Vol.1 (1) November 2023 : 18-23

JIEETech
Journal of Industrial, Energy and Environment Technology

Analysis of Hospital Liquid Waste Processing Results using Coagulation and Advanced Oxidation Process (AOP) Methods

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Article's Information

Received
23/10/2023

Revised
30/10/2023

Accepted
31/10/2023

ABSTRACT

Hospital waste has an impact on the environment, so good management efforts are needed with the aim of obtaining hospital conditions that meet environmental health requirements. In this research, hospital liquid waste processing was carried out using two methods, namely Coagulation and Fenton Process (Advanced Oxidation). Fenton has been developed in many places to process organic materials Biological Oxygen Demand/Chemical Oxygen Demand (BOD/COD), Total Suspended Solid (TSS), color, nitrogen, phosphorus and some metals contained in domestic industrial wastewater and raw drinking water. Alum coagulant ($Al_2(SO_4)_3$) has been widely known and widely used by the industrial community in relation to reducing colloidal particles in water which is quite cheap and effective. From the results of the analysis, an effective method was obtained to reduce the levels of pH, BOD, COD, TSS and , and free NH_3 using the Fenton process (Advanced Oxidation) after the coagulation process with a pH reduction percentage of 31.6% w/v, BOD of 91% w/v, COD was 73% w/v, TSS was 69% w/v and the reduction in free NH_3 was 88% w/v.

Keywords: *Hospital Waste, Coagulation, Advanced Oxidation Processing (AOP), BOD, COD, TSS*

1. INTRODUCTION

The requirements for hospital environmental health, that hospitals are health service facilities, places where sick and healthy people gather can become places for disease transmission and allow environmental pollution and hospital disruption to occur, as stated in Government Regulation No. 1204/MENKES/X/2004 [1].

Alternatives for clean water and waste treatment today tend to lead to membrane processing and also chemical processing because the composition of contaminants is increasingly complex and increasingly difficult for microbes to decompose. One of these chemical processing technologies is Advanced Oxidation Processes (AOPs) or advanced oxidation processes which are clean water and waste water treatment technologies with advanced oxidation principles using strong oxidizers and can be combined with sedimentation processes (coagulation-flocculation).

This oxidation principle is related to the chemical process of organic compounds, whereas when it is related to heavy metals what occurs is the process of destroying the chemical bonds of the metal, which are then precipitated with a coagulant. The advanced oxidation process is an alternative method for treating hospital post-treatment wastewater which is quite economical because it is able to save space and save money energy, low investment costs, safe, simple, the processing process is fast, quite effective and the processed water can be reused [2].

Hospital Waste

All waste generated from hospital activities and other supporting activities originating from hospitals is hospital waste. Because the impacts arising from this waste affect the environment, good management efforts are needed from infrastructure, finances to SOPs that are determined with the aim of obtaining hospital conditions that meet environmental health requirements.

Hospital waste contain various types of microorganisms depending on the type of hospital. Hospital liquid waste can contain organic and inorganic materials which are generally measured by BOD parameters, COD, TSS, etc. Meanwhile, hospital solid waste consists of easily decomposable waste, combustible waste, etc.

These wastes are likely to contain pathogenic microorganisms or dangerous toxic chemicals that cause infectious diseases and can be spread into the hospital environment due to inadequate health care techniques, mishandling of contaminated materials and equipment, as well as the provision and maintenance of sanitation facilities. which is bad luck. Disposal of this large amount of waste is best done by sorting the waste into various categories. For each type of category, different waste disposal methods are applied. The general principle of hospital waste disposal is to avoid the risk of contamination and trauma as far as possible [3].

Coagulation

Coagulation is defined as the process of destabilizing the colloidal load of suspended solids, including bacteria and viruses, with a coagulant forming micro spikes (micro flocs). So that fine flocs will be formed that can be deposited, the process of binding colloid particles can be seen in the picture. Flash mixing is an integral part of the coagulation process. The purpose of rapid stirring is to speed up and uniform the distribution of chemical substances through the treated water, colloidal particle types are the cause of turbidity in the water (Tyndall effect) which is caused by deviations in real light that penetrates the suspension.

Commonly used coagulants are aluminum sulfate, ferric sulfate, ferrous sulfate and PAC. The mechanism of deposition with coagulants on colloidal particles is related to the electrical charge on the colloidal particles. Generally, natural colloid particles have a negative charge. Colloidal particles have the same charge as each other. As a result, colloidal particles repel each other so that the formation of larger particles is hindered.

