Simultaneous Application of Fenton – Electrochemical Reactor for Removal of Organic Loading in Biological Waste Sludge

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Introduction

Wastewater treatment using activated sludge process (ASP) produces huge amounts of sludge that must be treated by efficient methods. Wastewater sludge handling is one of the most important economic-technical challenges of wastewater treatment projects. Conventional methods for this purpose are very time consuming, expensive and in lots of cases have limited success. In recent years the electrochemical oxidation techniques have been progressively used for water and wastewater treatment process. Many reports showed that these methods are very effective to eliminate or decrease the organic loading content of wastewater and sludge. Combination of electrochemical reactions and Fenton process has widely been studied for the destruction of organics and bio-refractory pollutants contained in industrial wastewater by highly oxidative hydroxyl radicals formed from reaction of H_2O_2 with Fe^{2+}. This method offers more advantages than the chemical Fenton process due to the high efficiency of Fenton reagents (e.g., H_2O_2) utilization and lower retention time. The integrated Fenton and electrochemical reactor were used to reduce concentration of volatile suspended solids in sludge. High consumption rate of divalent iron ions is one of the disadvantages of Fenton method compared with its reduction. In this research, the electrochemical method has been used to solve this problem. The electrochemical method increases the reduction rate of divalent iron by converting the trivalent iron ions into the bivalent ones and it reduces the production of iron sludge. In this research, the effective parameters including ratio of iron to hydrogen peroxide, pH, retention time, concentration of hydrogen peroxide and the amount of electric current were investigated.

Materials and methods

In the present study we have evaluated the efficiency of Fenton-Electrochemical process in reduction of organic contents of Secondary Sludge of Mahallati ASP wastewater treatment plant. This plant is located in Tehran, with treatment capacity of 4800m^3 per day and operates in extended aeration process. Table 1 shows the specifications of the investigated sludge. Our reagents were H_2O_2 and Fe^{2+}.

The evaluated Fenton-Electrochemical reactor has been shown in figure1. The reactor contains two grafit anodes and two grafit cathods. The electrodes dimentions were 1mm*140mm*60mm, and the distance between them is 1.5 cm. The volume of reactor has been selected 0.9 L. We used the mechanical mixer instead of electromagnetic stirer because of the sensitivity of Fe^{2+} ions to electromagnetic materials. The temperature during the test was between 13.8 and 15.6 ˚C. All tests were conducted according to standard methods (APHA, 1999) and each part of experiments was repeated three times.

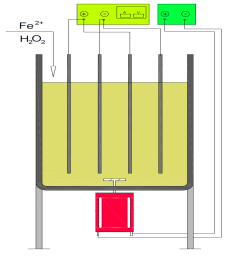

Figure 1. the evaluated EF reactor

Table 1. Investigated Sludge Specifications

property	Value
pH	6.53-7.33
Temperature(°C)	13.8-15.6
COD (mg/lit)	6051-11164
VSS (mg/lit)	3536-7782
VS (mg/lit)	4086-8382
TSS (mg/lit)	4088-8432
VSS/TSS	0.86-0.92

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Result and discution

The removal of volatile suspended solids (VSS) as the efficiency factor haveevaluted the effects of the ration of Fe^{2+} concentration on H_2O_2 concentration ($[Fe^{2+}]/[H_2O_2]$), time, pH, H_2O_2 concentration and current density as the effective process operation parameters. To obtain the most efficient we have investigated the operational parameter serily. The firest parameter that is studied is $[Fe^{2+}]/[H_2O_2]$. Figure 2 showes the effect of $[Fe^{2+}]/[H_2O_2]$ to removal of VSS. Regarding to the diagram, the removal of VSS increases sharply as $[Fe^{2+}]/[H_2O_2]$ increases to 0.58 (optimum point) and reach its maximum in this point and is constant to about 1.015 and then decreases slightly. The second parameter is pH. It has been studied in the optimum point of $[Fe^{2+}]/[H_2O_2]$. Adjustment of pH has been done by 98% sulfuric acid. Figure 3 shows that the removal of VSS is constant by increasing the pH up to 3, and then starts to decrease. The maximum VSS removal (approximately 72%) was attained in pH=3.1. Oxidation efficiency essentially decreases at pH values lower than 3. Figure 4 shows the relation of VSS removal and time. The time was assessed in the maximum point of the last two parameters. According to the diagram, the VSS removal increases by time and reaches its maximum in approximately 6 hours and then is constant.

