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Removal of Sesame Oil from Artificial Wastewater Applying Fenton Process and Comparing It with Actual Wastewater

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ABSTRACT

In this research the removal of sesame oil from aritifical water by Fenton process technique was investigated. The results of removal efficiency were compared with actual wastewater. Effect of time, pH, mixing speed, temperature, oil content were investigated to find the perfect circumstances. The conducted experiments revealed that the optimal conditions for this process were 160 minutes of reaction time in an acidic medium where pH was equal to 3.5, temperature was discovered to be 25 °C, the optimal mixing speed was at 500 rpm, and the Sesame oil concentration amounted to 1500 mg/l. Applying the optimal conditions for this processing, the results of compersion showed the sesame oil had a removal efficiency of 95% for the artificial wastewater in which the concentration decreased from 12800 to 68 mg/l, while the Fenton method was used to treat an actual sample of wastewater the removal efficiency is found to be 87%.

Keywords: sesame oil, wastewater, fenton, technique, efficiency.

INTRODUCTION

The increased need to identify the solutions to existing pollutants, as inorganic, organic, and mineral chemicals have constituted considerable environmental pollution in water since the growth in human activities, sparked interest in oxidation-related research in 2002 and onwards. AOPs, which can remove recalcitrant contaminants and poisons, or be used as a pretreatment to break down complex pollutants into simpler compounds that can be removed with additional treatments are among the beneficial approaches (Gzar et al, 2020, Nasir et al, 2022). Industrial wastewater (IWW) treatment is difficult due to the enormous amount of contaminants and poisons present. The treatment of such pollutants in conventional plants require the addition of chemicals that leave residues to be treated (Nasir et al, 2021, Alhendal et al, 2020). Fenton has been investigated as one of the most advanced oxidation methods for the treatment of industrial waste water, with its efficiency verified (Garrido-cardenas and Agüera, 2020).

Vegetable oils are incredibly vital to humans, not only in the food industry, but also in the chemical, medical, and cosmetic industries, where they are used as key ingredients. It is also being employed as a source of renewable energy recently. Considering how much vegetable oil is produced and consumed globally, one can realize how critical it is to the global economy (Anilakumar et al, 2010).

Three modified Fenton procedures are heterogeneous Fenton, photoFenton, and electroFenton. (Gernjak et al., 2003). The photoFenton system is a modification of the standard Fenton system that incorporates ultraviolet light to promote photocatalytic conversion of dissolved ferric iron (Fe+) to ferrous iron (Fe^{+2}). There us also the electro-Fenton approach, which creates two Fenton detectors via electrochemical methods. (Moreira et al., 2017). Hydrolysis is another method for producing water and hydrogen peroxide (Villeneuve et al., 2009). Advanced oxidation was investigated on wastewater while AOPs were applied to secondary effluents capable of eliminating harmful wastewater products and converting them to less toxic compounds.

Ebrahim et al., (2013) studied the advanced oxidation process by Photo Fenton system to treat the wastewater that contains oil. Commercial gas oil was used to make an artificial sample.The oil concentration ranged between 500–2000 mg/l, FeCl was added between 10–100 mg/l and H_2O_2 between 100–800 mg/l, the results showed that the removal efficiency for the system equals 72%.

Vergara-Sanchez and Silva-Martinez (2010) reported the degradation of spent cooking safflower oil aqueous solution by photolysis, Fenton under solar light,the processes were carried out in a photochemical reacor with recirculation, the experimental results showed that the sole effect of the solar irradiation (photolysis) aided in decreasing 65% of COD at neutral pH in a reaction time period of 15hr.

The current study aimed to remove the sesame oil from aritifical water by the Fenton process technique and compare the result of removal efficiency with these of actual wastewater.