The coagulant containing a charge opposite to the charge of the colloid particles will absorb the colloid on its surface and reduce the repulsive force between the colloid particles so that the particles are no longer blocked from forming larger particles and can settle [4] [5] [6][7].

Fenton Process or Advanced Oxidation Processes (AOP)

The Fenton Process or Advanced Oxidation Processes (AOP) utilizes a reagent between hydrogen peroxide (H_2O_2) and an iron catalyst, also called Fenton's reagent. Hydrogen peroxide is a commonly used oxidizing agent. This oxidizer has a high active oxygen content. This active oxygen content has an effect on reducing process costs. Hydrogen peroxide decomposes easily into oxygen and water. Factors that can influence the decomposition of hydrogen peroxide are temperature and pH. The reaction of hydrogen peroxide is so slow that it requires a catalyst. The commonly used catalyst is iron sulfate ($FeSO_4$) [8].

Fenton's reagent uses hydroxyl radicals as reactive groups and iron as a catalyst for the formation of these hydroxyl radicals. The reaction for the formation of hydroxyl radicals is as follows:

$$Fe^{2+} + H_2O_2 \rightarrow Fe^{3+} + OH^- + .OH \quad (1)$$
$$Fe^{3+} + H_2O_2 \rightarrow Fe^{2+} + .OOH + H^+ \quad (2)$$

This reaction produces free radicals ·OH, as well as the reformation of Fe^{2+}. Ferrous iron can change back to ferrous iron in the next reaction with excess H_2O_2 molecules. The Fenton-oxidation stage includes adjusting the pH of the waste liquid to 3-6, adding an iron catalyst as a $FeSO_4$ solution, and slowly adding H_2O_2. If the pH of the waste fluid is too high, the iron will be removed more quickly oxidized turns into $Fe(OH)_3$ and decomposition of H_2O_2 occurs [9].

Based on the COD parameter (chemical oxygen demand), the Fe–H_2O_2 ratio is 1:5 – 1:10 (w/w) with an iron concentration < 25–50 mg/L which can react for 10–24 hours. The oxidation products (organic acids) separate from the iron. Fenton's reagent is quite effective as a preliminary treatment for waste with COD values > 500 mg/L. Iron catalysts can be used either in the form of ferrous (Fe^{2+}) or ferric (Fe^{3+}) salts. This is because the circulation of changes in these two ions is very fast. However, if the concentration of Fenton's reagent used is low (< 10–25 ppm H_2O_2), then it is better to use ferrous salts.

The reaction rate of Fenton's reagent increases with increasing temperature (20–40 °C). However, if the reaction temperature is > 40–50 °C, the role of H_2O_2 as an oxidizer is reduced because the decomposition of H_2O_2 is accelerated. Apart from temperature, the working speed of Fenton's reagent is also influenced by the pH value (3–6). The basic mechanism of the Fenton treatment process consists of chemical oxidation and chemical coagulant of organic compounds. The Fenton oxidation process normally consists of four steps, namely: pH adjustment, oxidation reaction, neutralization and coagulation.

Hydroxyl radicals are strong oxidants that can damage organic substrates (RH) quickly and causes chemical decomposition of a compound.

$$RH + HO\bullet \rightarrow R\bullet + H_2O \quad (3)$$
$$R\bullet + Fe^{3+} \rightarrow R^+ + Fe^{2+} \quad (4)$$
$$R^+ + H_2O \rightarrow ROH + H^+ \quad (5)$$

Hydroxyl radicals can react with Fe^{2+} or hydrogen peroxide.

$$HO\bullet + Fe^{2+} \rightarrow HO^- + Fe^{3+} \quad (6)$$
$$HO\bullet + H_2O_2 \rightarrow H_2O + HO_2\bullet \quad (7)$$

Fe^{3+} formed through reactions (1) and (6) can react with H_2O_2 by a mechanism involving hydroxyl and hydroperoxyl radicals:

$$Fe^{3+} + H_2O_2 \leftrightarrow Fe\text{-}OOH^{2+} + H^+ \quad (8)$$
$$Fe\text{-}OOH_2+ \rightarrow HO_2 \bullet + Fe^{2+} \quad (9)$$
$$Fe^{2+} + HO_2 \bullet \rightarrow Fe^{3+} + HO^{2-} \quad (10)$$
$$Fe^{3+} + HO_2 \bullet \rightarrow Fe^{2+} + H^+ + O_2 \quad (11)$$

