Various Methods Of Electrochemical Oxidation And Theirapplications In Treatment Of Industrial Wastewater

Praveen Bhai Patel[1], Ramendra Singh Niranjan[2], Abhishek Kumar Chandra[3], Arun Kumar Gupta[4] and Gaurav Verma[5]
1,3,4-Chemical Engineering Deptt., UIET, CSJM University, Kanpur
2-Mechanical Engineering Deptt., UIET, CSJM University Kanpur
5- Academy of Scientific and Innovative Research Ghaziabad
*-pbpatel@csjmu.ac.in

Abstract

This article will give a complete assessment of the current literature on wastewater treatment, with a special focus on the use of direct and indirect electrochemical oxidation processes as an alternative to more traditional techniques of wastewater treatment. The goal of this article is to provide a review that is both comprehensive and focused. The most fundamental pieces of equipment required for carrying out this process are electrodes, potentiostats and galvanostats, as well as containers that can tolerate high temperatures. It is not necessary to use containers specifically built to withstand high temperatures.

Keywords: ***electrode position, electrochemistry, Waste.***

INTRODUCTION

Electrode placement is an old method that describes the process of placing a thin coating of one metal on another metal in order to change the characteristics of the surface. This was done in order to make the surface behave differently. This method, also known as electroplating (in its longer form), aims to produce a surface that possesses characteristics distinct from those of the starting surface. This method is a procedure that involves the utilization of an electrical current in order to decrease the quantity of cations that are present in a certain substance while the item in question is suspended in an electrolyte. Following this process of decreasing the total amount of cations, the material in question is next deposited onto the top of a conductive substrate in the form of a very thin layer. The concept of electrolysis serves as the foundation for this method. This is done to obtain a suitable amount of electrical and corrosion resistance, as well as to meet aesthetic objectives, decrease wear and friction, and boost the material's capacity to withstand heat. In addition, this helps fulfill the aims of meeting aesthetic goals. Because of this, the surface characteristics of a material may be changed, and researchers can use this technology to investigate the potential of generating new materials that are suited for a broad variety of applications. The rise of industrial activity over the second part of the 19th century and into the 20th century eventually resulted in major environmental contamination that had devastating impacts on the atmosphere, water, and soil. Since the beginning of the 20th century, this practice has been carried out. There is a connection that can be made between the commencement of this influence and the beginning of the industrial revolution.

Comprehensive pollution reduction measures are required as a result of the constraints imposed on businesses and individuals by newly passed regulations. Not only should these actions concentrate on lowering industrial aqueous effluents and gaseous emissions, but they should also guarantee that thorough soil remediation is carried out. In the second potential scenario, many different kinds of poisons may have built up over time as a result of extended periods of unregulated garbage disposal, and the process of reclamation may pose a huge environmental issue. Due to the fact that the development of a contamination is dependent on a wide variety of circumstances that are specific to each event, there is no one remedy that can be applied uniformly to all situations. It is standard procedure to put wastewater through one of the following three stages of treatment: primary, secondary, or tertiary. The stage of treatment that is selected is determined by the characteristics of the pollutants that need to be removed.

Because of the biorefractory nature of the substrates, it is probable that it may never be feasible to eliminate organic pollutants from wastewater by the use of biological processes. Because of this, physicochemical approaches are strongly suggested; However, oxidation with ozone or chlorine dioxide does not always work, and the safe processing of the materials might be significantly hampered by the logistics of transporting and storing the reagents.

Strategies for the Treatment of Wastewater 3 In recent years, there has been a substantial rise in the number of attempts that are being made to investigate how electrochemistry might be utilized to reduce the influence that it has on the surrounding environment. This shift in emphasis is the consequence of growing knowledge of the possible benefits that may be gained by making use of such an application. Since the groundbreaking research conducted by Deshpande in the 2012, Ramakant, Satyanarayan, and Comninellis in the early 1990s, there has been a great deal of interest in the prospect of converting or eliminating organic substrates that are found in sewage. It is generally agreed that Deshpande was the one responsible for igniting this interest. These studies have conducted comprehensive research on the influence that the kind of electrode material has on the anodic mineralization of organic compounds. The findings of these studies indicate that anodes with a high oxygen content provide the optimal circumstances for the process. To summarize, electrochemical oxidation is accomplished by the action of powerful oxidizing agents, which is comparable to chemical destruction. Nevertheless, in situ electro generation enables better efficiency in the reduction of organic substrates. This entry was posted in Chemistry and tagged chemical destruction, electrochemical oxidation. These two processes are quite similar to one another and should be treated as such. Since the late 1980s, several anode materials have been put through rigorous testing to evaluate whether or not they are capable of oxidizing a wide range of dissolved organic pollutants in water, with a specific focus on the electrochemical destruction of the anode materials themselves. When it comes to anodic mineralization, many organic substrates have complicated reactivity; under these conditions, it is vital to consider the primary function of adsorbed hydroxy radicals as well as the adsorption strategy of organic species. In addition, it is essential to examine the main role of adsorbed hydroxy radicals.

