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ELECTRO-OXIDATION AND ITS EFFECT ON PARAMETERS AFFECTING WASTEWATER QUALITY AND STABILITY

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ABSTRACT

Electro-oxidation (EO) is a new way to treat wastewater that looks like it could be a good way to get rid of both organic and inorganic pollutants from both commercial and household wastewater. In this study, the process of electro-oxidation is looked into, along with how it affects important aspects of wastewater quality, including pH, sediment, biological oxygen demand (BOD), chemical oxygen demand (COD), and total organic carbon (TOC). An electric current is sent through wires to create reactive oxygen species like hydroxyl radicals. These radicals oxidize and break down complicated pollution into simpler molecules that are not harmful. EO is very good at breaking down toxins like heavy metals, dyes, and medicines that are hard to break down. This makes the waste much better and the world safer. Additionally, electro-oxidation helps to stabilize wastewater by lowering the number of pathogens and increasing biodegradability. This makes cleaned water safe to reuse or release into the environment. Different operating factors, such as electrode material, current density, electrolyte content, and holding time, can change how well EO works. Even though there are problems with how much energy it uses and how much electrodes cost, the rising need for environmentally friendly and effective water treatment methods makes EO even more important. This research shows that electro-oxidation could be a good choice to or addition to current ways of treating wastewater.

Keywords: Electro-oxidation, Wastewater treatment, Chemical oxygen demand, Water quality, Stabilization.

I.INTRODUCTION

Electro-oxidation (EO) is an advanced oxidation process (AOP) that has gotten a lot of attention lately because it looks like it could be used to treat a lot of different kinds of garbage. Pollutants like organic molecules, viruses, nutrients, heavy metals, and lingering harmful substances are becoming more and more common in urban and industrial wastes. These pollutants are very bad for the environment and people's health. Traditional ways of treating wastewater are sometimes useful, but they often fail to get rid of all contaminants, even those that are hard to get rid of. In this case, electro-oxidation has become a good option or extra treatment method because it is more effective, doesn't harm the environment, and can be done on-site with little chemical input. Electro-oxidation works by running a straight electrical current through plates that are buried in dirty water. This process creates highly reactive oxidizing species that can break down a wide range of toxins, either directly on the anode surface or indirectly in the solution. Depending on the material of the electrode and how it is used, hydroxyl radicals (•OH), ozone (O), hydrogen peroxide (HO), and other reactive oxygen species (ROS) are some of the most important oxidizing agents. EO works best when certain electrode materials are used, like boron-doped diamond (BDD), platinum, graphite, or dimensionally stable anodes (DSA). Other factors that affect its performance include current density, pH, temperature, holding time, and the presence of an electrolyte.

When organic toxins are broken down by electricity, they turn into safe minerals like carbon dioxide and water. This makes a big difference in lowering the amount of chemical oxygen demand (COD), biological oxygen demand (BOD), total organic carbon (TOC), and color from dyes or pigments. Electro-oxidation has also been shown to be successful at getting rid of pathogens, medicine leftovers, pesticides, and chemicals that mess with hormones. This makes cleaned effluents more stable for microbes and chemicals. EO offers a better technology that doesn't create as much leftover material as other methods, which often create extra sludge or need a lot of extra steps after cleaning. Electro-oxidation has many effects on the quality factors of wastewater. It improves physical properties like stabilizing pH, lowering turbidity, and making the water clearer. What's more, it changes dangerous chemicals into less harmful or inactive forms, which makes the wastewater easier for living things to break down. Because of this, electro-oxidation can be used as a treatment method on its own or as a useful step before or after other treatments in integrated water treatment systems. In industrial settings like textile, pharmaceutical, petrochemical, and food processing wastewater, which usually has a lot of pollutants and a lot of different types of materials, EO is a strong option that can work with different types of input and different sizes of operations.