In this way, organic substances can be removed through two steps, namely oxidation and coagulation. Apart from that, the completion of oxidation depends on the ratio of hydrogen peroxide. Meanwhile, the oxidation level is determined by the initial iron concentration and temperature. In the Fenton process (Fe/H_2O_2) salt or iron powder is used as a catalyst. In an acidic atmosphere iron powder reacts with hydrogen peroxide to produce iron ions. From an environmental point of view, the advantage of implementing iron powder (Fe) instead of iron salts is the avoidance of unnecessary burden on the water system dealing with anions [10]

2. MATERIAL AND METHODS

Fenton's reagent is a peroxide compound which is reacted with a Fe^{2+} ($FeSO_4$) catalyst and then produces hydroxyl radicals (*OH) which effectively oxidize other compounds. Fenton has been developed in many places to process organic materials Biological Oxygen Demand/Chemical Oxygen Demand (BOD/COD), Total Suspended Solid (TSS), color, nitrogen, phosphorus and some metals contained in domestic industrial wastewater and raw drinking water. Alum coagulant ($Al_2(SO_4)_3$) has been widely known and widely used by the industrial community in relation to reducing colloidal particles in water which is quite cheap and effective. Ferric sulfate coagulant ($Fe_2(SO_4)_3$) has the ability to reduce turbidity and color quite significantly. PAC / Polyaluminium Chloride ($Al_{10}(OH)_{15}Cl_{15}$) is commonly used in many industries due to the efficiency of the amount of coagulant used. Potassium ferrate VI (K_2FeO_4) has a fairly high level of efficiency, especially in reducing turbidity and organic matter content as COD.

Based on this, the researchers conducted research by experimenting in the laboratory by processing liquid hospital waste using the coagulation and Fenton methods and analyzing the results of waste processing with several parameters in the form of BOD, COD, TSS, pH and free NH_3 analysis.

2.1 Materials and Equipment

The equipment used is a measuring cup, Erlenmeyer, measuring flask, measuring pipette, stirrer, analytical balance, vacuum pump, Fenton reactor and holding tank. The materials used in this research were hospital liquid waste from post treatment, alum coagulant, Fe and hydrogen peroxide.

2.2 Stages of the Coagulation Process

a) Wastewater Analysis (Sample)

A total of 50 liters of hospital waste samples underwent initial analysis. The standard sample analysis results are based on Governor Regulation No. 8 of 2012 concerning quality standards for liquid waste for hospital activities which include pH, BOD, COD, TSS and free ammonia. The aim of the first stage of analysis is to determine whether the characteristics of hospital liquid waste meet hospital wastewater quality standards or not, so that processing can be carried out to reduce the level of waste that is still present.

b) Determination of Optimum Dosage of Alum Coagulant

The wastewater was examined using Jartest to determine the dose of coagulant to be used, which consisted of stirring and settling. After allowing the waste water to settle, a laboratory test is carried out by measuring parameters which will later determine the optimum dose of coagulant from the hospital's post-treatment liquid waste. These parameters are pH, COD, BOD, free ammonia. In determining the optimum dose of hospital post-treatment liquid waste coagulant, it is 1750 ppm [12].

c) Advanced Coagulation and Oxidation Process (Fenton addition)

The coagulation tank has a rib length of 40 cm, with a certain dose of alum. After being passed to the coagulation tank, it flows to the oxidation reactor via the outlet. A stirred Fenton tank with a Fenton $FeSO_4.7H_2O$ concentration of 3 mmol/L and an H_2O_2 concentration of 90 mmol/L, a molar ratio of 1:30 with a volume of 100 ml each. After the oxidation time, sodium thiosulfate is added to stop the reaction in the waste. After passing through the Fenton tank, samples are taken and then measured for pH, BOD, COD, TSS and free ammonia.

3. RESULTS AND DISCUSSIONS

The results of analysis of pH, BOD, COD, TSS and ammonia free from hospital liquid waste before and after the coagulation and fenton processing processes can be seen in Table 1.