Electrode position

Electroplating, also known as electroplating, is a technology that uses a type of processing known as "soft solution coating" to deposit certain materials on solid conductive or semi conductive surfaces. The method known as electrode placement is considered one of the most popular techniques for growing solutions. Because it is simple, inexpensive, and able to provide degrees of freedom while still creating materials or nanostructures that are not readily available through high-vacuum vapor deposition methods, this method is widely used. It is also capable of providing degrees of freedom. The morphology, orientation, and gloss of materials can be controlled by the use of additives in solution, the pH of the solution, and the applied voltage or current density at the electrode surface. This can be achieved by checking the morphology, orientation and gloss of the materials. [2-6] Although other solution growth methods, such as chemical bath deposition, sol-gel processing, and hydrothermal synthesis, possess some of these capabilities, electrode position still has unique properties, such as. the precision of the control of the deviation from the equilibrium potential by externally applied bias, ii) the control of the stoichiometry of the deposited compounds and metal alloys by the applied potential or the current density and iii) the control of the rate of deposition. Although other solution culture methods, such as.

Electroplating is a process that can be used on a variety of substrates to create a variety of materials and structures. This can be done by applying an electrical current. Electroplating can be done from a variety of materials, such as metals, metal alloys, oxides, magnetic materials, hybrid materials, etc. They can be manufactured in a controlled way as polycrystalline or epitaxial films, superlattices, nanocrystals of various shapes (such as cubes, triangles, rods, tubes, and spheres), porous lattices, and chiral morphologies can be deposited. These morphologies can also be deposited as porous networks. [1] Coating the epitaxial growth of thin films, superlattices and composites of two functional materials was the main focus of the research carried out by the group led by von Switzer. Swatter's team used electrodeposition techniques to produce magnetite (Fe_3O_4), bismuth oxide (Bi_2O_3), copper oxide (CuO), copper oxide (Cu_2O), zinc oxide (ZnO), cobalt oxide (Co_3O_4) and lead dioxide. (PbO_2) ii) biomaterials, including calcite ($CaCO_3$) [3,9] and metal chalcogenide semiconductors, including lead sulfide (SnS) The electrochemical deposition of thin layers and superlattices of epitaxial metal oxides occupies part of the space dedicated to the discussion part of this thesis.

Factors affecting the coating

1. The existing density level.
2. The presence of anions or cations in the form of solutions.
3. The temperature and content of the tank.
4. A measure of the concentration of the solution.
5. The waveform of the current coming from the power supply.
6. The presence of pollutants in the environment.
7. The physical and chemical properties of the substrate surface.

Electrochemical reduction of metal oxides to metals

The electrochemical reduction of metal oxides (or metal hydroxides) to equivalent metals has been studied for decades by the metallurgical industry as a possible alternative to hydrometallurgical techniques. This line of research began when the industry realized that hydrometallurgical processes had limitations. This is in the hope of discovering a method of producing similar metals that is less harmful to the natural environment. This strategy has a number of advantages that make it an attractive option. To begin with, there are not many complications with this process. Starting from metal oxides (and occasionally from minerals as well) it is possible to produce metals directly without resorting to complicated processes. Second, the price is not exorbitant at all. Electrodes, potentiostats and galvanostats and vessels capable of withstanding high temperatures are the main equipment needed to perform this method. Containers designed for high temperatures are not required.

In addition, this technique does not have a negative impact on nature. Unlike traditional hydrometallurgical processes that release tons of carbon dioxide into the environment each year, the electrochemical reduction of metal oxides does not lead to the production of toxic by-products. The phenomenon known as the "greenhouse effect" is strongly influenced by the presence of carbon dioxide, which is an important component of other gases. This strategy has the potential to be used in the preparation of other metals from the oxides and hydroxides of these metals as well. Although most of the research on this topic has focused on the production of iron from its oxides and hydroxides, this strategy also has the potential to be used in the production of other metals. Examples of this process are the electrochemical reduction of TiO_2 to titanium, CuO to copper, SiO_2 to silicon, and ZrO_2 to zirconium. For example, even with the most advanced technology available today, extracting pure versions of the elements titanium and silicon still requires a series of long and costly steps. Consequently, there is a significant need for electrochemical reduction techniques capable of producing metals such as titanium and silicon. Electrochemical reduction of mixed powders of many different metal oxides can result in metal alloys in addition to pure metals. Metal alloys are produced with this process. To promote the electrochemical reduction of a variety of metal hydroxides and oxides, which will be discussed in the following sections, it is necessary to use a variety of media (electrolytes) as well as experimental conditions.

