Bulletin of Environment, Pharmacology and Life Sciences
Bull. Env. Pharmacol. Life Sci., Spl Issue [3] 2022: 394-398

Online ISSN 2277-1808
Journal's URL:http://www.bepls.com
CODEN: BEPLAD

SHORT COMMUNICATION **OPEN ACCESS**

Treatment of waste water by the process of electro-oxidation

Hakimuddin Jinwala[1], Indrani Bhattacharya[2], Dhwani Upadhyay[2], Prasad Andhare[3], Shilpi Gaur[3] , Anjali Thakur[2]
1: Student, Department of Environmental Science, Parul Institute of Applied Science, Parul University, Vadodara, Gujarat -391760, (India)
2: Assistant Professor, Parul Institute of Applied Sciences, Parul University, Post Limda, Waghodia, Gujarat, 391760
3: Assistant Professor, Biological Sciences, PDPIAS, Charotar University of Science and Technology, Changa, Anand, Gujarat.
3: Deputy laboratory Incharge, Prakruti Environmental Engineers, Bill, Vadodara, Gujarat-391410, INDIA
*corresponding author:Dr.Anjali Thakur ,Email Id: anjali.thakur6736@paruluniversity.ac.in

ABSTRACT
Water is an essential component for sustaining life across various organisms, including humans, animals, and plants. In order to combat the issue of water pollution, advanced oxidation processes (AOPs) have been employed to treat persistent biological wastewater and enhance water quality. Electro-oxidation, an environmentally friendly technology, is utilized for the treatment of domestic and industrial wastewater. This process involves the oxidation of organic compounds at the interface between the anode and the aqueous solution, facilitated by the reduction reaction at the cathode. Experimental tests were conducted on wastewater samples obtained from a sewage outlet chamber, utilizing an electro-oxidation cell equipped with stainless steel plates and mild-steel plates. The removal of pH and chemical oxygen demand (COD) was examined at specific voltages of 75A, 150A, and 200A, as well as various electrolysis durations (5, 10, 15 minutes) on both types of plates. The findings indicate that electro-oxidation proves effective in reducing pH and COD levels by 81% at a voltage of 75A when employing stainless steel plates. Consequently, the treated effluent meets the required standards for disposal into the environment without causing pollution.
Keywords: *Electro-oxidation, Electro-coagulation, Advanced oxidation process, stainless steel plates, mild-steel plates.*

Received 01.08.2022 Revised 21.09.2022 Accepted 05.10.2022

INTRODUCTION

The water crisis in India is a persistent issue that affects a significant portion of the population each year. This scarcity of water has wide-ranging impacts on the environment, agriculture, and both rural and urban communities. Despite having a population of over 1.3 billion people, India only possesses 4 percent of the world's freshwater sources. The depletion of rivers and streams during the summer season, just before the arrival of the monsoons, exacerbates the country's water problem, as does the unequal distribution of freshwater. To address this severe scarcity of water for everyday needs, various government and non-governmental organizations have implemented measures such as rainwater harvesting, water management, and more efficient irrigation methods. It is worth noting that agriculture accounts for 80 percent of the country's total water usage [1].

According to a study conducted by the Central Pollution Control Board in 2015, India is now capable of treating nearly 37% of its wastewater, equivalent to 22,963 million liters per day (MLD), compared to the daily sewage output of 61,754 MLD. India possesses an abundance of water resources, including 113 rivers and large sandy basins that can hold significant amounts of groundwater. Additionally, the snow-capped peaks of the Himalayan range contribute to the country's diverse water demands. However, due to rapid population growth and the increasing need to meet agricultural, domestic, and industrial water consumption, many regions in India are experiencing a decline in water resources and a deterioration in water quality. The primary sources of contamination in India are domestic wastewater, effluent, and agricultural run-off [2-3].

