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RESEARCH ARTICLE

COD REMOVAL FROM MUNICIPAL WASTEWATER USING ELECTROCOAGULATION BY DIFFERENT AL/FE ELECTRODES

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Abstract

In the present study different combinations of Al and Fe electrodes are used for improving the treatment efficiency in the electrocoagulation (EC) process to purify the domestic wastewater. Various factors are to be studied for the assessment of the COD removal efficiency in the form of pH (3–9), time (10–60 min), and density of current (9.0–40 A/m²). Depending on the influencing factor Al–Al and Fe–Fe able to minimize COD percentage up to 85.0 % and 90% respectively. Similarly 86.0 % and 87.50 % of COD were removed, when aluminium and iron were combined as Al–Fe and Fe–Al respectively. Further, the operating parameters were investigated on the removal of COD. The present study reported that, the combination of electrodes affects greatly on the efficiency of percentage removal of COD using the EC technique.

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Introduction:-

Due to manmade activities and industrialization, wastewater is the prime source of degrading environment and leads to the pollution which changes the biological ecological condition when directly discharged into nature without any treatment (Nemade et al., 2021a; Nemade et al., 2010). Developing countries create major changes and enormous threats to the whole of mankind due to the lack of inadequate water supply, improper sanitation, and hygiene-related to water contamination with wastewater (Wagh and Nemade, 2017). Municipal and domestic wastewater waste water contains various contaminants like kitchen, bath, dishwashers, medicines, liquid etc. pollutants which disturb the ecosystem and pollutes the quality of water (Nemade et al., 2021b; Okadera et al., 2020) and also, some technology used to treat and environment friendly with soil biotechnology such as constructed soil filter (Nemade et al., 2010).

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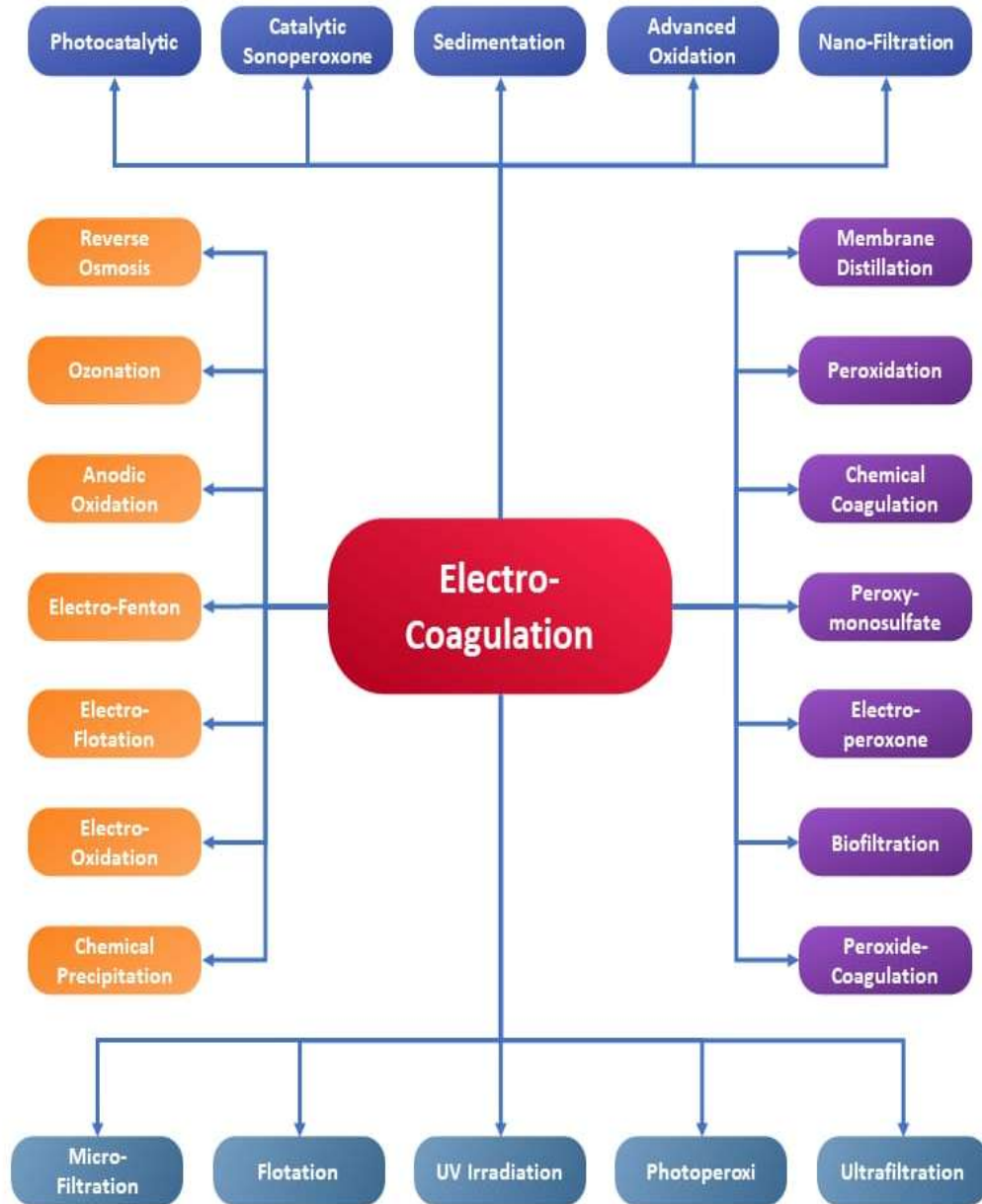
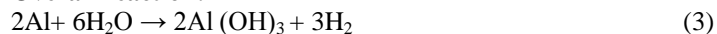