Sewage water

There are many obstacles to overcome, especially when it comes to proper wastewater treatment in the chemical industry. Significant efforts have been made over the last century and a half to reduce pollution at the source by improving process efficiency, reusing resources, and better managing waste disposal during the production phase. This has led to significant progress. However, due to the huge amounts of industrial wastewater to be treated, for example for the recovery of some solvents, residues are inevitably produced that sometimes require a delicate final treatment. This is due to the nature of the materials to be recovered, such as some solvents. On the other hand, traditional destruction techniques can lead to corrosion and, more importantly, emissions if treatment requirements are not actually met. This can be a problem when it comes to disposing of hazardous materials. Since there are no great principles or simple methods in this industry, the subject must be studied from the perspective of the industry. Due to the great variety of industrial emissions, it is necessary to examine different techniques and, where possible, the treatment should be adapted to each individual case. This is imperative due to the large amount of industrial emissions. Despite efforts to develop environmentally friendly processes, stricter environmental standards should lead to the search for more efficient treatments that allow the production of more environmentally friendly effluents. This research is motivated by the need to comply with increasingly stringent environmental standards.

OBJECTIVE

1. Research in electrochemical oxidation.
2. Research on the treatment of industrial effluents.

RESEARCH METHODOLOGY

It is a method; Wastewater treatment processes are divided into primary, secondary and tertiary treatment respectively. The use of processes such as precipitation, reduction and oxidation are some of the distinguishing features of tertiary treatment, often referred to as advanced wastewater treatment.

Process design issues

When designing an electrochemical oxidation system, it is important to consider electrode materials, cell design (layout), operating conditions, and power consumption.

Electrode material

The electrode materials used in the process are of paramount importance due to their influence on the selectivity and efficiency of the process. Due to the complexity of electrode performance and the lack of relevant information, selecting the best electrode for a given process based on theory alone is not a practical option.

Energy consumption

Power consumption must be minimized to reduce the cost of electricity bills. The total amount of current required takes into account contributions from electrolysis and movement of the solution or electrodes. Oxygen growth on different electrode materials is broken down by potential and presented in Table 1 (Chen, 2004).

Table 1: V vs typical hydrogen electrode, oxygen evolution potential of different anodes (Chen, 2004)

Anode	Potential (V)	Conditions
Pt	1.3	0.5 mol L^{-1} H_2SO_4
Pt	1.6	0.5 mol L^{-1} H_2SO_4
IrO_2	1.6	0.5 mol L^{-1} H_2SO_4
Graphite	1.7	0.5 mol L^{-1} H_2SO_4
PbO_2	1.9	1.0 mol L^{-1} H_2SO_4
SnO_2	1.9	0.5 mol L^{-1} H_2SO_4
TiO_2	2.2	1.0 mol L^{-1} H_2SO_4
Si/BDD	2.3	0.5 mol L^{-1} H_2SO_4
Ti/BDD	2.7	0.5 mol L^{-1} H_2SO_4

Mobile phone design

Since most of the reactions that take place during electrochemical processes occur at electrode surfaces, one of the most challenging aspects of cell design is ensuring that reasonable mass transfer rates are achieved.

DATA ANALYSIS

Electrochemical oxidation applications in wastewater treatment

Since electrochemical oxidation is generally considered an effective treatment method, research has been conducted to determine whether or not it is effective in cleaning a variety of difficult wastewater types, including a variety of toxins. In addition, new efforts have been made to remove micro-pollutants by applying an electrochemical oxidation strategy. This effort was made recently. Direct electrochemical operations or the generation of "killer" chemicals such as hydroxyl radicals are two methods that can generally be used to kill microorganisms It is a desirable alternative to combine contaminant removal and wastewater disinfection in a single treatment step. This is especially true for water reclamation and reuse applications that must ensure the effective removal of pathogens to protect the health of the general public. Table 2 provides information on the effectiveness of electrochemical oxidation in treating various effluents.

Table 2: Electrochemical oxidation is used in wastewater treatment.