Table 1. Characteristics of sesame oil

Characteristic	Value
pH	4.33
Density (g/cm³)	0.95
Viscosity (cp)	1.33

MATERIALS

Pollutants

Sesame oil has a wide range of uses outside the home, including resistance to smoke and discoloration. It is often used in frying and cooking. Sesame oil has unique properties that allow it to separate water from oil. Palmitic acid, linoleic acid, stearic acid, linolenic acid, and oleic acid are found as well (Anilakumar, 2010). The characteristics of the sesame oil used are shown in Table 1.

Chemicals used

This investigation used a variety of chemicals from the sanitary laboratory that met certain criteria, as well as distilled water for dilution. The chemicals as shown in Table 2.

Fenton process (H_2O_2/Fe^{+2})

Fenton (1894) discovered the traditional Fenton technique for the oxidation of malic acid more than a century ago by interacting dissolved iron ion with hydrogen peroxide in an acidic solution, the process generates hydroxyl radicals., as in Eq. 1 and as appeared below (Wadeley and Waite, 2004, Singa et al., 2018):

$$Fe^{+2} + H_2O_2 \rightarrow Fe^{+3} + OH^- + \boldsymbol{OH^\bullet} \quad (1)$$

$$Fe^{+3} + H_2O_2 \rightarrow Fe^{+2} + \boldsymbol{OH^\bullet 2} + H^+ \quad (2)$$

$$Fe^{+2} + \cdot\,\boldsymbol{OH} \rightarrow \boldsymbol{Fe}^{+3} + OH^- \quad (3)$$

$$\boldsymbol{\cdot OH + H_2O_2 \rightarrow H_2O + HO_2^\bullet} \quad (4)$$

$$\boldsymbol{HO^\bullet{}_2 + Fe^{+3} \rightarrow Fe^{+2} + HO} \quad (5)$$

$$\boldsymbol{HO^\bullet{}_2 + Fe^{+2} + H^+ \rightarrow Fe^{+3} + H_2O_2} \quad (6)$$

Table 2. Chemicals used

Compound	Formula and vender
Sodium dodecyl sulfate	$C_{12}H_{25}Na_4S$ Biltrec (Spain)
Hydrogen peroxide	H_2O_2 Solvochem (UK)
Ferrous sulfate heptahydrate	$FeSO_4.7H_2O$ Hopkin and Williams (England)
Sodium thiosulfate	$Na_2S_2O_3$ Central Drug House (P) Ltd. (India)
Sodium hydroxide	NaOH Central Drug House (P) Ltd. (India)
Sulfuric acid	H_2SO_4 Central Drug House (P) Ltd. (India)

The interactions depicted above are only those that occur between species in Eq.(1), not the majority of other interactions that occur as a result of other species' influence or the root that results (for example, HO_2). The dissociation of H_2O_2 in the presence of a reagent, such as iron, is the net reaction in the Fenton step. in the Fenton phase, the net reaction (Umar et al, 2010):

$$\boldsymbol{Fe^{+2}} + H_2O_2 + \mathbf{2}\,\boldsymbol{H}^{+2} \rightarrow \mathbf{2}\,\boldsymbol{Fe^{+3}} + \mathbf{2}\,\boldsymbol{H2O} \quad (7)$$

This implies that the reaction takes place in an acidic environment, implying that H^+ is required for hydrogen peroxide decomposition. Iron catalyses the reactions above by switching between Fe^{+2} and Fe^{+3}. In Fenton chain reactions, the rate constant for reaction Eq. 1 is around 63 m-1s-1, while the rate constant for reaction Eq. 2 is (0.001– 0.01) m-1s-1, indicating that The rate of Fe^{+2} consumption exceeds that of Fe^{+2} production by a large margin. As a result, Fe^+ is the most prevalent iron type. When dealing with recalcitrant organic debris in wastewater, the Fenton reagent was used with outstanding results.The Fenton process results in the development of iron sludge because Fe^+ precipitates iron oxyhydroxides at higher pH (Trujillo et al., 2006).