Figure 1:- Combination of technologies which can be attached with electrocoagulation.

Electrocoagulation (EC) is system where metal electrodes generates the metal ions in situ at sacrificial anode with the help of electric current which produces Nano scale particles or coagulants that converts and destabilizes ions and entraps enforcing them to conglomerate to form flocs and precipitate and removes the pollutants from wastewater. (Ebba et al., 2021; Nemade et al., 2021c). The EC process was a system with other appurtenances and increase the movement of suspended and colloidal particles/pollutants with the help of gases bubbles caused at cathode and anode when electric current was applied to wastewater (Wagh and Nemade, 2018; Qi et al., 2020).

Many researchers recommended that EC is the best technology applied for water and wastewater treatment due to its economic and environment friendly, the high removal efficiency of arsenic and fluoride (Nemade et al., 2007; 2021b; 2021c), high energy efficiency and cost effective (Nagarajappa and Impa, 2015) escaping the usage of chemicals. Also, the EC is an effective process for removal of pollutants from wastewater; medical (Dehghani et al., 2014), domestic (Nagarajappa and Impa, 2015), dairy wastewater (Chezeau et al., 2019). According to (Dermentzis, 2016), the anodic and cathodic reactions is formed for Aluminium and Iron electrodes respectively look like as follows;

Anode reaction for Aluminium:**Cathode reaction for Aluminium:****Overall reaction:****Anode reaction for Iron:****Cathode reaction for Iron:****Overall reaction:**

The generated Aluminum hydroxide from Al^{3+} and OH^- and Iron Hydroxide Fe^{2+} and OH^- ions were used as a coagulant for destabilizing the pollutants from wastewater. Amorphous metallic hydroxide precipitates are shaped through these coagulants. They have an excellent affinity for dispersed particles and dissolved contaminants due to their superior adsorption properties. Coagulation can then separate the contaminants from the aqueous phase. The voids produced from the hydrogen at the cathode make significant turbulence in the process and bond with contaminants, decreasing their relative weight. As a result, they improve the flotation separation process (An et al., 2016). Electrocoagulation was once chosen for the remedy of domestic wastewater due to the fact it is an easy manner superior form, has greater elimination effectivity with much less power consumption, does not require the use of chemical compounds in the cure process, and produces much less sludge after treatment. In this study, the elimination proportion of COD was once decided underneath the consideration of pH, current density (A/m^2), and electrolysis time (minutes) using the electrocoagulation process. This was once investigated with the aid of arranging electrodes as Al–Al, Fe–Fe, Al–Fe, and Fe–Al.