Type of wastewater	Electrode material	Performance	references
Slaughterhouse Wastewater	aluminum	96.8% color, 81.3% BOD, and 85.0% COD removals.	Awang et al.(2011)
Textile Wastewater	iron electrode	78% COD, and 92% turbidity removals	Kobya et al. (2009)
Textile Wastewater	graphite electrodes	100% dye removal	Kariyajjanavar et al. (2011)
Landfill leachate	graphite Carbone	68%COD, 84% color, and 70% BOD removals.	Bashir et al. (2009)
Landfill leachate	30% RuO_2 and 70% TiO_2 coated titanium	73% COD, 57% TOC, 86% color removals	Moraes and Bertazzoli, (2005)
Industrial paint wastewater	stainless steel	44.3% COD, 86.2% color, and 87.1% turbidity removals	(Körbahti and Tanyolaç, 2009)
paper mill effluents	-A cylindrical lead sheet as anode - a cylindrical stainless steel sheet as cathode	97% COD, and 100% color removals	El-Ashtoukhy et al. (2009)
paper mill effluents	-Ti/RuPb(40%)Ox as anode -Ti/PtPd (10%)Ox as cathode.	99% COD and 95% of color and polyphenols removals	Zayas et al. (2011)
Olive oil mill Effluents	RuO_2 coated Ti	99.6% COD, 99.85% turbidity, and 99.54% oil-grease removals	Un et al.(2008)
Pharmaceutical Wastewater	Carbon electrode	35.6% COD removal	Deshpande et al. (2012)
Tannery Wastewater	-graphite cathodes -$Ti/SnO_2/PdO_2/RuO_2$ anode	72.9 % COD removal	Naumczyk and Kucharska (2011)

The electrochemical oxidation process was developed by Faraji, S. et al. as a potential post-treatment method for slaughterhouse effluents (2011). The best results were a COD of 220 mg/L, a current density of 30 mA/cm2 and a reaction time of 55 minutes. This resulted in 96.8% color removal, 81.3% BOD removal, and 85.0% COD removal. Under optimal operating conditions (initial pH of 6.9, current density of 10 mA/cm2, conductivity of 3990 micro-S/cm and electrolysis time of 10 minutes), the electrochemical oxidation managed to eliminate 78% of COD and 92% turbidity. Wastewater from the textile industry. These results were determined by measuring the removal efficiency.

Energy and electrode consumption was calculated as follows: 0.7 kWh/kg COD (1.7 kWh/m3) for energy and 0.2 kg Fe/kg COD (0.5 kg Fe/m3) for electrodes when conditions were optimal (Naumczyk J, Kucharska 2011). Chen G (2004) achieved a maximum COD removal of 68% with leachate from landfills treated electrochemically with carbon graphite electrodes. The reaction time was set at 4 hours and the current density was 79.9 mA/cm². The baseline COD value was 1414 mg/l. According to the results of Farrokhzad, MA, Saha, (2014), the removal of approximately 73% COD, 57% TOC and 86% color required a current density of 116.0 mA/cm2 and a reaction time of 180 minutes. Faraji, S. Abdul Rahim (2013) found this combination sufficient to achieve the desired results. In their experiment, they used titanium oxide, which was coated as an anode electrode.

"Research on the electrochemical treatment of water-based industrial paint effluents was carried out in a continuous-operation tubular reactor. The effects of reaction time on COD color reductions, and turbidity were evaluated using a current density of 66.8 mA/cm2 at a" temperature of 30 degrees Celsius, 35 grams of electrolyte per liter, and 7,496 milligrams of COD. per liter of reaction start. . According to Cai F, Jiang C, Fu P, and Ji V (2015). the ideal residence time in the reactor was set at 6 hours for a cost-oriented strategy. This resulted in COD removal rates of 44.3%, color removal rates of 86.2%, and haze removal rates of 87.1%, respectively. Electrochemical removal of organic contaminants from paper mill effluents was reported by El Cai F, Jiang C, Fu P, and Ji V (2015). reviewed. Based on the data, the COD and color removal percentage ranged from 97 to 100%. According to the estimation of energy consumption, depending on the operating conditions, the energy consumption can range between 4 and 29 kWh/m3 of wastewater. In another study, the electrochemical oxidation of paper mill effluents using a dimensionally stable Ti/RuPb anode (40%) was investigated.

