Treatment of Spray Paint Wastewater by a Coupled Electro-Fenton and SBR Technology

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Abstract. Spray painting wastewater is industrial wastewater created during the painting process; its composition is complicated, comprising a significant number of difficult biodegradable organic matter; nevertheless, the existing technology is not optimal, and the process cannot reach the desired criteria. The water quality of the entry has a higher demand for investment and occupying a vast land. High maintenance expenses, high water quality after treatment, and other issues exist. In this study, the oily spray paint wastewater was treated using an electrochemical and Fenton process, which has a high oxidation capacity, a fast oxidation rate, and a wide application of the characteristics of the Electro-Fenton process used in the pretreatment of spray paint wastewater. This study focuses on the electrochemical optimization and improvement of the Fenton technique, and it employs Fe2+ and H2O2 generated by the electrochemical approach as a continuous source of Fenton reagent. Simultaneously, electrode-related oxidation may destroy organic matter, effectively reducing the concentration of organic matter in spray paint wastewater, and when paired with the traditional Sequencing Batch Reactor Activated Sludge Process (SBR) operation treatment mode, offers a comprehensive process idea. While improving the efficiency and quality of spray paint wastewater treatment, the cost should be kept as low as feasible in order to provide effective reference schemes for spray paint wastewater treatment, allowing for future study.

Keywords: Electrochemistry; Electro-Fenton; SBR; oxidation; spray paint wastewater.

1. Introduction

The rapid development of industrial production has caused water shortage and increasingly serious pollution of the water environment. The wastewater treatment problem generated in the spray painting process needs to be solved urgently. Currently, the most common painting workshop is the water curtain painting room, a construction facility that consumes huge amounts of water and is costly. Spray paint wastewater is a kind of industrial wastewater composed of organic solvents and heavy metals, and its direct discharge without treatment will cause serious pollution and harm to the environment. However, many enterprises may use low-end wastewater treatment facilities and manual operation due to economic cost constraints, resulting in poor wastewater treatment results.

Electrochemical oxidation is a mature wastewater treatment technology with the advantages of high efficiency, low cost and stable performance. The research shows that electrochemical oxidation technology can effectively remove organic pollutants and heavy metal ions in water, and has broad application prospects in the field of spray paint wastewater treatment. For example, Hernández et al. used electrochemical oxidation technology to treat water containing phenol, which achieved a removal rate of 96% [1]. Zhu et al. used electrochemical oxidation techniques to treat copper ions, achieving a removal rate of 99.9% [2]. However, it is rarely used in industrial production at home and abroad, so this study uses the electrochemical-Fenton advanced oxidation method to treat spray paint wastewater. While improving the treatment efficiency and quality of spray paint wastewater, it also reduces the cost as low as possible, so that it is widely used in industrial production. To reduce the cost of wastewater treatment and promote the sustainable development of the industry.

This study discusses the working mechanism and advantages of electrochemistry and Fenton technology in the treatment of spray paint wastewater. The mechanism and design scheme of Electro-Fenton and SBR combined treatment process were further studied.

2. Spray Paint Wastewater Treatment Process

2.1 Processing Process

The paint workshop of the enterprise can be divided into dry type and wet type according to the treatment of paint fog. The dry type is direct trapping, which traps paint mist and processes it by means of filter materials or equipment such as paint blocking board and filter layer (bag). The wet type is indirect trapping, and the exhaust gas of the spray painting room is cleaned by means of circulating water system, and the paint mist is captured, and the paint coagulant is added to the circulating water to make the paint mist lose its viscosity. Wet spray booth is used in machinery, auto parts, metal products, decorative parts, home appliances, furniture and other industries of the workpiece spraying and large and medium-sized workpiece such as automobile body advanced spraying. With water as the medium to capture the paint fog, water and paint fog mixed together to form spray paint wastewater, in the cycle process, the concentration of pollutants in the water continues to increase, at this time must be treated and discharged. The common spray painting wastewater treatment in enterprises is the coagulation and precipitation process method of adding paint mist coagulant ab, as shown in Fig. 1.