Materials And Methods:-**Materials:-**

Locally available domestic wastewater was collected from Pune city area, Maharashtra, India. Wastewater is characterized by a pH of 6.1–9.1, temperature 21–29.5°C, and electrical conductivity of 925–1600 $\mu\text{S}/\text{cm}$. The digital pH meter, reactor for COD, wires of copper, clips, magnetic stirrer, DC power supply, EC cell, electrodes of Iron and Aluminium which are purchased from Pune, India with make TATA steel with 92% purity standards used for the present study.

Methods:-

The laboratory setup for the EC reactor and process is shown in Figure 1. The electrodes of Iron and Aluminum were used in the present study due to cost-effective and easily available in the local market having weights of 32g and 47g with dimensions of 60mm, 120mm, and 9mm length, width, and thickness respectively. A domestic wastewater sample was collected from the local area of Pune city and added to the EC cell and kept on the magnetic stirrer. The literature reported the 1cm spacing between anode and cathode for all numbers of experimental trials. The electrode plates were connected to DC power supply and submerged into the EC cell. Further, the power was supplied to EC cell with fixed reaction time and varying parameters, the experimental study was carried out for the evaluating the removal of COD percentage for various combinations of electrodes such as Al–Al, Fe–Fe, Al–Fe, and Fe–Al.

Analysis

With various combinations electrodes like Al–Al, Fe–Fe, Al–Fe, and Fe–Al the removal efficiency of COD was evaluated by considering density of current, pH, and reaction time. The percentage removal of COD (Hamada et al., 2018) was determined according to the following formula shown in Eq. (7).

$$\text{COD} (\%) = [\text{COD}_0 - \text{COD}_T] / \text{COD}_0 \times 100 \quad (7)$$

Where, COD_0 = initial chemical oxygen demand at time =0
 and COD_t = final chemical oxygen demand at time =t

Results And Discussion:-

Removal efficiency of COD

The share elimination effectivity of Chemical Oxygen Demand (COD) used to be decided for the electrode mixtures of Al-Al, Fe-Fe, Al-Fe, and Fe-Al. This used to be executed by using fixing the parameters such as pH, current density, and electrolysis time such that they have their influences on the elimination effectivity of COD.