After 15 minutes of electrolysis, almost 98% of the COD and 95% of the color and polyphenols are removed. The generation of hypochlorite ions (ClO-) during the electrolysis process was verified using the UV-Vis spectrum, demonstrating that electrochemical oxidation occurs through an indirect mechanism involving hypochlorite ions. This was evidenced by the fact that the electrolysis process produced hypochlorite ions (Zayas et al., 2011). The increase in applied current density, salt chloride content, circulation rate and temperature contributed to a higher removal of organic compounds in the crusher effluents. The initial COD content of 41,000 mg/L was reduced to 167 mg/L after 7 hours of electrolysis at 135 mA/cm2, 2M NaCl, 7.9 cm3/s and 40 degrees centigrade. Furthermore, 99.85% of turbidity and 99.54% of oily fat were removed (Un et al., 2008). The effectiveness of the electro-oxidation process in the treatment of pharmaceutical wastewater was investigated and factors such as the initial pH (3-11) and the current density, which ranged from 40 to 120 A/m2, were investigated.

Under optimal operating conditions (CD 80 A/m 2 ; pH 7.2), the aluminum electrode process removed 24% of the COD after 25 minutes, while the carbon electrode process removed 35.6 % COD after 90 minutes Naumczyk J, Kucharska M (2011).A study was carried out on the treatment of wastewater from tanneries with graphite cathodes and an anode composed of Ti/SnO2/PdO2/RuO2 with a current density of 2.1 A/dm2. After waiting 55 minutes, the catholyte is transferred to the anode compartment and then operation is resumed. After applying electrofenton therapy for 55 minutes, COD decreased by 52.0%. The anodic process supported electrooxidation, resulting in ammonia removal in fifty-five minutes and a seventy-two point nine percent reduction in COD (Zayas T, Picazo M, Salgado L, 2011).

It can be concluded that the electrochemical oxidation process is a valid alternative when the presence of refractory and toxic contaminants prevents the use of conventional biological treatments due to the exceptional performance of the process in the treatment of a wide range of effluents, especially effluents from industrial plants and landfill leachate. containing a high percentage of toxic and non-biodegradable contaminants. In fact, the electrochemical oxidation process has shown exceptional performance in the treatment of this type of wastewater. Under correct operating conditions it is possible to eliminate: COD, colorants, ammonia and microorganisms.

Opportunities and challenges

The appearance of contaminants that cannot be controlled with traditional biological and chemical treatments, as well as the promulgation of new laws that impose stricter restrictions, have caused a significant increase in the research effort in electrochemical oxidation. Sewage water. It has just been discovered that electrochemical oxidation is an environmentally friendly technology capable of completely removing non-biodegradable organic compounds and eliminating nitrogenous species; Researchers in this field have focused their efforts in two different research directions: first, I will use electrochemical oxidation instead of more conventional techniques, and second, I will integrate electrochemical oxidation into existing treatment plants. The use of photovoltaic (PV) modules as a power source is expected to result in lower operating costs. This is because the electrochemical oxidation process consumes most of the available electrical energy In fact, high energy consumption is quite common, which narrows the field of possible financially sustainable future applications. Two actions were taken to reduce treatment costs: I by integrating this technology with other processes such as a pretreatment or polishing stage and (ii) by using renewable energy sources to power the electrochemical oxidation. These two steps have been completed (O. Simond, V. 2018).

In addition to the amount of energy consumed, there are a number of other critical aspects that must be taken into account when designing the process, particularly in the design of electrodes and cells. Some of these are cost, ease of use, security and maintenance, and ease of maintenance. In addition, the performance of the electrodes must be maintained during the period of time that the cells are to be used However, a partial oxidation of ammonia to nitrate ions was observed, so electrochemical oxidation as a post-treatment step in combination with other processes such as ion exchange could be a viable solution to this problem. Although electrochemical oxidation has been established as a technically feasible method to remove organic contaminants, partial oxidation of ammonia to nitrate ions has also been observed. Consequently, M Panizza, M Delucchi (2015) revealed the optimistic results obtained from industrial wastewater treatment using integrated electrochemical oxidation techniques. These findings lay the groundwork for more studies to be conducted in the near and distant future. Creating a sustainable process based on a variety of efficient technologies is one of the main obstacles to be overcome before electrochemical oxidation can be implemented on a large scale. Cao H, Wang L, Qiu (2016)

CONCLUSION

The effectiveness of this electrochemical oxidation wastewater treatment technique has been studied in the laboratory for a long time. Electrochemical oxidation technologies, on the other hand, are not yet mature enough to be used commercially. This could be due to the high capital outlay required, as well as high energy costs. Consequently, in order to carry out electrochemical oxidation in wastewater treatment on a large scale, it is necessary to reduce operating costs and provide efficient electrode materials.

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