EXPERIMENT WORK

Preparing the artificial wastewater sample

The artificial wastewater was made from a vegetable oil emulsion that was employed as a critical portion of the wastewater contaminated with sesame oil. The following steps were used to make the emulsion according to (Tony, et al., 2012):

1) A 100 ppm emulsifier was made by weighing (100 mg) sodium dodecyl sulfate ($C_{12}H_{25}Na_4S$) on an analytical balance and then mixing it into (1 l) distilled water.
2) A 5 ml of the produced emulsifier was pipette-measured and added to each litre of distilled water.
3) Using a magnetic stirrer, 100 mL of oil was gradually added to the solution that had formed.
4) Using a magnetic stirrer, the resulting mixture was mixed for 48 hours, then a little detergent was added if necessary to complete the oil-water mixing. To make the sesame oil emulsion, 6 ml Bubblegum was added.
5) The resulting oil-water emulsion was allowed to stand for 1 hour to ensure that the heterogeneous oil separated from the emulsion.
6) Quantitative filter papers were used to filter the emulsion twice.

Procedure of sesame oil removal from artificial wastewater by Fenton process technique was provided in the following steps:

1) To guarantee full mixing, the needed oil concentration was created within the range (1000–2000) mg/l with stirring for 30 minutes.
2) Prior to treatment in the reactor, H_2SO_4 or NaOH was employed to stabilize the required pH of (3.5, 7, and 10.5).
3) The magnetic stirrers mixing speed and temperature were set to be (500–1000) rpm and (25–45) °C, respectively.
4) The concentration of hydrogen peroxide H_2O_2 injected was between 500 and 2500 mg/l.
5) As a Fenton reagent, the Ferric Sulfate catalyst Fe_2SO_4.7H2O was added to the reactor solution in the range of 50 to 250 mg/l., without the use of UV-lump.
6) To stop the reaction, an excess of NaS_2NO_3 (8–13%) Ferric Sulfate was applied.
7) The removal efficiency calculated using the following formula

$$\text{Removal efficiency \%} = \\ = \frac{Conc.intial - Conc.final}{Conc.intial} \times 100,\% \quad (8)$$

RESULTS

Different variables have been investigated in order to find the ideal circumstances for maximum removal efficiency. To analyze all factors, the original concentration of sesame oil (1500 mg/l) was employed in all studies. The initial settings were pH = 7, 750 rpm mixing speed, and a temperature of 30 °C throughout all trials. The concentration of additive H_2O_2 dose was kept constant of (500 mg/l) and the Fe_2SO_2.7H2O catalyst was (50 mg/l).

Effect of reaction time

The reaction time was tested in order to find the optimal where the treatment lasted for 220 minutes and the test was done every 60 min. It was discovered that as the reaction time grows,

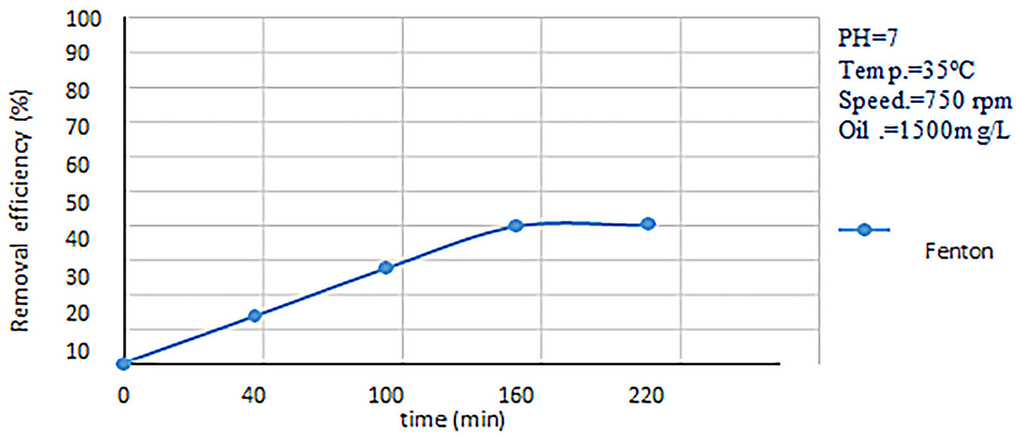

Figure 1. Effect of reaction time on removal efficiency of Sesame Oil in artificial wastewater by Fenton process