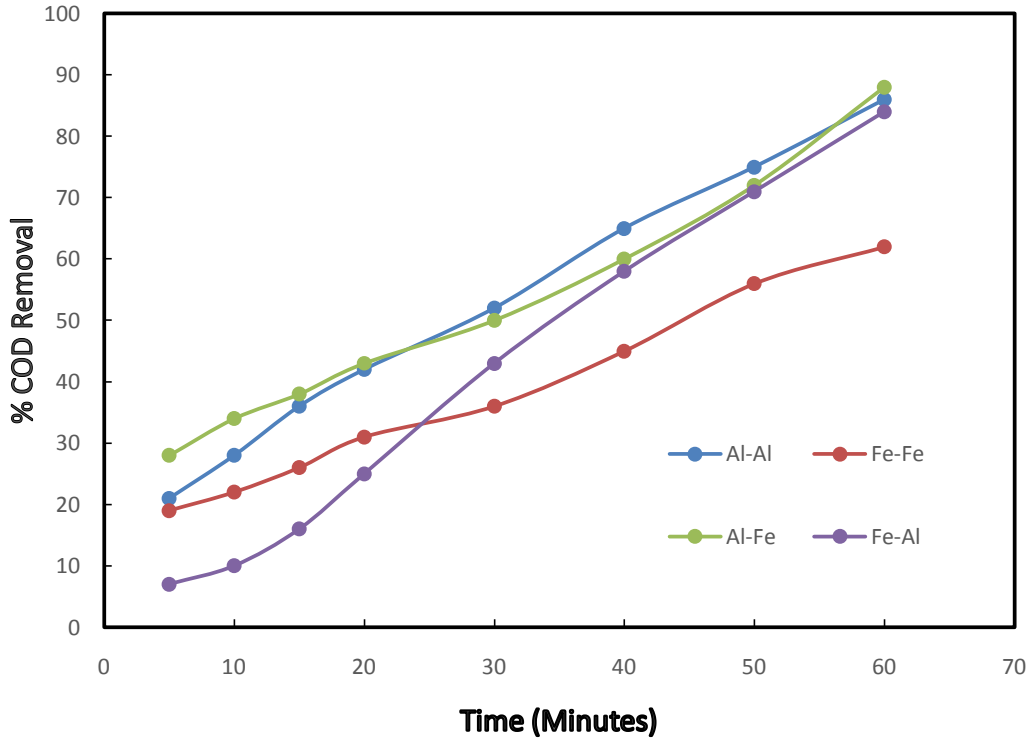


Figure 2:- Removal efficiency of COD at pH (6), and current density (20 A/m²).

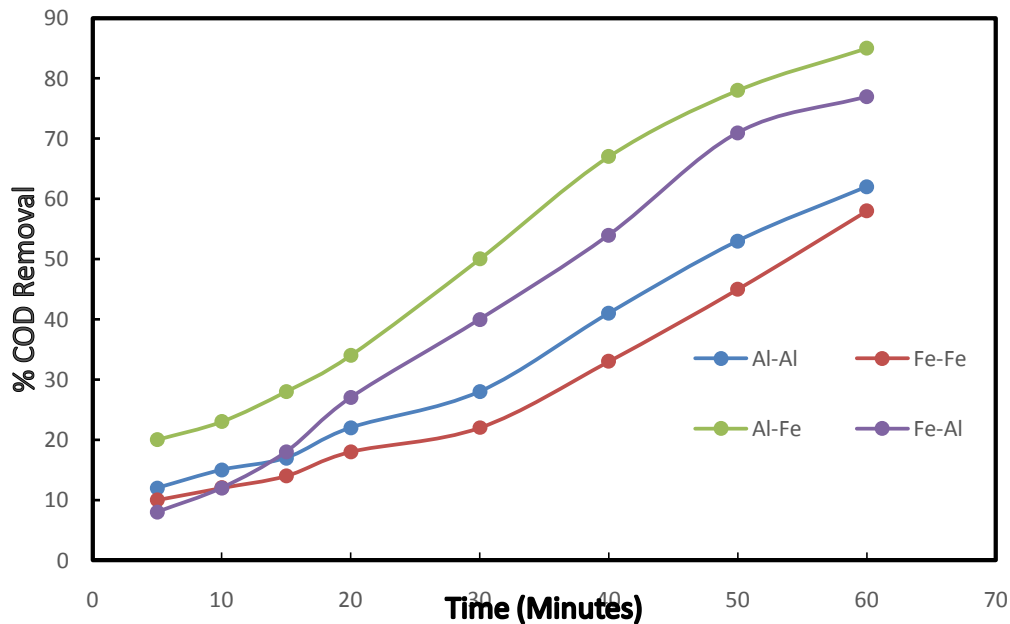


Figure 3:- Removal efficiency of COD at pH (3), and current density (9.23 A/m²).