In terms of stability, electro-oxidation helps make cleaned wastewater safer for the environment over the long term by reducing the chance of recontamination or bacterial growth. In situations where cleaned wastewater is put back into natural systems or used again for farming and industry, this is especially important. The burning process gets rid of harmful organisms and any leftover organic matter that could be used by microbes to grow. Unfortunately, electro-oxidation is still hard to use in real life, even though it has many benefits. These include the need for a lot of energy, the high cost of electrode materials, and problems with scaling up. But recent improvements in electrode design, mixed reactor designs, the use of green energy, and process optimization are slowly getting around these problems. Combining EO with other treatment methods like electrocoagulation, membrane filtering, and biological treatment is also being looked into as a way to make the whole process more efficient and save money. Electro-oxidation is a strong and flexible technology that can make a big difference in improving the quality of wastewater and making sure that cleaned effluents stay stable. By making it easier for stubborn toxins to break down and improving the physical, chemical, and biological qualities of wastewater, EO is a forward-looking way to handle water resources in a time when environmental worries and government regulations are growing. As the field grows, it will likely be used in more situations and work better. This will make it an important part of long-term plans for treating garbage.

II.REVIEW OF LITERATURE

Navarro, Javier et al., (2021) It is hard for biological oxidation processes (BOPs) to get rid of persistent organic pollutants (POPs) and emerging pollutants (EPs). These pollutants stay in the environment and could hurt marine ecosystems and people's health. The electro-oxidation (EO) method has been used successfully as an alternative way to break down many of the toxins listed above in wastewater. The EO method has been attacked, though, because it uses a lot of energy and might make waste goods. In order to get around these problems, combining it with organic oxidation processes have been suggested as a way to cut costs and get rid of a lot of pollutants in wastewater quickly. So, where the EO is placed in the treatment line is a crucial choice that needs to be made because it impacts the creation of by-products and the improvement of biodegradability. This essay talks about the pros and cons of using EO before and after treatment along with BOPs. There is also a look at the EO scale-up, where hydrodynamics and the link between A/V (area of the electrode/working volume of the electrochemical cell) studies are looked at and talked about.

Ungureanu, Nicoleta et al., (2020) after being properly treated wastewater can be used again by farmers in dry and semi-dry places because it includes nutrients that plants need. Electro oxidation is a technology that is used to clean up wastewater from homes, businesses, and zoos. It is safe for the environment. In electro oxidation, organic chemicals are oxidized where the anode meets the water solution. This happens because of a reduction process at the cathode. A cow farm's pond wastewater was used in tests, which were done in an electro oxidation cell with stainless steel electrodes. Researchers looked into how to get rid of pH, conductivity, turbidity, color, total N, total P, COD, and BOD at different volts (0.025 V cm {^{2}, 0.05 V cm {^{2}, and 0.1 V cm {^{2}) and for different amounts of time (15, 30, and 120 minutes). It was found that electro oxidation can lower total N by 24%, total P by 47%, BOD by 47%, and COD by 82%. When the tests were over, the solids that were floating in the water were pushed toward the anode area by the coagulant Fe 2+/Fe3+ ions that were made when the anode broke down. This made the water clearer. If the wastewater meets the standards, it can be used again to water plants that can handle salty soils.

Ardhianto, Rachmad & Bagastyo, Arseto. (2019). Pharmaceuticals and personal care products (PPCPs) are found in personal care wastes. The chemicals were in organic pollution that need to be cleaned up before the water can be released. Electrochemical methods, including electro-coagulation and electro-oxidation, were used to get rid of things in trash that don't break down naturally. Using aluminum electrodes as the anode and cathode in electrocoagulation as a pretreatment. Using Ti/Pt and Ti/IrO2 as anode electrodes for electro oxidation and changing the current by 0.6 A, 0.7 A, 0.8 A, and 1 A. Using aluminum plates to remove COD and TSS works well in electrocoagulation. Aluminum electrodes get rid of 76.1% (5.41 g) of COD and 90.3% (6.10 g) of TSS. When the pH is set to 4.8 to 4.9, the aluminum electrode does not change the pH. When aluminum electrocoagulation wastewater COD was treated with Ti/Pt and Ti/IrO2, the removal rates were 34.30% (1.55 g) and 39.71% (1.80 g). When using Ti/IrO2, increasing the current makes the COD reduction rate work better than when using Ti/Pt. It took 1.0 A to get rid of 34.30% of COD (2,3 Ah/L; 1,5 g) with Ti/Pt and 39.71% (2,3 Ah/L; 1,80 g) with Ti/IrO2 compared to 0.6 A (1,4 Ah/L), 0.7 A (1,6 Ah/L), and 0.8 A (1,9 Ah/L).