the efficiency of Sesame oil improves. After 160 minutes the best elimination effectiveness was calculated to be 40%. It is worth noting that because the rate of oxidation of sesame oil is faster with less time, a treatment duration of 160 minutes can be used in different economic situations as shown in Figure 1.

Effect of pH

Different pH values (3.5, 7, and 10.5) were tested, and the best pH value generated the best oil removal efficiency. It can be seen from Figure 2, at pH of 3.5 the efficiency was acceptable, but at pH of 10.5 it dropped. This result show that at the alkaline medium, the Fenton process has a low efficiency.

Effect of mixing speed

The influence of mixing speed on removal efficiency was investigated at three different rotational speeds (1000, 750, and 500 rpm) regulated by a magnetic stirrer device where the other variables remained constants. From Figure 3 it can be seen the removal efficiencies for the sesame oil by Fenton method was 50% at 500 rpm, 7.5% at 750 rpm and 25.7% at 1000 rpm, With these various speeds the results show that at a low mixing speed of 500 rpm the maximum removal efficiency was obtained. which reduces the time necessary for hydrogen peroxide to react with ferrous sulfate as compared with a high speed, which aids in the creation of hydroxyl radical, which speeds up the advanced oxidation process.

Effect of temperature

Temperatures of 25, 30, and 45 °C were used to test the influence of reaction temperature on oil removal. The experimental data showed that a highest reported removal efficiency reached 37% at 25 °C and the efficiency was decreaed when the temperature increased as shown in Figure 4.

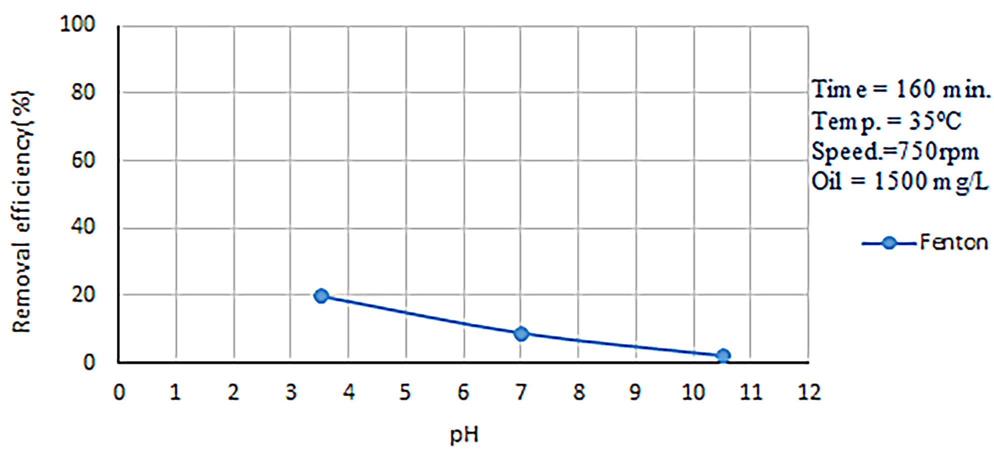

Figure 2. Effect of pH value on the removal efficiency of sesame oil in artificial wastewater by Fenton process