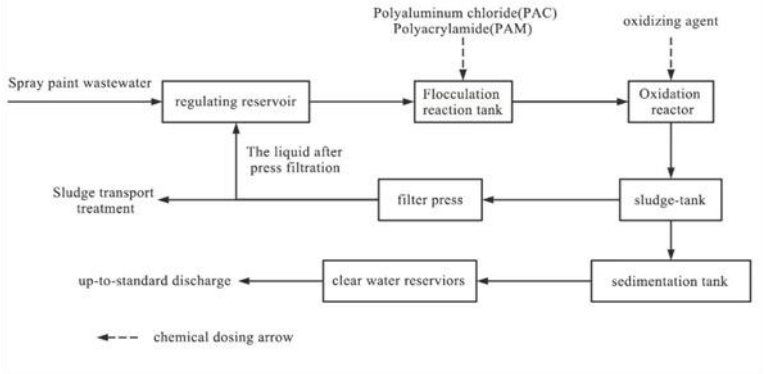

Fig. 1 Spray paint wastewater treatment process flow

2.2 Analysis of Process Flow

Spray paint wastewater because of different coatings produce different acid and alkali. The regulating tank is to regulate acid-base neutralization reaction and control PH value. Alkali neutralizer such as caustic soda and lime is added to acidic wastewater, and acid neutralizer such as hydrochloric acid and sulfuric acid is added to alkaline wastewater. Flocculation reaction tank is used by adding agents PAC, PAM, etc., and stirring at the same time, so that the floc alum flowers are quickly generated and become phosphate precipitation, and the emulsified oil is broken at the same time. Oxidation reaction tank use the oxidants to oxidize and decompose pollutants. Hydrogen peroxide and ferrous ion (Fenton) are often used to oxidize pollutants that are difficult to biodegrade and have low oxidation capacity [3]. Spraying paint mist coagulant requires a large amount of chemical agents, and the treatment cost is high. This method can only condense the paint mist, and can not completely decompose the organic matter, so it is difficult to achieve the treatment effect. The treated sediment is large, difficult to handle and dispose, and causes pollution to the environment. In order to solve these problems, it is necessary to find a more environmentally friendly and more efficient spray paint wastewater treatment method.

3. Combination of electrochemical and Fenton

3.1 Basic Principles and Research Progress

In the traditional Fenton oxidation process, Fe^{2+} acts as a catalyst to decompose H_2O_2 into hydroxyl free radicals (·OH). The hydroxyl radical, with an oxidation potential of 2.8V, is a strong non-selective inorganic oxidizing agent that oxidizes organic matter into small molecules. In the oxidation process, Fe^{2+} is oxidized to Fe^{3+} and accompanied by the occurrence of coagulation precipitation, which can remove a large amount of organic matter. However, Electro-Fenton technology faces the problems of high reagent cost and low H_2O_2 utilization. Combining Fenton with electrochemistry, H_2O_2 and Fe^{2+} generated by electrochemistry can be used as continuous sources of Fenton reagents. The combination can not only reduce the cost caused by reagents, but also degrade organic matter through electrode oxidation and electroadsorption in addition to the oxidation of hydroxyl radicals. The advantage of electric Fenton is that it can generate H_2O_2 in the cathode and realize the regeneration and reduction of Fe^{3+}, which solves the problem of the use of H_2O_2 and the safety of iron mud in the traditional Fenton reaction.

At present, the research of Electro-Fenton process mainly focuses on three aspects, which are the preparation of new cathode, preparation of heterogeneous catalysts and the transformation of cathode reactor structure. Heterogeneous element doping and direct modification are the main research directions of cathode and heterogeneous catalyst preparation. In order to realize the high yield of H_2O_2 and the efficient reduction of Fe^{3+}, the dual cathode reactor structure will be the main research direction. For treatment effect, the removal rate of target pollutants in various studies can basically reach more than 90%. For reaction conditions, the heterogeneous catalyst Electro-Fenton system broadens the pH range of the reaction, and can still maintain efficient processing capacity in neutral or even weakly alkaline environments [4].

3.2 Advantage of Electro-Fenton

Electro-Fenton covers a small area, easy to operate, can be designed according to the actual water treatment of specific programs. Compared with traditional Fenton, the drug cost is reduced to a certain extent. At the same time, because the oxidation of hydroxyl free radicals is non-selective, it has a variety of roles, such as degrading COD, ammonia nitrogen, nitrate nitrogen, disinfection, color removal, odor and odor removal. The operation is flexible, and the reaction can be adjusted at any time by changing the external voltage and current. As a pretreatment of high concentration organic wastewater, this method can improve the biodegradability of wastewater. It can also be used in advanced treatment to deeply degrade refractory organic matter to achieve effluent index.