Insufficient access to drinking water and sanitation facilities is a significant environmental and public health concern in both rural and urban areas of India. Surface water sources have been negatively impacted by organic pollution and bacterial contamination, rendering them unsafe for human consumption without proper treatment. Sewage, which refers to wastewater discharged from various sources such as households, businesses, organizations, and government buildings, exhibits characteristics such as solids, indicators of organic matter, nitrogen, phosphorus, and fecal contamination. Indirect methods like biological oxygen demand (BOD) and chemical oxygen demand (COD) are commonly used to measure organic matter in sewage.

Electro-oxidation, also known as electrochemical treatment or oxidation, is an electrochemical method used to treat wastewater, particularly industrial effluents. In its simplest form, this method involves connecting two electrodes, functioning as anodes, to a power supply. When the system receives sufficient energy and an appropriate amount of supporting electrolyte, potent oxidizing species are generated, which interact with contaminants and degrade them. Complete mineralization converts refractory compounds into reaction intermediates, water, and carbon dioxide. Electro-oxidation has gained popularity due to its simplicity and effectiveness in decomposing refractory organic pollutants that are challenging to treat using traditional methods. It has been successfully employed to treat a wide range of harmful and non-biodegradable contaminants. However, due to its relatively high operating costs, it is often combined with other treatment methods, such as biological remediation, to reduce costs while maintaining high degradation standards. Electro-oxidation can also be used in conjunction with other electron transport mechanisms, such as electro-coagulation, to further reduce operating costs [4-5].

The electro-oxidation process is carried out using an electrochemical cell, where the electrodes are subjected to a voltage difference, resulting in the formation of reactive species, particularly hydroxyl radicals, at the electrode surface. The efficiency of the electro-oxidation process is often evaluated using two key metrics: current efficacy and specific energy consumption. Current efficacy is determined by dividing the charge required for the oxidation of the target compound by the total charge passed during electrolysis. Although methods for continuous current efficacy measurement have been proposed, they have limitations due to the presence of unstable intermediates or the need for specialized equipment.

In the electro-oxidation process, stainless steel plates and mild steel plates are commonly used as electrode materials. The dimensions of the stainless steel plates are 15.3cm x 9cm, with a weight of 190g, while the mild steel plates measure 14.8cm x 9.3cm and weigh 200g.

The objective of this study was to assess the impact of electro-oxidation on the characteristics that influence sewage sludge stabilization. Electro-oxidation was employed in two different downstream processes: pretreatment to enhance the solubilization of organic material and improve anaerobic digestion.

MATERIAL AND METHODS

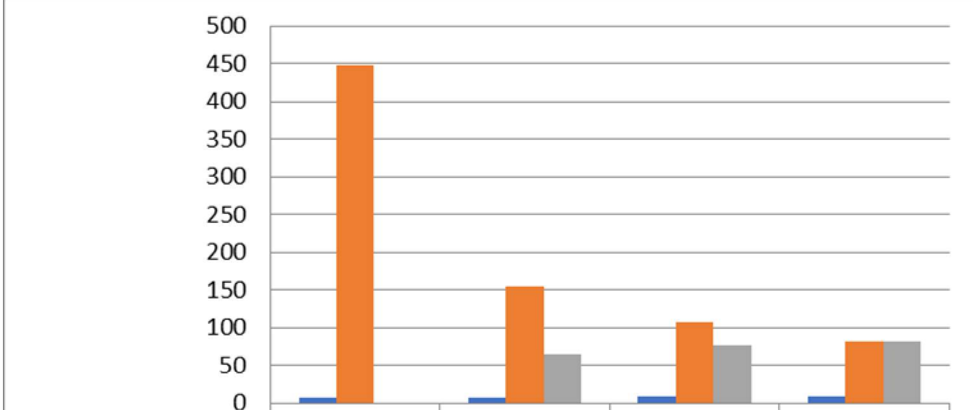
The materials used in this study included stainless steel plates, mild steel plates, a funnel, measuring cylinder, wooden sticks, wires, filter papers, beakers, a large vessel, and test tubes. The sewage sample was collected from the inlet chamber of the Nandesari Area sewage treatment plant and transferred to a container for further treatment. The parameters observed during the process were pH and chemical oxygen demand (COD). The sewage water was subjected to different voltages (75A, 150A, and 200A) using stainless steel plates and mild steel plates as anodes for varying time intervals. After treatment, three samples were taken for each voltage, and the parameters were measured.