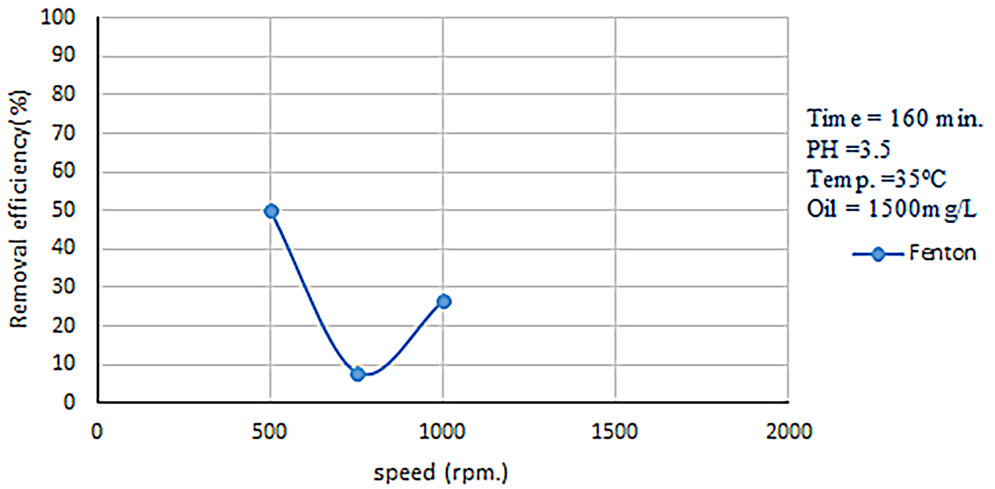

Figure 3. Effect of mixing speed value on removal efficiency of sesame oil in artificial wastewater by Fenton process

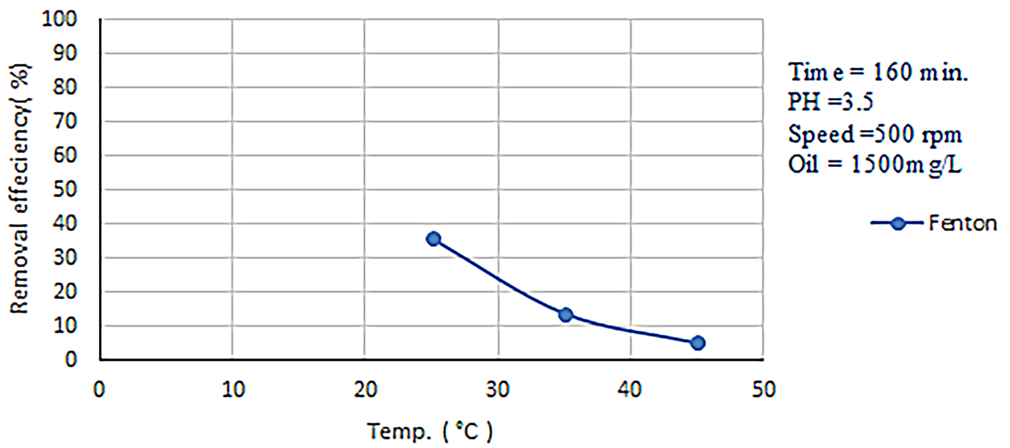

Figure 4. Effect of temperature on removal efficiency of Sesame Oil in artificial wastewater by Fenton process

Effect of sesame oil concentrations

Sesame oil concentrations ranging between (1000–2000) mg/l were used, the concentrations were close to (1000, 1500, 2000) mg/l for the same variables obtained in the previous experiments.

Oil removal increases along with oil concentration increase, where optimum removal efficiency in the three processes is between the concentration of (1500) and (2000 mg/l), this process is effective at all concentrations used, and the maximum efficiency reaches over 80%. The removal