3.3 Reaction Mechanism

The reaction mechanism produces Fe^{2+} and H_2O_2 from the electrode, which further produces hydroxyl radicals. During the reaction, at the anode, the water molecules are oxidized, producing hydroxyl radicals, while the iron anode dissolves Fe2+. As shown in equations (1)-(2).

$$H_2O\text{-}e^- \rightarrow \cdot OH + H^+ \quad (1)$$

$$Fe\text{-}2e^- \rightarrow Fe^{2+} \quad (2)$$

In the acidic medium, the cathode continuously produces H_2O_2, as shown in equation (3).

$$O^2 + 2H^+ + 2e^- \rightarrow H_2O_2 \quad (3)$$

Fe^{2+} reacts with H_2O_2 to form hydroxyl radicals, which in turn oxidizes and decomposes organic matter, as shown in equation (4).

$$Fe^{2+} + H_2O_2 \rightarrow Fe^{3+} + \cdot OH + OH^- \quad (4)$$

In general, under the condition of pH > 4, Fe^{3+} will precipitate into $FeOH_3$ floc, which has flocculation effect on pollutants in spray paint wastewater, The reaction mechanisms were shown in equations (5)-(8).

$$Fe^{3+} + H_2O_2 \rightarrow Fe^{2+} + H^+ + HO_2 \quad (5)$$

$$HO_2+H_2O_2 \rightarrow O_2+H_2O+\cdot OH \quad (6)$$

$$RH+OH \rightarrow R+H_2O \quad (7)$$

$$R+Fe^{3+} \rightarrow R^{+}+Fe^{2+} \quad (8)$$

The main principle of the electric Fenton process is shown in Fig. 2 [4].

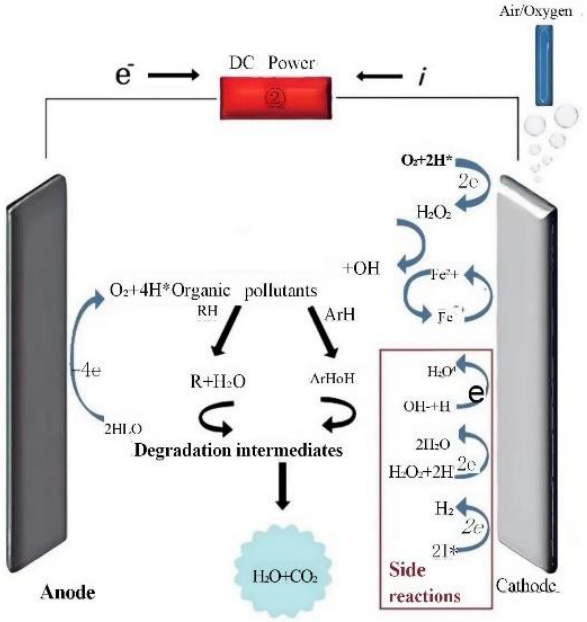

Fig. 2 Schematic diagram of organic matter degradation by Electro-Fenton

4. Combination of Electro-Fenton and SBR process

4.1 Basic Principles of SBR Process

The essence of the SBR process (sequencing batch activated sludge method) is a activated sludge sewage treatment technology operated by intermittent aeration, which is characterized by the basic operation mode composed of five basic processes of orderly and intermittent influence, aeration, precipitation, drainage and standby, so that the spray paint wastewater can complete the homogenization, initial settling, biodegradation, secondary settling and other processes in a reaction tank. Therefore, the processing equipment is less, the operation is flexible, and the maintenance and management are easy. In addition, it has good wastewater treatment effect, high efficiency and good effluent water quality.

4.2 Advantages of the Combination

Electro-Fenton combined with SBR process is a method to treat spray paint wastewater, which combines the advantages of electrochemical Fenton oxidation and sequencing batch reactor SBR process to achieve better treatment effect. The following are the advantages of the Electro-Fenton combined with the SBR process. (i) Electro-Fenton oxidation can quickly oxidize organic matter in spray paint wastewater, and SBR process can effectively remove oxidized substances, and the treatment effect is remarkable. (ii) Electro-Fenton oxidation and SBR processes are mature wastewater treatment technologies with simple equipment and low maintenance costs. (iii) The process has low requirements for water quality and can treat all kinds of wastewater containing organic matter. (iv) The SBR process is a simple wastewater treatment process, which can be automatically controlled and reduce manual intervention.

However, Electro-Fenton oxidation requires a lot of energy consumption, so the energy consumption is relatively high when treating a large amount of wastewater. At the same time, attention should be paid to the monitoring of transformed substances. After electrochemical Fenton

oxidation, many conversion substances are formed, which need to be monitored to ensure that they do not have a negative impact on the environment.

