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A review on the electrochemical treatment of the salty organic wastewater

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Abstract. Electrochemical technologies have proved to be useful for the treatment of wastewater, and recent years, there are growing interests in electrochemical treatment of the salty organic wastewater. The aim of this paper is to mainly present the source of the salty organic wastewater, the mechanism of direct and indirect oxidation process, and the research advances of electrochemical technologies in the salty organic wastewater by literature reports review.

1. Introduction

The processes used for wastewater treatment can be grouped into three major categories: chemical, physical, or biological treatment processes. It is possible for treatment processes to be a combination of these three major categories. The main contaminants of concern in wastewater are organic compounds, suspended solids, nutrients, and pathogens [1].

One of the most commonly used biological wastewater treatment processes is the activated sludge process. The activated sludge process is a suspended-growth process that recycles a portion of the solids from the secondary clarifier back into an aerated bioreactor in order to maintain a high population of microorganisms (biomass) within the bioreactor. The microorganisms convert biodegradable organic matter and some inorganic compounds, such as nitrogen and phosphorus, into new biomass and other products that are used in their metabolic processes. Biomass is separated from the treated wastewater in the secondary clarifier with a portion of the biomass being recycled and a portion of the biomass being wasted. Many municipal wastewater treatment plants use the activated sludge treatment process because it is highly flexible, reliable, and effective.

Because of the microbial activity is limited in high salt conditions by the traditional biological method in wastewater treatment [2]. Recent years, with the development of the industry, environmental protection become a hot focus of academe and government, and new laws demanding more strict environmental protection are being approved, and so, the search for more effective methods, such as low cost, high efficiency, multifunction, easy operation and pollution free, is increasing [3, 4]. Among the different techniques for wastewater treatment [5, 6], electrochemical methods have achieved a relevant place. In particular, the oxidation method of organic pollutants is anodic oxidation using different electrodes [7-10] or cathodic generation of hydrogen peroxide [11-13].

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2. Treatment mechanism

The process of electrochemical degradation of pollutants can be divided into direct and indirect oxidation process. In the direct oxidation process, pollutants are adsorbed by the surface of the anode at first, and then through the electron transfer reaction of hydroxyl radical formation (•OH); strong oxidative free radical damage of pollutant molecular structure, decomposition to CO_2. However, competitive reaction of oxygen evolution exists for this process consume part of free radical, reduce the oxidation efficiency. Therefore, the development of high oxygen evolution potential of the electrode is the main way to improve the efficiency.

In the indirect electrochemical oxidation process, to produce strong oxidizing agents such as hypochlorous acid/chlorine, ozone, H_2O_2, etc., oxidant pollutants subsequent generation and electrochemical oxidation occurs in solution. The oxidant will be generated and used all of it momently. Shortcoming of the chlorine oxidation method is concerns in the electrolytic process may produce organic chlorides increase the toxicity of the wastewater.

The hydrogen peroxide (H_2O_2) the advantages of easy to store, transported and its safety procedure process with high efficient, it is widely used as an oxidative agent. With the technical developments of the catalytic component materials of active coal, silica textures, zeolites, nafion membranes, structured clay and goethite formed Fe.

The Advanced Oxidation Processes (AOPs) fully or partially used in wastewater treatment aimed to oxidative degradation of the persistent organic contaminants are successful, and usually, it is using a combination of oxidants being more worthwhile to transform them into biodegradable aliphatic carboxylic acids followed by a biological process. With the very high oxidative potential, HO is the decision maker of the oxidation process by different mechanisms [14, 15].

3. Research and development of electrode materials

As mentioned above, the electrode material is one of the effects of electrochemical degradation of organic matter limit factors. Traditional insoluble anode materials, such as graphite electrode, platinum electrodes, still get a wide range of uses in wastewater treatment. In order to improve the efficiency of electrochemical processing, researchers began to study and develop anode materials which have higher catalytic activity, higher over potential and higher stability.

Three dimensional shape-stable anode (DSA) is a kind of metal Ti as catalyst coating substrate (for example: RuO_2 and IrO_2) electrode, precipitation on the chlorine and oxygen have a very high catalytic activity, electrochemical process has long been used in chlor alkali industry. Because the DSA electrode and releasing oxygen over potential is relatively low, the current efficiency of direct oxidation process of organic matter degradation of low [16, 17], however, in the presence of chloride ion in the solution conditions, the electrode surface is indirect oxidation of chlorine evolution, will promote the degradation of organic matter, the practical wastewater treatment, so this type of electrode is especially suitable for high NaCl, such as olive oil, printing and dyeing, tanning wastewater [18-20].