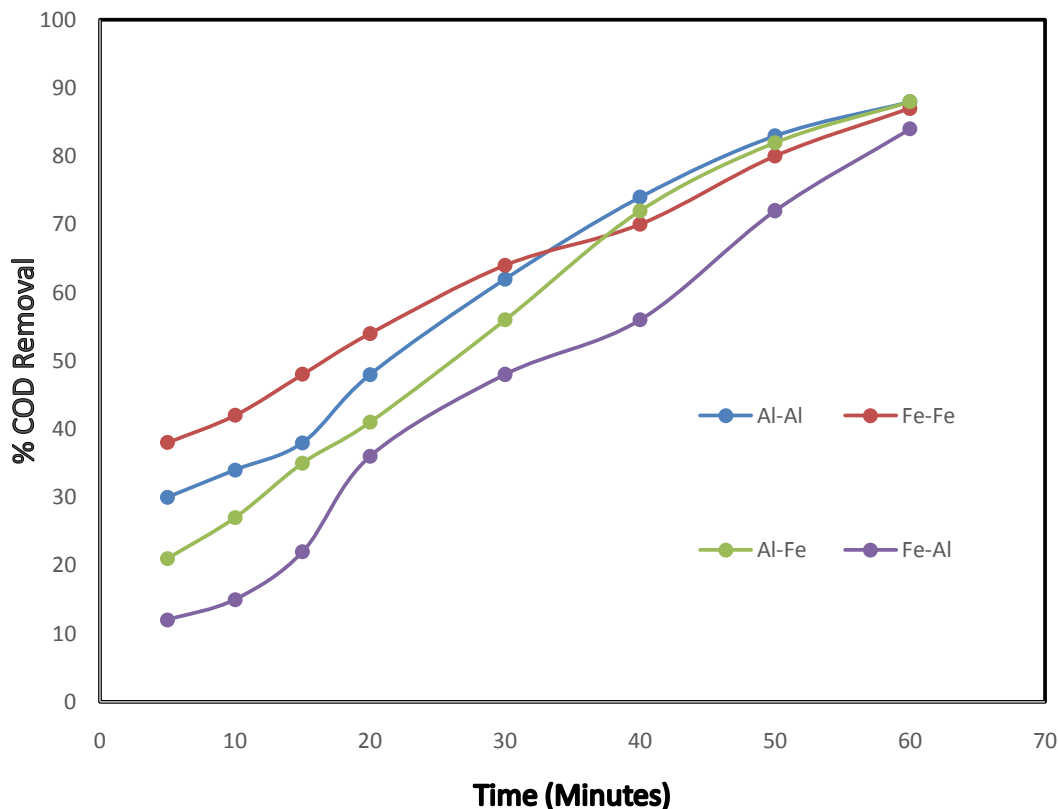


Figure 4:- Removal efficiency of COD at pH (9), and current density (45 A/m^2).

Al–Al (anode-cathode/cathode-anode)

The removing effectiveness of COD was once measured all through the Al–Al combination. When the pH was 3 and the current density used to be 9.23 A/m^2 , chemical oxygen demand (COD) used to be eliminated to the most of 61.54% at the response time of 60 min Figure 2 additionally suggests the elimination percentages of COD in 15, 30, and 45 min have been 15.38%, 23.08%, and 38.46% respectively. In Figure 3, the elimination share of COD used to be 25%, 37.5 %, 50 %, and 62.5% in 15, 30, 45, and 60 min respectively, when pH used to be 6, and current density used to be 20 A/m^2 . Similarly, when the pH was 9 and the current density used to be 45 A/m^2 , the most elimination effectivity of COD used to be 87.5% when the response time was once 60 min which is proven in Figure 4. This shows that the elimination effectivity of COD was once accelerated through growing pH, response time, and current density the usage of the electrocoagulation system for domestic wastewater.

Fe–Fe (anode-cathode/cathode-anode)

This was also another electrode combination method used to test COD elimination effectiveness. In Figure 3, keeping the pH was 3, and current density was 9.23 A/m^2 good removal efficiency of COD was evaluated such that it can be removed up to 63.33% when the reaction time was 60 min. Similarly, around 18.18, 27.27, and 45.45 % of COD removal were achieved in 15, 30, and 45 min respectively. Increasing the electrolysis time resulted in a high removal percentage of COD by keeping the pH was 6, and current density (20 A/m^2) which was indicated in Figure 4. This indicates good progress of COD removal percentages such that 33.33, 50, 66.67, and 83.33 % removal was achieved in 15, 30, 45, and 60 min respectively which are shown in Figure 3. On the other hand, when pH was 9, and current density was (45 A/m^2), the removal degree of COD was 40, 60, 80, and 90% in 15, 30, 45, and 60 min respectively which has shown in Figure 4. In Fe–Fe, good removal percentage of COD was achieved by increasing the reaction time by keeping other factors constant at the different number of experimental investigations.