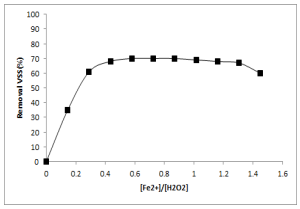

Figure 2. VSS removal and $[Fe^{2+}]/[H_2O_2]$ relationship

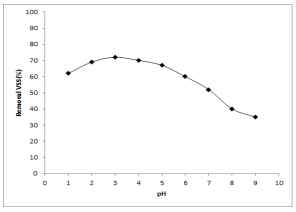

Figure 3. VSS removal and pH relationship

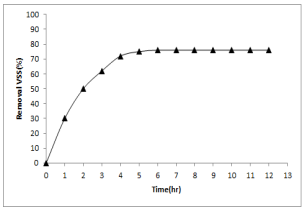

Figure 4. VSS removal and time relationship

In order to attain the best concentration of Fe^{2+} and H_2O_2, we studied the effect of H_2O_2 concentration on VSS removal. The optimum ratio of $[Fe^{2+}]/[H_2O_2]$ can be attained from figure2. Fe^{2+}concentration are also resulted by determining the optimum H_2O_2 concentration. The tests carried out in the most effective point of prior parameters and the results has been shown in figure 5. According to the diagram, the highest VSS removal was obtained when the H_2O_2 concentration is approximately 1568mg/L. Finally, after determining the optimum point for ($[Fe^{2+}]/[H_2O_2]$), detention time, pH, H_2O_2 concentration, and the effect of Current density was evaluated. Current density improves the reduction of trivalent iron to divalent iron, i.e., it enhances the efficiency of Fenton process. According to figure 6, the maximum VSS removal has been reached in (650-750) mA current density. The remained Fe^{2+} concentration has also been investigated. As shawn in the figure 7, approximately (40-70)% of inserted $[Fe^{2+}]$ adsorbed on the electrodes, (7-15)% was remained in the sludge layer and (23-45)% in the sludge liquor.

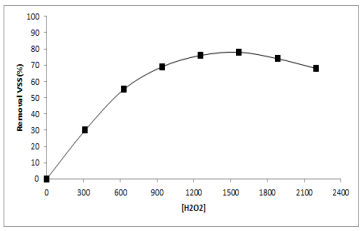

Figure 5. VSS removal and $[H_2O_2]$ relationship

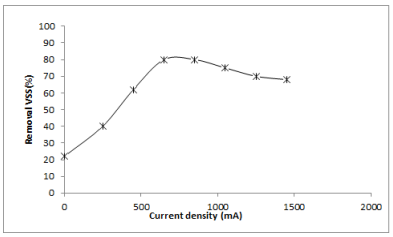

Figure 6. VSS removal and current density relationship

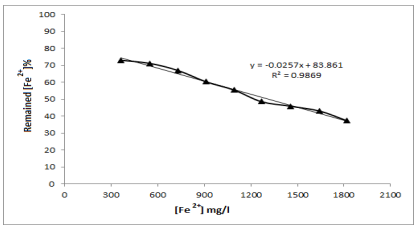

Figure 7. Remained and consumed $[Fe^{2+}]$relationship

Fenton and electrochemical-Fenton were compared on an equal basis. According to the figure 8, the efficiency of electrochemical-Fenton is 76%, while the efficiency of Fenton is 22%. Figure 9 shows the current density of energy consumption. By increasing the current density rate, energy consumption increases exponentially.

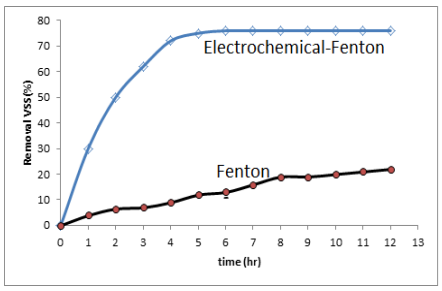

Figure 8. VSS removal efficiency of Fenton and Fenton-electrochemical regarding detention time

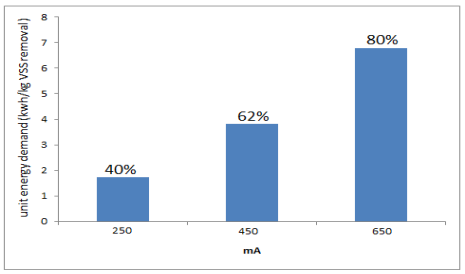

Figure 9. Current density of energy consumption in Fenton- electrochemical

Conclusions

Even if in the recent decades many efforts have been done in order to enhance usual sludge treatment or commence novel more efficient methods, lots of researches have focused on techno-economical issues carefully. The key purpose of the researches is to eliminate the organic load of sludge and improve its quality in order to be reused in various applications like fertilizer in agriculture. In this study we have evaluated a combined Fenton-Electrochemical process with the aim of stabilizing excessive biological sludge of municipal wastewater treatment plant. For this purpose, several determining parameters have been selected and investigated in a lab-scale pilot. The results showed that the system has preserved its stability in a wide range of pH (3-7), also the organic load of the sludge decreased noticeably (maximum decreasing efficiency of the sludge was approximately 81%). Comparison of the results of Fenton or other usual systems and combined Fenton-Electrochemical process showed that the later system is appropriate and efficient method to get better quality of stabilized sludge and operational conditions.

Keywords: biological waste sludge, fenton– electrochemical method, organic loading reduction, wastewater treatment.