Table 1. Analysis of pH, BOD, COD, TSS and Ammonia free from Hospital Liquid Waste Processing

Sample	Parameter				
	COD (mg/L)	BOD (mg/L)	TSS (mg/L)	pH	Free NH_3 (mg/L)
Before Processing	975	565	112	9,5	0,25
After Coagulation Process	430	177	55	5,2	0,23
After Fenton Process	260	50	35	6.5	0,03
Standard Quality Pergub No.16 (2012) [11]	80	30	30	6-9	0,1

In the coagulation process, the mechanism for the formation of precipitates is due to the addition of alum coagulant (Aluminium Sulfate), namely alum in water will decompose into Al^{3+} and undergo hydrolysis to form $Al(OH)_3$. Decomposing Al^{3+} can cause destabilization, changing the nature of pollutants that cannot be deposited into easily settleable ones by reducing the repulsive force between colloidal particles, so that colloidal particles can combine to form flocs. $Al(OH)_3$ resulting from alum hydrolysis has low solubility and a fairly large surface area that can absorb surrounding particles and precipitate them.

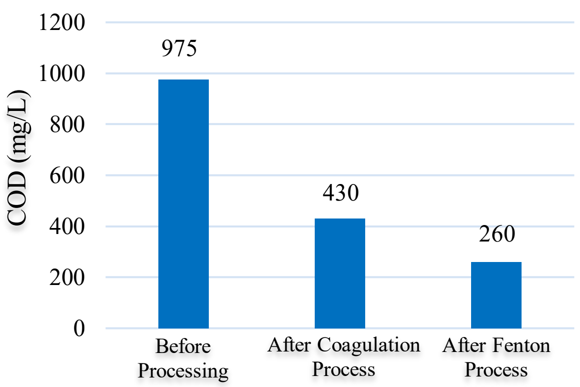

Figure 1. Effect of the Coagulation and Fenton Process on the Results of COD Content

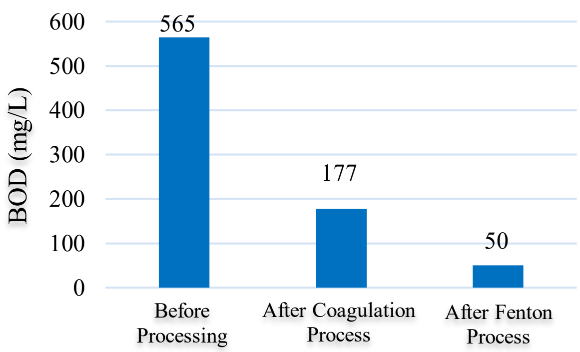

Figure 2. Effect of the Coagulation and Fenton Process on the Results of BOD Content

Coagulation pH determines the solubility of $Al(OH)_3$. The solubility of $Al(OH)_3$ can increase at acidic or basic pH, the more acidic or basic the higher the solubility of $Al(OH)_3$. This absorption capacity can reduce the levels of COD, BOD, TSS and free ammonia contained in liquid waste.

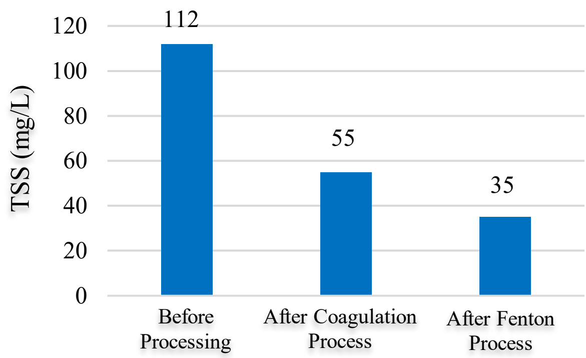

Figure 3. Effect of the Coagulation and Fenton Process on the Results of TSS Content

In the free NH_3 content, the decrease in pollutant levels did not change significantly, only 0.02 mg/L, which is estimated to be due to the small ability of aluminum sulfate or alum to reduce NH_3. The characteristics of NH_3 itself in water are in the form of Ammonium NH_4OH. If there is an excess of one hydrogen atom (H) in this NH_4OH compound, it will turn into an ionic compound that has a positive charge. If it reacts with aluminum sulfate, the two compounds will have difficulty reacting, so aluminum sulfate or alum is not suitable for reducing NH_3 levels and is proven by the low levels of ammonium. free which can be removed by the coagulation process using alum (can be seen in figure 4).