PbO_2 electrode has the advantages of low price, easy preparation, good electrical conductivity, high chemical stability and large surface area, high oxygen evolution over-potential. It is an excellent electrode with the experimental detection to the electrode surface producing a large number of •OH. PbO_2 electrode has been applied to the electrochemical degradation of salty organic wastewater, and gradually extended to the practical wastewater treatment, such as printing and dyeing wastewater, indole production wastewater, pesticides and herbicides wastewater, landfill leachate, tanning wastewater and anionic surface active agent [21-24].

Others have their own advantages such as graphite electrode, activated carbon fiber anode, SnO_2 electrode, boron doped diamond (BDD) electrode, are also widely used to electrochemical treatment of the organic wastewater [25-27]. Graphite electrode is cheap, large surface area, it can be combined with the use of adsorption and electrochemical degradation; activated carbon fiber (ACF) is a new type of porous carbon materials, it is numerous pores, large surface area and very strong adsorption; SnO_2 electrode materials are widely used in organic matter degradation; diamond membranes has high hardness, high thermal conductivity, high chemical stability and other excellent properties, and the

BDD membranes has good net conductive properties and semiconductor properties, it is get more and more application in wastewater treatment.

Composites material electrode research also had an advance in wastewater biological treatment recent years. Jiang [28] prepared three nano-composites, LDH/lysozyme, LDH/GO and LDH/GO/FeP, with the MgAl-NO_3-LDH as the carrier. Since it is a novel biological technologies, Jiang and her team were tried to apply to wastewater treatment. During their experimental study, the composites materials can continue to be used without replacement. Therefore, it would become a potential new disinfectant in the enzymatic treatment of sewage because of its good bactericidal activity and no pollution. In Liu's [29] studies, with carbon nanotube as the template, the polypyrrole/carbon nanotube (PPy/CNT) composites were prepared in ethanol solution through chemical oxidation method. The effects of preparation conditions on properties of PPy/CNT were studied to obtain the optimum preparation conditions. Besides these, Liu and her team also carried out to synthesize polypyrrole/polyaniline (PPy/PANI) composites in PANI dispersion. In Yang's [30] studies, in order to change the tactic pattern of tradition electrode matrix material, by considering the internal composition structure of the electrode composites material, Yang and her team decided to use the aluminum as the in-core, with the outer layer by the titanium gable layered composite construction matrix material, which in the electrode the core as aluminum for fine electrical conductivity, to play an important part of reducing the interface resistance and the equalization current distribution, and the outer layer using the titanium gable, to still maintain the original electrochemistry nature. Experimental results indicate that the change of the electrode matrix material not only improved electrode performance, but also attained the purpose of saving energy and reducing consumption.

4. Research and development of electrochemical reactor

Traditional electrolytic reactor is adopted in 2D planar electrode, the reactor has the advantages of small volume, small amount of body processing unit, but its low current efficiency and mass transfer efficiency make it restricted in electrochemical use. The main problem of the electrochemical wastewater treatment practical application is how the laboratory batch reactor will turn into continuous zoom processing unit in practice. Scholars have carried out a series of research on the new type of electrochemical reactor recent years.

Korbahti et al. [31] designed for processing simulation of printing and dyeing wastewater by electrochemical tubular continuous reaction, using iron as anode, stainless steel as cathode, investigation under the optimized conditions, researched the relationship between residence time and COD, color removal, turbidity, pH changes. The results showed that, the residence time increases to promote the removal of COD and chroma. Also, this processing device was used in coating wastewater [32].

Sakalis et al. [33] using a continuous reactor, NaCl and sodium sulfate as electrolyte, using Pt/Ti as anode material, carbon felt as cathode, studied the electrochemical degradation of dye wastewater. Under the optimal conditions, the removal efficiency of dye reached 94.4%, BOD_5 and COD were decreased by 35% and 45%, COD/BOD_5 value down from 4.3 to 3.6. This reactor is suitable for pretreatment of biological pretreatment. Szpyrkowicz [34] designed a continuous unidirectional filtration electrochemical reactor, provides a computational model for printing and dyeing wastewater treatment in different velocity, and the study of electrochemical reactor for treatment of industrial wastewater of direct and indirect oxidation process through the fluid mechanics.