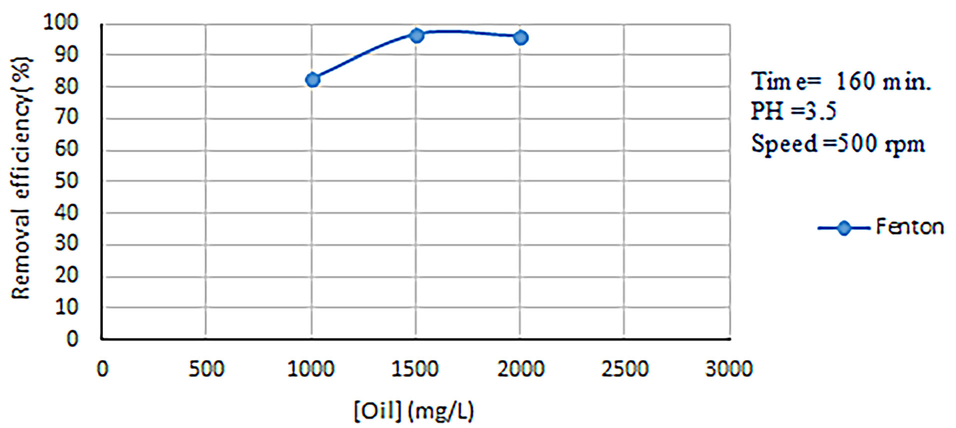

Figure 5. Effect of oil concentration on removal efficiency of sesame oil in artificial wastewater by Fenton process

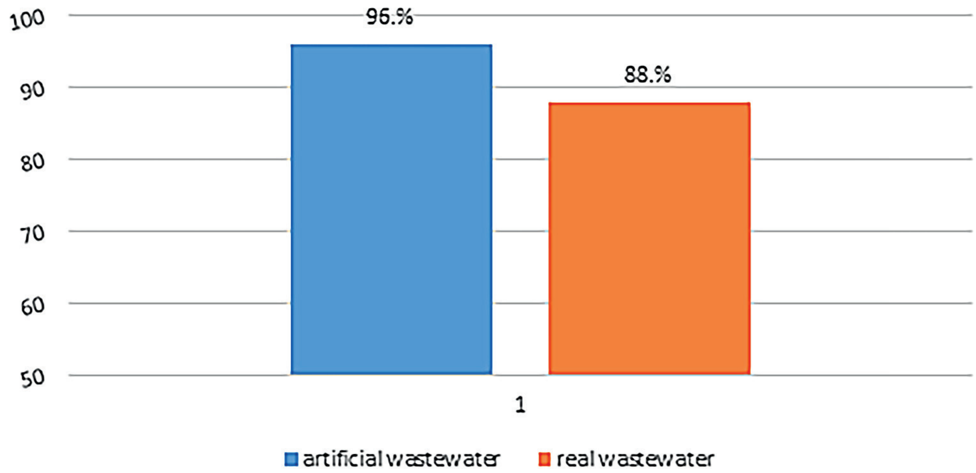

Figure 6. Comparison between treating artificial and the actual wastewater by Fenton process

efficiency was the highest possible at (1500 mg/l) of 97% as shown in Figure 5.

Optimal conditions and comparsion

The optimal operating conditions for the Fenton oxidation of artificial wastewater specify operating conditions were time 160 minutes, pH of 3.5, mixing speed of 500 rpm and Sesame oil concentration of 1500 mg/l. These conditions produce Sesame oil oxidation with an estimated efficiency of 96%.

In the Fenton procedure, the removal efficiency was found to be 88% when actual wastewater was used instead of artificial water. Figure 6 shows a comparison of the Fenton process' efficiency in treating artificial wastewater and the actual wastewater. The efficiencies for both treatments was similar and effective, but it was lower for the actual wastewater than that in artificial wastewater because it contains a wide range of pollutants that cannot be controlled by this treatment alone.

CONCLUSIONS

The Fenton process as an advanced Oxidation Process, which is used to handle Sesame Oil has a high removal efficiency. The optimum conditions of this process include a reaction time of 160 minutes, mixing speeds of 500 rpm, the best temperature is 25 °C and Sesame oil concentration 1500 mg/l. To achieve enhanced oxidative action, the Fenton requires an acidic media, hence the ideal pH is 3.5. The maximum oil degradation efficiency of artificial wastewater containing sesame oil was determined to be 95%, while the maximum oil degradation efficiency of the actual wastewater was determined to be 87%.

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