4.3 Process Design

Electro-Fenton was used as pretreatment method to treat spray paint wastewater in combination with SBR. The spray paint wastewater pretreated by Electro-Fenton enters the SBR system for biological treatment, which can reduce the impact of spray paint wastewater on the SBR system and improve the biodegradability of spray paint wastewater. The reaction pool is divided into reaction zone and drainage zone, and the Electro-Fenton joint reaction occurs in the reaction zone, as shown in Fig. 3a. The reaction zone of the reaction pond generates Fe^{2+} and H_2O_2 by electrochemical reaction as a continuous source of Fenton's reagent, while Fe^{2+} acts as a catalyst to decompose H_2O_2 into hydroxyl radical (·OH). The hydroxyl radical (·OH) generated in the reaction zone of the reaction pond and the metal complex oxidized and broke, after breaking the heavy metal into free heavy metal ions. At this time, alkali precipitation is added to remove heavy metals. The generated hydroxyl group is free (·OH) and reacts with organic matter in the reaction zone to oxidize and decompose into small molecules, as shown in Fig. 3b. When the reaction reaches a certain level, the electrification and aeration are stopped, so that the polluted substances in the SBR reaction tank begin to precipitate, as shown in Fig. 3c. After precipitation reaches a certain level, the density of the water changes and the drain opens, as shown in Fig. 3d. Stop drainage when the effective minimum water level (20% of the effective volume) is reached, as shown in Fig 3e. The sludge is discharged, the mixed liquid in the drainage area is returned to the reaction area, and the spray paint wastewater is recycled for treatment, as shown in Fig. 3f.

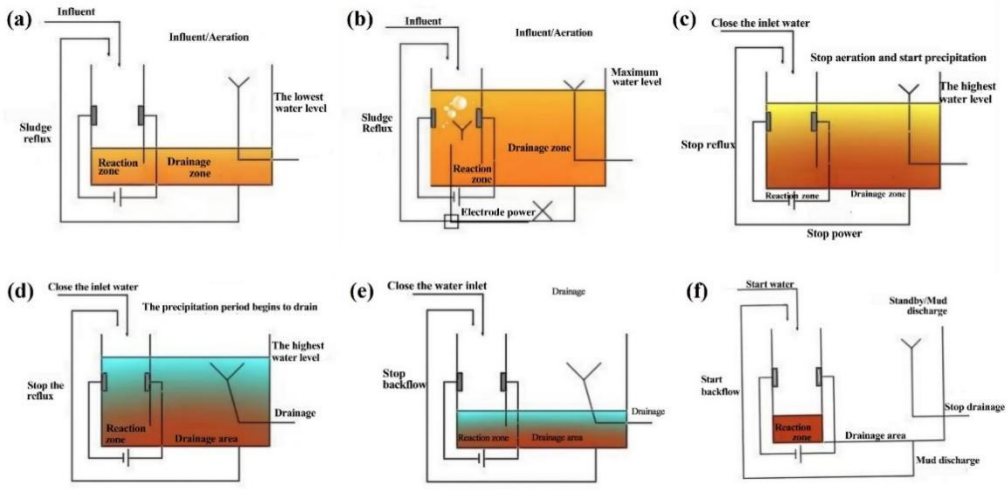

Fig. 3 (a) Combined process reaction tank; (b) Combined reaction tank; (c)Combined process reaction tank; (d) Combined reaction tank; (e) Combined process reaction tank; (f) Combined process reaction tank (f)

The above is the process design of SBR pool. According to the investigation of similar wastewater treatment, the designed effluent water quality of SBR pool is basically below 100 mg/L, which meets the national industrial wastewater discharge standards [4].

5. Conclusion

Electro-Fenton can reduces the treatment cost of spray painting wastewater, reduce the cost of materials and reagents, and the operation is simple, reducing the equipment investment. At the same time, the subsequent equipment operation and maintenance costs are reduced because of the convenient operation. The Electro-Fenton advanced oxidation combined treatment of spray paint wastewater can effectively improve water quality, achieve the expected treatment effect, and is

environmentally friendly, without adding other agents. The designed process method is environmentally friendly, without the addition of chemicals, and the by-product is not harmless to the environment. However, at present, the electrode materials and catalyst costs of the Electro-Fenton system are generally high. The electrode is prone to side reactions leading to problems such as electrode passivation, and the maintenance cost is high. Therefore, the current operating cost and material cost are the main economic factors limiting the promotion and application of Electro-Fenton. Combination of Electro-Fenton and SBR process can combines the advantages of electrochemical Fenton oxidation and sequencing batch reactor SBR process to achieve better treatment effect.

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