Chemicals used in the COD process included titratable ferrous ammonium sulfate (0.1N FAS), standard potassium dichromate ($K_2Cr_2O_7$), and ferroin indicator solution. Titratable ferrous ammonium sulfate was prepared by dissolving 39.2g of $Fe(NH_4)_2(SO_4)_2.6H_2O$ in distilled water, adding 20ml of concentrated H_2SO_4, cooling the solution, and diluting it to 1000ml. Standard potassium dichromate was prepared by dissolving 4.903g of primary standard grade $K_2Cr_2O_7$, previously dried at 150°C for 2 hours, along with 167ml of concentrated H_2SO_4 and 33.3g of $HgSO_4$ in approximately 500ml of distilled water. The solution was then diluted to 1000ml after complete dissolution and cooling to room temperature. Ferroin indicator solution, which indicates changes in the solution's oxidation-reduction potential and the completion of dichromate reduction by ferrous ion, was also prepared.

RESULTS AND DISCUSSIONS

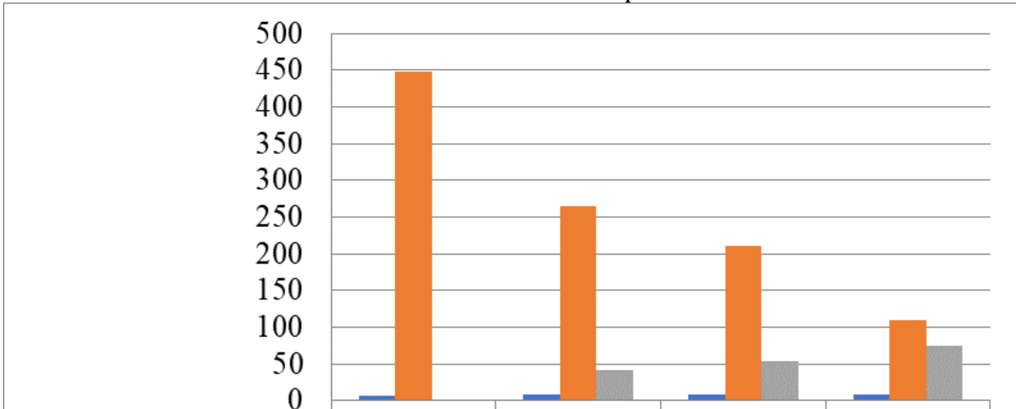
The experiment involved the electro-oxidation of sewage wastewater using different amperes (75A, 150A, 200A) to reduce the levels of physico-chemical contaminants. The sample volume used was approximately 1.5L, and stainless steel plates were used for the 75A, 150A, and 200A tests, while mild-steel plates were used for the other tests. The time interval for each test was 5 minutes.

The observations showed that the pH of the wastewater increased over time in all tests, and flocks started to form around 5-10 minutes later. The color of the flocks was reddish brown, and the sludge formation ranged from 70ml/L to 140ml/L. The reduction in chemical oxygen demand (COD) was satisfactory in the tests with stainless steel plates, but not in the tests with mild-steel plates. Graphical representations of the results can be seen in figures 1-6.
It is important to note that higher energy consumption is not recommended due to similar water quality measures between the tests. To prevent temperature rises as the electric current strength increases, appropriate conditions for wastewater treatment should be established.
Overall, electro-oxidation has shown potential as an effective method for wastewater treatment, and it can be further enhanced by combining it with other treatment methods.