Tien, Tran & Luu, Tran. (2019). Tannery wastewater is known to have a lot of harmful chemical and organic substances, including heavy metals, nitrogen, sulfur, and bacteria. Biological methods like aerobic and anaerobic processes can't handle the high salt content of tannery wastewater. Electrochemical oxidation looks like a good way to solve this issue. The study looked at how to clean up raw tannery wastewater using DSA® Ti/ RuO_2, Ti/IrO_2, and Ti/BDD electrodes in systems with constant flow. Researchers looked into the effects of different current levels and electrolysis times to figure out how well the process worked and how much energy it used. The findings showed that a Ti/BDD electrode can treat more effectively than Ti/IrO_2 and Ti/RuO_2 electrodes in all areas except Total Nitrogen. When tanning wastewater is put on a Ti/BDD electrode, it oxidizes directly on the electrode surface and makes oxidants like oOH and Cl_2. On the other hand, when it is put on a DSA® Ti/RuO_2 or Ti/IrO_2 electrode, it oxidizes by making chlorine. After 6 to 12 hours of electrolysis, the effluents can be released into the environment. Electro oxidation is a potential way to get rid of the nutrients and chemical compounds that don't break down in tannery wastewater.

Särkkä, Heikki et al., (2015) Every day, industrial processes make huge amounts of dangerous waste water. Standard methods of cleaning, like biological methods (aerobic and anaerobic treatment) and chemical coagulation are often used to clean wastewater. Ultrafiltration, ozonation, adsorption, and UV light decontamination are some of the tertiary treatment methods that have also been looked at. However, these methods can't get rid of all the dangerous chemicals and infectious bacteria in wastewater. So, new methods should be created that can be used with these techniques to make the cleaning work better.

Woisetschläger, D et al., (2013) the use of boron-doped diamond (BDD) anodes in electrochemical oxidation creates a very effective oxidizing environment by creating hydroxyl radicals. This effectively cleans water by getting rid of lingering pollution. This project looks into how fast organic and artificial things break down. Synthetic and industrial wastewaters were used in lab and small scale experiments. Performance was measured by how much total organic carbon/chemical oxygen demand (COD) was removed, how much specific energy was used, and how well the current flowed. This advanced oxidation technology along with more traditional technologies was then used in a landfill leachate wastewater treatment idea. The low metabolic oxygen demand/ COD ratio raw leachate was electrochemically oxidized to clean it up so it could be dumped into a sewer or a body of water. The estimate of operation and capital costs looks at the economics of treating highly dirty waste water.

Anglada, Ángela et al., (2009) this article talks about some basic ideas of electrolytic oxidation and gives up-to-date details on how this technology can be used to clean wastewater. Electrochemical oxidation has become more popular recently because it is so good at getting rid of many of the pollutants that are usually found in wastewater, such as refractory organic matter, nitrogen species, and bacteria. Electrochemical oxidation can be used to meet the strict limits on waste and health quality standards set by law. But the prices of care need to go down before this technology can be used on a large scale. Two steps in the right way are using electrochemical oxidation with other technologies and getting power for this process from clean sources. This technology has been used to clean up a lot of different kinds of industrial waste, including waste from the food industry, the chemical industry, the textile industry, the tannery industry, and landfills. Because it works very well and can kill germs, electro-oxidation is a good tool for programs that recover water.