Al–Fe (anode-cathode)

This used to be additionally every other electrode aggregate technique used to check COD removal effectiveness. In Figure 3, retaining the pH was once 3, and current density was once 9.23 A/m^2 proper elimination effectivity of

COD used to be evaluated such that it can be eliminated up to 63.33% when the response time used to be 60 min. Similarly, round 18.18, 27.27, and 45.45 % of COD elimination had been completed in 15, 30, and 45 min respectively. Increasing the electrolysis reaction time resulted in a excessive elimination proportion of COD by using preserving the pH was 6, and density of current (20A/m^2) which used to be indicated in Figure 4. This shows exact development of COD elimination percentages such that 33.33, 50, 66.67, and 83.33 % elimination used to be finished in 15, 30, 45, and 60 min respectively, which are proven in Figure 3. On the different hand, when pH was 9, and current density used to be (45A/m^2), the elimination of COD used to be 40, 60, 80, and 90% in 15, 30, 45, and 60 min respectively, which has proven in Figure 4. In Fe–Fe, proper elimination share of COD was once completed with the aid of growing the response time through preserving different elements steady at the unique range of experimental investigations.

Fe–Al (anode-cathode)

The mixture of Iron and Aluminum, Fe–Al the elimination effectivity used to be effective, particularly when the pH was 9, and the current density was 45A/m^2 , 33.33, 55.56, 77.78, and 88.89 percent of COD was once eliminated at the response time of 15, 30, 45 and 60 min respectively that proven in Figure 4. In addition to this, the proportion elimination of COD from domestic wastewater for Fe–Al (Anode-Cathode) used to be proven in Figures 2 and 3 when pH used to be 3, 6, and 9 for each figures one after the other at extraordinary response times. As shown in Figures 2, 3, and 4 the elimination proportion of COD used to be extended steadily from 28.57 to 88.89% as a pH enlarge (3–9), response time from (15–60 min), and modern density from ($9.23\text{--}45\text{A/m}^2$). Moreover, preserving regular the cost of contemporary density and response time, when the pH used to be 3 and 6, Fe–Al used to be extra positive than different combinations, and additionally when pH was 9, Fe–Fe was once the fine positive in contrast to others. Generally, via what structure Aluminum and Iron have been blended the elimination effectivity of COD used to be accelerated when the pH, modern density, 0 and response time increased.

Effects of pH on COD removal

One element that affects COD elimination effectiveness from wastewater is pH. Since there was a variation of wastewater pH, it was adjusted to acidic, basic, or impartial condition based at the favored level the usage of sulphuric acid or sodium hydroxide. On this look at pH of wastewater changed into adjusted to 3, 6, and 9 that have been proven in Figures 2, 3, and 4 respectively. Because the price of pH value of the wastewater sample increased from 3-6 and 6-9, the elimination diploma of COD became stronger at the same time as wastewater was gone through an electrocoagulation process for distinct electrode combinations below the equal operating parameters. This is due to the fact the increase in pH during the electrocoagulation procedure seems to be broadly speaking because of the speedy evolution of hydrogen gas on the cathode, and the attention of hydroxyl ions in the answer will increase as a result of electrochemical tactics that lead to high percentage elimination (Ebba et al., 2021). An expansion of metallic hydroxide species are shaped in electrocoagulation treatments depending on the pattern pH, and the steadiness of insoluble hydroxides are in addition regulated with the aid of pattern acidity and basicity (Bener et al., 2019; Niazmand et al., 2019).

Effects of current density on COD removal

The current density is an electric modern implemented in keeping with an effective area of electrode for electrocoagulation. It is a vital parameter in electrocoagulation as it regulates the scale and increase of the flocs, which affects removal prices and quantity of metal ion dissolved from sacrificial electrodes, ensuing in a huge quantity of precipitate for the elimination of pollutants from wastewater (Mohamud et al., 2018). As proven in Figures 2, 3, and 4 current density become 9.23A/m^2 , 20A/m^2 , and 45A/m^2 respectively. This indicates increasing the current density as an operating parameter, increases the elimination percent of electrocoagulation. The current density glide makes a decision the coagulant produced from the anode, that is recognized with the complete electric rate going through the terminal, as characterized by Faraday's standards of electrolysis (Mohamud et al., 2018). Therefore, the current density accelerated, and extra coagulant was made to weaken colloidal particles, bringing approximately more quickens that settled efficiently within the electrocoagulation mobile (Mohamud et al., 2018).