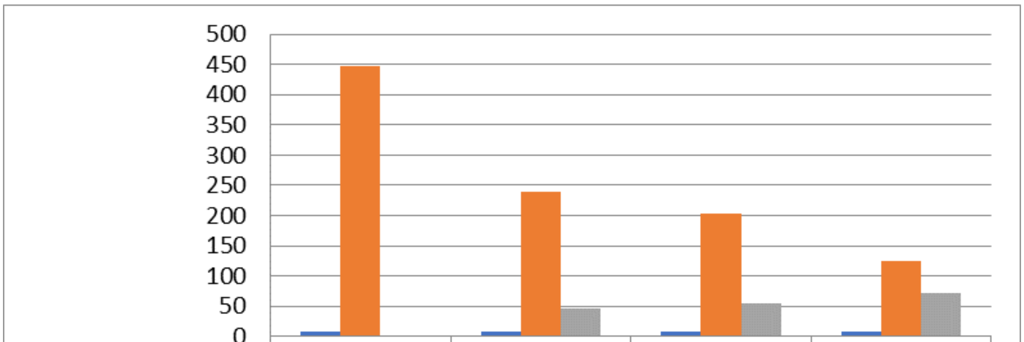
	Raw	0:05:00	0:10:00	0:15:00
pH --	7.27	7.96	8.24	8.30
COD mg/L	448	154	108	82
% COD Reduc. %		65.6	75.9	81.7

Figure 1 – Analysis of parameters – pH & COD at voltage 75A on stainless steel plates for 5 mins for 1.5 liters of volume of sample



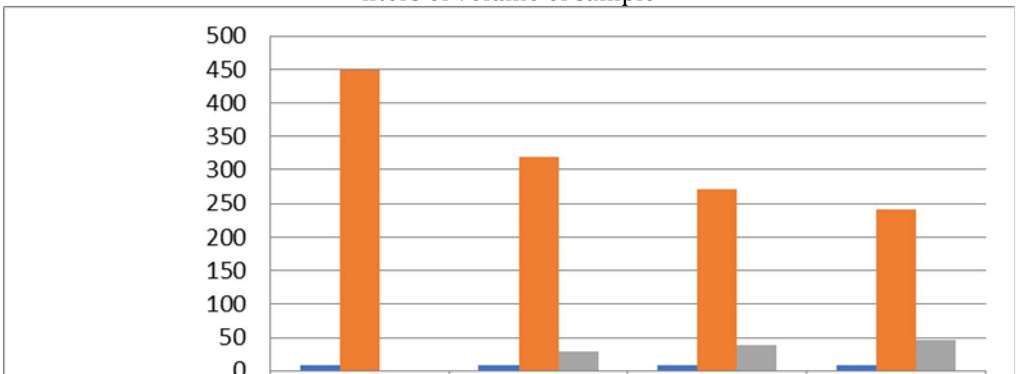
	Raw	0:05:00	0:10:00	0:15:00
PH --	7.12	7.95	8.24	8.30
COD mg/L	448	265	210	110
% COD Reduc. %		40.8	53.1	75.4

Figure 2-Analysis of parameters – pH & COD at voltage 150A on stainless steel plates for 5 mins for 1.5 liters of volume of sample



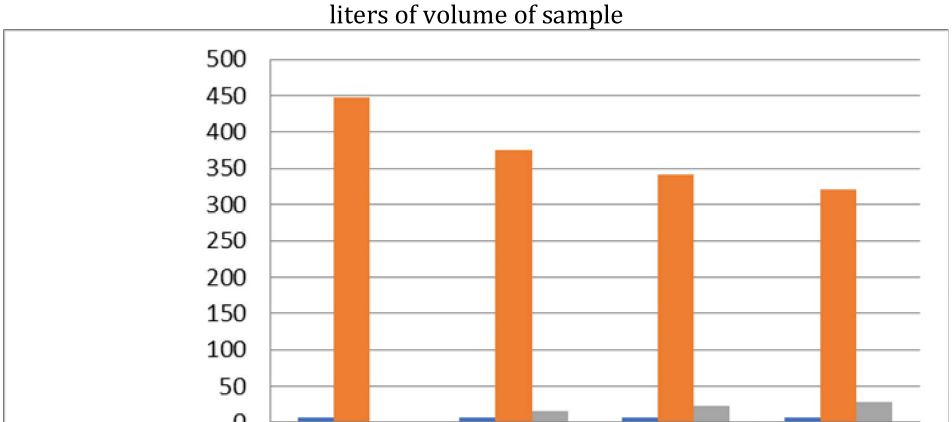
	Raw	0:05:00	0:10:00	0:15:00
PH --	7.28	8.05	8.16	8.38
COD mg/L	448	240	204	124
% COD Reduc. %		46.4	54.5	72.3