III.MATERIAL AND METHODS

A funnel, a measure cylinder, wooden sticks, wires, filter papers, beakers, a big tank, and test tubes were some of the things that were used in this study. The sample of sewage was taken from the Nandesari Area sewage treatment plant's entrance chamber and put in a container to be treated further. pH and COD were the factors that were watched during the process. Using stainless steel plates and mild steel plates as anodes, the sewer water was put under different voltages (75A, 150A, and 200A) for different amounts of time. Three samples of each voltage were taken after treatment, and the parameters were found. 0.1N FAS, normal potassium dichromate (K2Cr2O7), and ferroin indicator solution were some of the chemicals used in the COD process. It was made by mixing 39.2 grams of Fe (NH4)2(SO4)2.6H2O with pure water, adding 20 milliliters of concentrated H2SO4, letting the solution cool, and then adding 1000 milliliters of water to thin it out. It was possible to make standard potassium dichromate by mixing 4.903g of main standard grade K2Cr2O7 that had been dried at 150°C for two hours with 167ml of concentrated H2SO4 and 33.3g of HgSO4 in about 500ml of pure water. After the whole thing was dissolved and cooled to room temperature, it was diluted to 1000ml. A ferroin indicator solution was also made. This shows when the oxidation-reduction potential of the solution changes and when the dichromate reduction by ferrous ions is complete.

IV.RESULTS AND DISCUSSIONS

Using different amperes (75A, 150A, and 200A) to electro-oxidize sewage wastewater and lower the amounts of physical and chemical toxins were part of the experiment. The sample size was about 1.5L, and plates made of mild steel were used for the other tests and stainless steel plates were used for the 75A, 150A, and 200A tests. There was a 5-minute break between each test.

All of the tests showed that the pH of the wastewater rose over time, and about 5 to 10 minutes later, groups began to form. The groups were a dark brown color, and the amount of sludge they made went from 70ml/L to 140ml/L. In the tests with stainless steel plates, the drop in chemical oxygen demand (COD) was good enough, but not so good in the tests with mild steel plates. Tables 1 through 6 show the data in the form of graphs. It's important to remember that using more energy is not a good idea since the water quality measurements were similar between tests. So that the temperature doesn't rise as the electric current strength does, the right conditions should be set for treating garbage. Overall, electro-oxidation has shown promise as a way to clean up wastewater, and it can work even better when combined with other cleaning methods.

Table 1: Variation in pH, COD Levels, and COD Reduction Percentage over Time during Wastewater Treatment at voltage 75A on stainless steel plates

Sample	pH	COD (mg/L)	% COD Reduction
Raw	7.21	441	
0:05:00	7.89	152	65.5%
0:10:00	8.21	102	76.9%
0:15:00	8.26	78	82.3%

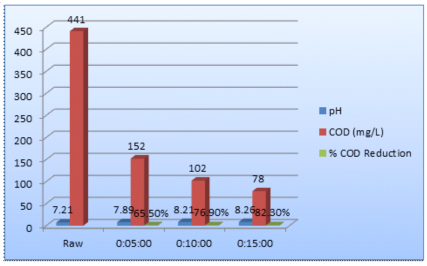

Figure 1: Graph showing Variation in pH, COD Levels, and COD Reduction Percentage over Time during Wastewater Treatment at voltage 75A on stainless steel plates

Table 1 shows that wastewater treatment at 75A using stainless steel plates results in a significant and rapid reduction in COD levels, with a drop from 441 mg/L to 78 mg/L over 15 minutes—an overall COD reduction of 82.3%. The pH increased steadily from 7.21 to 8.26, indicating a shift towards alkalinity likely due to electrochemical reactions. This suggests that stainless steel electrodes at 75A are highly effective for organic pollutant removal in a short time; showing superior performance compared to mild stainless steel plates.