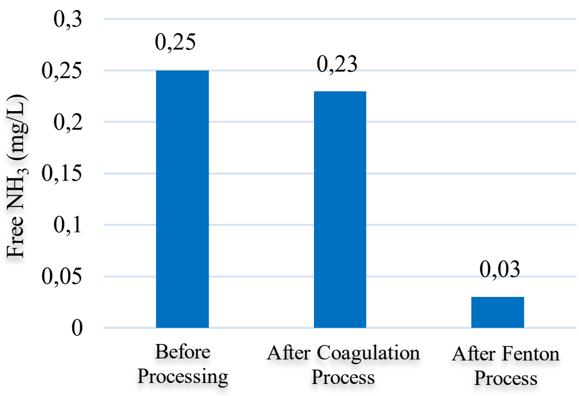

Figure 4. Effect of the Coagulation and Fenton Process on the Results of Free Ammonia

Based on the figure 5, it shows that alum can reducing pH. Al^{3+} ions from alum ($Al_2(SO_4)$) which are hydrolyzed in water will bind OH compounds from the water and form $Al(OH_3)$ precipitates so that the water becomes excess H^+ and then binds with sulfate compounds to form sulfuric acid. The formation of sulfuric acid causes a decrease in the pH of the water.

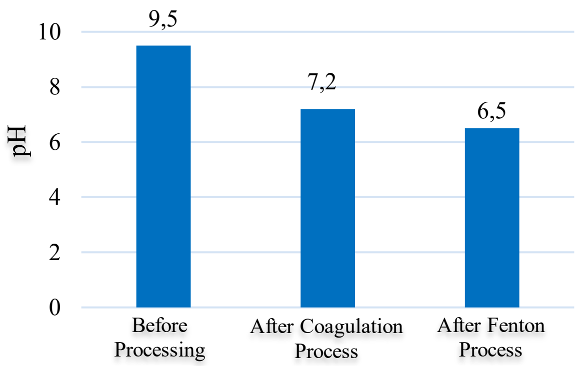

Figure 5. Effect of the Coagulation and Fenton Process on the Results of pH Analysis

Based on data from the Fenton Analysis results which can be seen from figure 1, 2, 3, 4 and figure 5 with a $FeSO_4.7H_2O$ concentration of 3 mmol/L and an H_2O_2 concentration of 90 mmol/L, a molar ratio of 1: 30 with a volume of 100 ml each. Based on table 1 above, it can be seen that the parameters analyzed such as pH, BOD, COD, TSS and free ammonia experienced a decrease in value after adding 3 mmol/L of $FeSO_4.7H_2O$ and H_2O_2 concentration 90 mmol/L, molar ratio 1:30 with respective volumes 100 ml each.

This shows that the composition between the iron catalyst and hydrogen peroxide is balanced so that maximum hydroxyl radicals are formed which results in a decrease in pH, BOD, COD, TSS and high levels of free ammonia.

The working mechanism of the Fenton process begins with the initiation stage where the reaction occurs when the weakest bond in the reactants or in one of the reactants is broken to produce free radicals. Next is the propagation stage where free radicals attack reactants and produce product molecules and other reactive species. These new free radicals react further and form free radicals until they attack the reactant molecules again.

From the propagation process, products and chain carriers are produced which are formed continuously. Finally, the termination stage is where the reaction ends because at this stage it converts free radicals into stable free radicals. These three stages show that the hydroxyl radical stage to oxidize organic substances takes quite a long time because of the complexity of the organic substances in the waste and the gradual reaction mechanism.

This is evident from the large percentage reduction in parameters analyzed from the coagulation process and Fenton process which reached optimum levels which include: BOD levels of 565 mg/L can be reduced to 50 mg/L with a reduction efficiency of 91% w/v, COD levels of 975 mg /L can be reduced to 260 mg/L with a reduction efficiency of 73% w/v, TSS levels of 112 mg/L can be reduced to 35 mg/L with a reduction percentage of 69% w/v, Free ammonia 276.99 mg/L can be reduced to 69.25 mg/L with a reduction percentage of 75% and a reduction in free NH_3 from 0.25 mg/L can be reduced to 0.03 mg/L with a reduction percentage of 88% w/v, and for a decrease in pH from 9.5 down to 6.5 with a percentage of 31.5%.

4. CONCLUSIONS

Processing hospital waste using the Coagulation process method and the Fenton process is one solution that can be used in processing hospital waste which is proven by reducing levels of pH, BOD, COD, TSS and free ammonia, even though it meets the quality standards for liquid waste in river processing. This is only a pH of 6.5 and the free ammonia level is 0.03 mg/L. Meanwhile, BOD, COD and TSS levels do not yet meet hospital waste quality standards, so it is necessary to treat the Fenton process in more than one stage to meet hospital waste quality standards.

ACKNOWLEDGEMENTS

The researcher would like to thank colleagues and parties who have supported this research activity so that it can run well.

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