5. Conclusions

Electrochemical oxidation technology has a very strong degradation ability of the salinity organic wastewater treatment, and it has a good prospect in field of salty organic wastewater treatment with the development of the theory of electrochemistry, the electrode materials, the electrochemical reactor technology and the joint use application with other methods.

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References

[1] Tchobanoglous G, Burton F L and Stensel H D 2003 *Wastewater Engineering: Treatment and Reuse 4th Ed* (New York: Metcalf & Eddy, Inc.)
[2] L'Amoura R J A, Azevedo E B, Leite S G F, et al. 2008 *Sep. Purif. Technol.* **2** 142-3
[3] Anastas P T and Lankey R L 2002 *ACS Symp. Ser.* **23** 1-4
[4] Lancaster M 2002 *Green Chemistry, An Introductory Text* (London: Royal Society of Chemistry)
[5] Rajeshwar K and Ibanez J 1997 *Environmental Electrochemistry Fundamentals and Applications in Pollution Abatement* (San Diego, CA: Academic Press Inc)
[6] Simonsson D 1997 *Chem. Soc. Rev.* **3** 181-3
[7] Brillas E, Cabot P, Casado J 2003 *Environ. Sci. Pollut.* **26** 235-6
[8] Iniesta J, Expósito E, González-García J, et al. 2002 *J. Electrochem. Soc.* **5** D57-8
[9] Iniesta J, González-García J, Expósito E, et al. 2001 *Water Res.* **14** 3291-2
[10] Jiang J, Chang M and Pan P 2008 *Environ. Sci. Technol.* **8** 3059-60
[11] Expósito E, Sánchez-Sánchez C M and Montiel V 2007 *J. Electrochem. Soc.* **8** E116
[12] Sánchez-Sánchez C M, Expósito E, Casado J, et al. 2007 *Electrochem. Commun.* **1** 19-20
[13] Brillas E and Casado J 2002 *Chemosphere* **3** 241
[14] Pera-Titus M, Garcia-Molina V, Banos M A, et al. 2004 *Appl. Catalysis B: Environ.* **47** 219-20
[15] Wang H and Wang J 2007 *Appl. Catalysis B; Environ.* **77** 58-9
[16] Li X Y, Cui Y H, Feng Y J, et al. 2005 *Water Res.* **10** 1972
[17] Feng Y J and Li X Y 2003 *Water Res.* **10** 2399
[18] Chatzisymeon E, Dimou A, Mantzavinos D, et al. 2009 *J. Hazard Mater.* **1-3** 268
[19] Vaghela S S, Jethva A D, Mehta B B, et al. 2005 *Environ. Sci. Technol.* **8** 2848-50
[20] Costa C R, Botta C M R, Espindola E L G, et al. 2008 *J. Hazard Mater.* **1-2** 616
[21] Andrade L S, Ruotolo L A M, Rocha R C, et al. 2007 *Chemosphere* **11** 2035-6
[22] Keech P G and Bunce N J 2003 *J. appl. Electrochem.* **1** 79
[23] Panizza M, Sires I and Cerisola G 2008 *J. Appl. Electrochem.* **7** 923
[24] Martinez-Huitle C A, De Battisti A, Ferro S, et al. 2008 *Environ. Sci. Technol.* **18** 6929
[25] Polcaro A M, Palmas S, Renoldi F, et al. 1999 *J. Appl. Electrochem.* **2** 147-8
[26] Yi F Y and Chen S X 2008 *J. Porous Mater.* **5** 565-7
[27] Liang L C, Chang J E and Wen T C 1995 *Water Res.* **2** 671
[28] Jiang F J 2014 *Application of Layered Double Hydroxide Composites in the Biological Treatment of Wastewater* (Ji'nan, China: Qilu University of Technology)
[29] Liu Q 2012 *Preparation and Evaluation on PPy Composite Electrode Materials for Capacitive Deionization Modules* (Tianjin, China: Tianjin University)
[30] Yang X Q 2010 *Preparation and Evaluation of the Layered Composites Electrode Materials of Ti-Al* (Kunming, China: Kunming University of Technology)
[31] Korbahti B K and Tanyolac A 2009 *J. Hazard Mater.* **2-3** 771-3
[32] Korbahti B K and Tanyolac A 2009 *Chem. Eng. J.* **2-3** 444
[33] Sakalis A, Mpoulmpasakos K, Nickel U, et al. 2005 *Chem. Eng. J.* **1** 63-4
[34] Szpyrkowicz L 2006 *J. Chem. Technol. Biotechnol.* **8** 1375-7