Table 2: Variation in pH, COD Levels, and COD Reduction Percentage over Time during Wastewater Treatment at voltage 150A on stainless steel plates

Sample	pH	COD (mg/L)	% COD Reduction
Raw	7.0	446	
0:05:00	7.8	266	40.4%
0:10:00	8.21	203	54.5%
0:15:00	8.24	104	76.7%

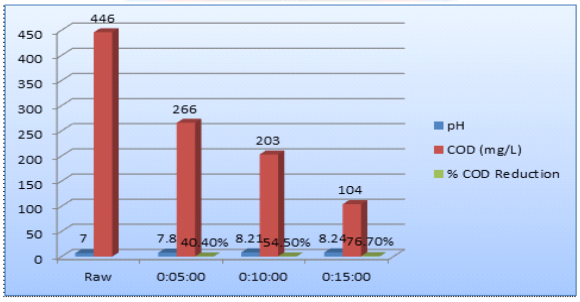

Figure 2: Graph showing Variation in pH, COD Levels, and COD Reduction Percentage over Time during Wastewater Treatment at voltage 150A on stainless steel plates

Table 2 indicates that wastewater treatment at 150A using stainless steel plates leads to a substantial reduction in COD levels from 446 mg/L to 104 mg/L over 15 minutes, achieving a 76.7% COD reduction. The pH increased from a neutral 7.0 to 8.24, indicating a shift towards alkaline conditions due to electrochemical activity. While slightly less efficient than the 75A treatment in Table 1, this setup still demonstrates strong treatment performance, particularly after 10 minutes, making it a viable option for effective pollutant removal.

Table 3: Variation in pH, COD Levels, and COD Reduction Percentage over Time during Wastewater Treatment at voltage 200A on stainless steel plates

Sample	pH	COD (mg/L)	% COD Reduction
Raw	7.30	450	
0:05:00	8.01	238	47.1%
0:10:00	8.15	201	55.3%
0:15:00	8.40	119	73.6%

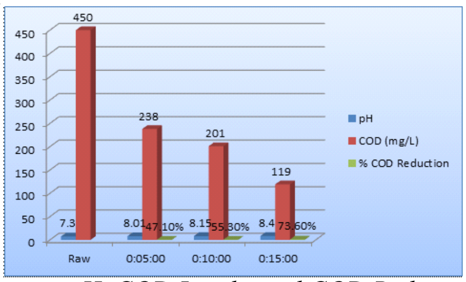

Figure 3: Graph showing variation in pH, COD Levels, and COD Reduction Percentage over Time during Wastewater Treatment at voltage 200A on stainless steel plates

Table 3 shows that at 200A using stainless steel plates, wastewater treatment results in a notable COD reduction from 450 mg/L to 119 mg/L within 15 minutes, achieving a 73.6% reduction. The pH rises steadily from 7.30 to 8.40, indicating increasing alkalinity due to electrochemical reactions. Although effective, the COD removal efficiency is slightly lower than at 75A (Table 1) and comparable to 150A (Table 2), suggesting that increasing voltage beyond 150A does not significantly enhance performance and may approach a saturation point in short-duration treatment.

Table 4: variation in pH, COD Levels, and COD Reduction Percentage over Time during Wastewater Treatment at voltage 75A on mild stainless steel plates

Sample	pH	COD (mg/L)	% COD Reduction
Raw	7.28	446	--
0:05:00	7.85	315	29.4%
0:10:00	7.80	277	37.9%
0:15:00	7.51	232	48.0%

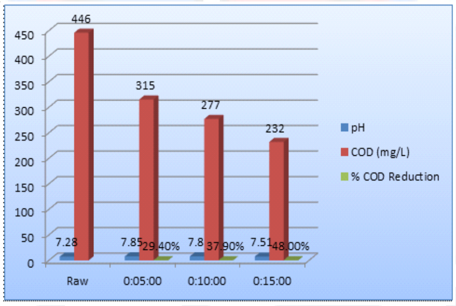

Figure 4: Graph showing variation in pH, COD Levels, and COD Reduction Percentage over Time during Wastewater Treatment at voltage 75A on mild stainless steel plates

At 75A voltage using mild stainless steel plates, the wastewater treatment showed a steady increase in pH from 7.28 to around 7.8 initially, then slightly decreased to 7.51 after 15 minutes. COD levels dropped significantly from 446 mg/L to 232 mg/L, achieving a 48% reduction in just 15 minutes. This indicates effective removal of organic pollutants and good treatment performance at this voltage within a short time frame..