Effects of reaction time on COD removal

The electrolysis time is an important metric in Electrocoagulation since it dictates how long water wishes to be dealt with to fulfill the specified criteria. As shown in Figures 2, 3, and 4, the reaction time of wastewater in electrocoagulation became 15, 30, 45, and 60 min. At 15 min, sure COD elimination became achieved and because the time development from 15 to 30 better COD was achieved in all electrode combinations despite the fact that

there may be a sure degree of version. Similarly, whilst the reaction time became superior to 45 and 60 min, an excessive degree of COD elimination was done which shows as pH increases the COD elimination become extended which was shown in Figures 2, 3, and 4. Anodic electro-dissolution causes the discharge of coagulant species all through electrolysis. Furthermore, the effectiveness with which pollution are removed is immediately proportional to the attention of metallic ions shaped on the electrodes. The attention of metal ions and related hydroxide flocs increases as the electrolysis time will increase (Niazmand et al., 2019). The formation of adequate portions of various ions from electrodes, which can be required for the era of adsorbents, together with $\text{Al}(\text{OH})_3$ or $\text{Fe}(\text{OH})_3$ inside the case of aluminium or Iron electrodes, in addition to the discharging of gases bubbles from both electrodes, which can be essentially provided with greater help to carry the destabilized pollution closer to the surface of the solution, is dependent on electrolysis time (Yasir et al.,2020).

Effects of electrode type and combination on COD removal

As within the EC process overall performance of the machine is suffering from the electrode fabric, particularly the anode, which determines the kind of cations launched into the aqueous shape. Due to the fact there was a few disagreement over the anode's dissolving mechanism, it become vital to analyze the effect of the anode material on the extent of electrocoagulation (El-Ashtoukhy et al., 2020). For special electrode substances, unique reactions arise, and the houses of the metallic hydroxides generated at some stage in the reactions are critical for the electrocoagulation manner' efficiency (Bener et al., 2019). In electrocoagulation, one of a kind material is used as electrodes. In electrocoagulation, several metal materials were utilized because the sacrificial electrode or anode. Al, Ag, As, Ba, Ca, Cd, Cr, Cs, Fe, Mg, Na, Si, Sr, and Zn are a number of these materials.

Iron inside the shape of moderate metal (MS) or stainless steel (SS), aluminium (Al), zinc (Zn), copper (Cu), and magnesium are the most usually applied steel electrode substances (Mg) (Al-Qodah and Al-Shannag, 2017). Many chemical and physical properties of these elements fluctuate, along with oxidation capacity, ion size and price, migration pace in answer, the polarity of the ion-OH connection, and hydroxide compound structure and length (Al-Qodah and Al-Shannag, 2017). Al and Fe had been used as an electrode due to low cost and locally available and the use of Fe as electrodes is higher than Al as the electrode for the elimination of COD. Electrodes manufactured from aluminium and iron plates in numerous mixtures Al–Al, Fe–Fe, Al–Fe, and Fe–Al had been used to investigating the electrocoagulation technique's talent as shown in Figures 2, 3, and 4. Even as Al–Al, Fe–Fe, Al–Fe, and Fe–Al mixed COD elimination performance carried out became 87.5, 90, 87.5, and 88.89 % respectively.

Conclusion:-

From the above take a look at, the electrocoagulation system is a tested generation for the elimination of COD from domestic wastewater using aluminum and iron electrodes with numerous mixtures either at anode or cathode. This changed into executed by combining aluminum and iron electrodes as cited thinking about diverse operating parameters consisting of pH, current density, and electrolysis time. Growing the pH(3–9), current density (9.23–45 A/m^2), and electrolysis time (15–60 min)resulted inside the increase of COD elimination possibilities from domestic wastewater in all electrode combos although there were variations in values. Fe–Fe mixture become the quality electrode aggregate compared to others below the same fixed working parameters for the elimination of COD (90 %) from home wastewater. Normally, various methods of aluminum and iron combination can affect the removal performance of COD from home wastewater with the aid of thinking about unique operating parameters the use of the EC manner.

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