it can be concluded that a better removal for all parameter occurred at pH of 8.

CONCLUSIONS

The peat water treatment using Fenton process mainly occurs in settling process after coagulation, flocculation and oxidation time of 60 minute. The organic removal efficiency is around 33.40% to 46.86% for oxidation and 53% for 15 minute settling, 69.12% to 79.66% for 30 and 60 minute settling. The highest removal of 37.92 mg/L organic resulted by the $[H_2O_2]/[Fe^{2+}]$ molar ratio of 4.5. For organic concentration of 26.65 mg/L, the highest removal resulted by the $[H_2O_2]/[Fe^{2+}]$ molar ratio of 3.5. The removal efficiency of iron, color and turbidity by settling process is 99% with all of the $[H_2O_2]/[Fe^{2+}]$ molar ratio. In oxidation process, the removal efficiency of iron is 2% to 4%. The color removal efficiency is 20% to 57% in oxidation process. For turbidity parameter the removal efficiency is 17% to 42% resulted from oxidation process.

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