Table 5: variation in pH, COD Levels, and COD Reduction Percentage over Time during Wastewater Treatment at voltage 150A on mild stainless steel plates

Sample	pH	COD (mg/L)	% COD Reduction
Raw	7.31	447	--
0:05:00	7.70	372	16.8%
0:10:00	7.59	335	25.1%
0:15:00	7.29	319	28.6%

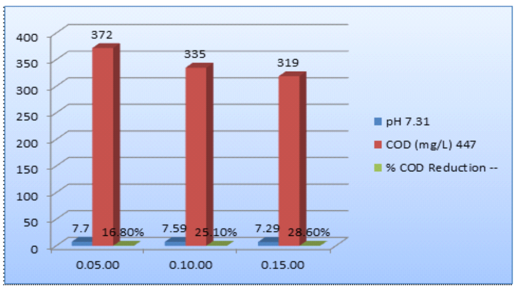

Figure 5 Graph showing variation in pH, COD Levels, and COD Reduction Percentage over Time during Wastewater Treatment at voltage 150A on mild stainless steel plates

Table 5 reveals that wastewater treatment at 150A using mild stainless steel plates results in only a modest COD reduction—from 447 mg/L to 319 mg/L over 15 minutes, corresponding to a 28.6% decrease. The pH initially increases slightly from 7.31 to 7.70 at 5 minutes, then gradually drops back to near-neutral levels. Compared to stainless steel plates at the same voltage, the treatment efficiency is significantly lower, indicating that mild stainless steel is less effective for COD removal under these conditions.

Table 6: variation in pH, COD Levels, and COD Reduction Percentage over Time during Wastewater Treatment at voltage 200A

Sample	pH	COD (mg/L)	% COD Reduction
Raw	7.28	445	--
0:05:00	7.65	335	24.7%
0:10:00	7.52	322	27.6%
0:15:00	7.32	309	30.6%

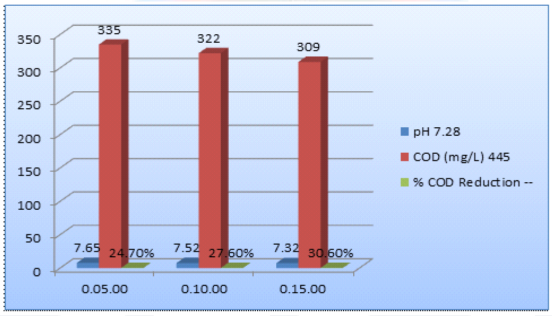

Figure 6- Graph showing variation in pH, COD Levels, and COD Reduction Percentage over Time during Wastewater Treatment at voltage 200A

Table 6 shows that at 200A using mild stainless steel plates, wastewater treatment yields only a gradual reduction in COD levels—from 445 mg/L to 309 mg/L over 15 minutes—resulting in a 30.6% COD reduction. The pH initially rises from 7.28 to 7.65 at 5 minutes, then slowly decreases to 7.32 by 15 minutes. Compared to stainless steel plates at the same voltage, the treatment efficiency is significantly lower, indicating that mild stainless steel is less effective in promoting COD removal at higher voltages.

CONCLUSION

Electro-oxidation has become a very good and long-lasting improved oxidation method for improving the quality and safety of wastewater. This method breaks down a lot of stubborn organic and metal pollution very well by using electrically produced reactive species, especially hydroxyl radicals. Key water quality factors like chemical oxygen demand (COD), biological oxygen demand (BOD), total organic carbon (TOC), turbidity, and microbial content all go down when electro-oxidation is used. This helps protect the environment and people's health in a big way. In addition, the process makes wastewater more stable and biodegradable, which means it, can be treated biologically or safely released into the environment. Several operating factors, such as electrode type, current rate, and buffer present, affect how well electro-oxidation works. All of these factors must be optimized to get the best treatment results. Even though problems like electrode decay and energy use still exist, new technologies and materials are working to solve these problems. As pollution and a lack of clean water become bigger problems around the world, using electro-oxidation in wastewater treatment systems is a smart way to deal with them.

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