Figure 3-Analysis of parameters – pH & COD at voltage 200A on stainless steel plates for 5 mins for 1.5 liters of volume of sample



	Raw	0:05:00	0:10:00	0:15:00
pH --	7.32	7.91	7.82	7.54
COD mg/L	448	320	272	240
% COD Reduc. %		28.6	39.3	46.4

Figure4-Analysis of parameters – pH & COD at voltage 75A on mild stainless steel plates for 5 mins for 1.5 liters of volume of sample



	Raw	0:05:00	0:10:00	0:15:00
PH --	7.32	7.72	7.62	7.31
COD mg/L	448	376	342	320
% COD Reduc. %		16.1	23.7	28.6

Figure 5-Analysis of parameters – pH & COD at voltage 150A on mild stainless steel plates for 5 mins for 1.5 liters of volume of sample

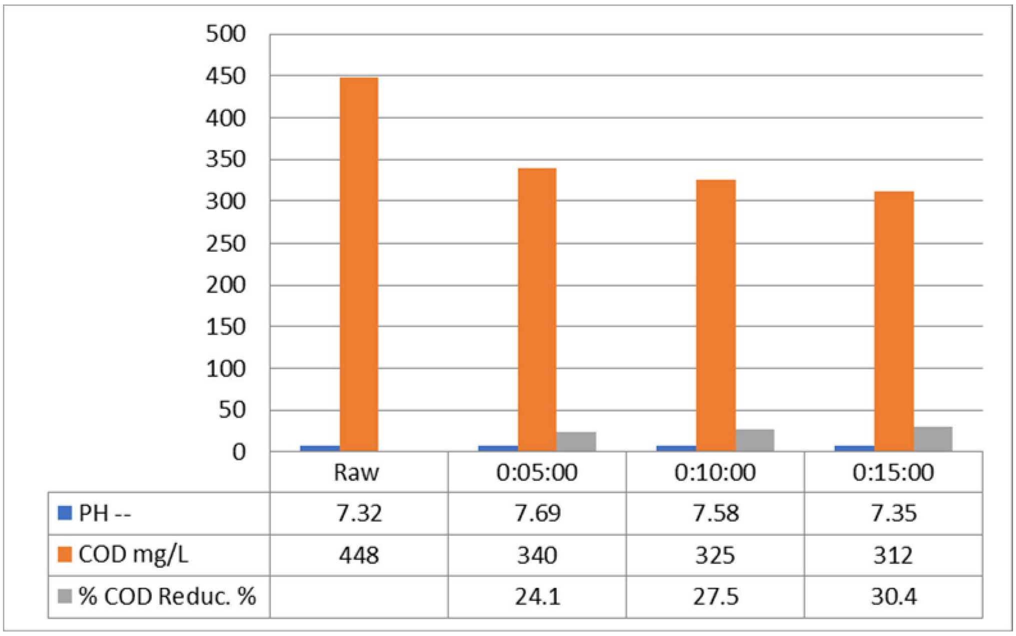


Figure 6-Analysis of parameters – pH & COD at voltage 200A on stainless steel plates for 5 mins for 1.5 liters of volume of sample

ACKNOWLEDGMENTS

This work was supported by the Department of Environmental Science, Parul Institute of Applied Sciences, Vadodara- 391760, Gujarat.

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CITATION OF THIS ARTICLE

Hakimuddin Jinwala, Indrani Bhattacharya, Dhwani Upadhyay, Prasad Andhare, Shilpi Gaur , Anjali Thakur· Treatment of waste water by the process of electro-oxidation. Bull. Env. Pharmacol. Life Sci., Vol Spl Issue [3] 2022: 394-398