Photovoltaic cell Electro- Oxidation for Oil Removal in oil field produced \( \text{H}_2\text{O} \)

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Abstract. This education compares Electro- oxidation of produced \( \text{H}_2\text{O} \) created through oil manufacturing using Al and Fe electrodes in photovoltaic batch reactor was designed and reflects the degree of its tradition in such produced \( \text{H}_2\text{O} \) purifying that is a cell as photovoltaic, a battery, DC to AC convertor, and reactor as electric –Fenton. During electro-oxidation processes, various limits of operation were tested, i.e., Current, \( \text{H}_2\text{O}_2 \), time of electrolysis and total organic carbon besides consumption of energy. Solution of pH, Sodium chloride and agitation speed had stayed engaged as 3, 0.25 g, 250 rpm correspondingly. High elimination of oil content was identified. Beneath the employed variables finest standards, further than 98% content elimination competence oil and 39.11 k Wh/m\(^3\) for the consumption of energy was got.

1. Introduction

Companies of oil production face complications of solution being difficult in relative to actions heading for ecological protection, owing to the waste huge quantities generation throughout exploitation and prospecting of oil, for instance produced \( \text{H}_2\text{O} \) (PW) [1]. It is definitely significant by way of legislative and ecological anxieties results. Lengthways as all, are envFemental supplementary stringent rules essential assorted waste \( \text{H}_2\text{O} \) treatments as manufacturers of gas and beforehand announcement and earlier reservoirs injection to reduce damage of creation [2]. the wastes of produced \( \text{H}_2\text{O} \) are a main source of aquatic ecological contamination [3], because of composition complexity which including inorganic and organic materials, along the chief constituents existence emulsified and free oils, phenols and salts. Amongst such devices [4]. Traditional handling developments have remained society to be fewer lively aimed at removing around pollutants from produced \( \text{H}_2\text{O} \) because of their poisonous, scenery as intractable and non-biodegradable [5]. Such obliging recycles conventional discount potable \( \text{H}_2\text{O} \) removal, a tremendously respected creation in many world areas [6], [7], [8]. Several traditional treatment have stayed rummage-sale to eliminate the oil content from produced \( \text{H}_2\text{O} \) : flocculation /coagulation [9] adsorption [10], treatment as biological [11], and separation of membrane [12],[13]. Existence technically humble, financial and \( \text{H}_2\text{O}_2 \) and Fe as main non-toxic reactants; Process of Fenton attitude being mostly possible Advanced oxidation processes (AOP). Conservative process of Fenton that brands homogeneous catalyst usage, are confronted through difficulties similar slower Fe\(^{2+}\) renewal extreme and rate Fe mud manufacture. Nonetheless so as for commercializing such method, such disadvantages should overwhelm. Such was beleaguered thru the heterogeneous Processes as Electrochemical Advanced Oxidation (EAOP’s), beyond that electro-Fenton procedure appeared by way of the general (EAOP) [14]. EAOP is unique of the talented electro-oxidation aimed at the comprehensive oxidation of tenacious organic content from waste \( \text{H}_2\text{O} \) [15].The electro-Fenton eco-friendly methods own some exciting compensations for
instance high adaptability, excellent competence, high acquiescence and ecological compatibility, which differentiate them from other AOPs [16, 17]. Such advance comprises the in-situ cohort of so sensitive free radicals substance being oxidized because of the reaction between electro made H$_2$O$_2$ and Fe$^{2+}$ in the arrangement. The process significant bounds is thin working pH (2.0−3.0) and Fe left-hand over in the conserved H$_2$O[18]. Among them, EAOPs have arose ended the preceding period by way of unique attractive approaches aimed at the organic pollutants broad-range treatment which are not essential the material outline owing to its redox reactions generation [19]. This education engrossed on oil removal in produced H$_2$O via photovoltaic electro- Fenton oxidation and detects the finest H$_2$O$_2$ concentration value, studying the electrolysis time and current possessions in photovoltaic electro-process of Fentones.

2. Materials and methodology

2.1. Produced H2O: The PW was got from wet oil’s component settling, field of Ahdab oil located in governorate of Wasit in Iraq. PW composed in situation similar to homebased native that encompasses O$_2$ untill process of treatment is helpful. The organization of PW is specified at Table 1.

| Parameter          | Value               |
|--------------------|---------------------|
| Oil                | 104.5 (mg/L)        |
| Turbidity          | 77.5 NTU            |
| pH                 | 6.74                |
| Dissolved O$_2$ content | 0.045 (mg/l) |
| SG                 | 0.998               |
| Conductivity       | 64520 $\mu$S/cm    |
| TDS                | 41292.8 (mg/L)      |
| Viscosity          | 1.106 m Pa/S        |
| Fe                 | 0.29 (mg/L)         |
| SO$_4$             | 45.8 (mg/L)         |
| TSS                | 16.6 (mg/L)         |

2.2. Electrodes and photovoltaic cell

The electrodes used in the education remained Al and Fe via anode and cathode way correspondingly. Fe electrode dimensions were 11 cm x 8 cm x 0.25 cm. Al electrode dimensions were 10 cm x 7 cm x 0.18 cm. Designed aimed at photovoltaic cell Electro- process of Fenton, the electrodes active area was kept as 30 cm$^2$ and electrode space being inner was supported as 6 cm. The photovoltaic cell (Fig. 1a) is whole of acrylic 4 blocks furthermore silicon rubber gaskets sheets remained co-located among them to avoid escapes. Such cell shape, allows 2 probable anode sites in unit of anolyte: at the plate ending (amongst acrylic blocks the anode determination remain z1 cm distant from the cathode, such location is showing at Fig. 1b).
Figure 1. (a) Chief flow-cell parts. b: Flow-cell, hydraulic circuit, and solar panel.

2.3. Process of electro oxidation: In electrochemical technique, the experimental was accepted out in reactor as batch comprising glass reactor (1000 cm³), PW of 3 hundred mL. pH as initial was adjusted to 3 via 1N hydrochloric acid and sodium hydroxide. Electrodes remained connected to source as DC power (RXN-305D) from cell as photovoltaic and additional NaCl (0.25 g). Power voltage source was conserved as 29.4 v. Operating the source of DC power heading for 15 min for sweeping the Fe ions in the reactor and previously added quantities of H₂O₂ with the speed of agitation which was secured at 200 rpm aimed at completely hearings by way of displayed in Fig.2. Samples stood unobtrusive at intermissions of regular time; centrifugation was done at 2000 rpm (in order to sludge distinguishing) for ten minutes where supernatant was tranquil heading for oil estimate. PW reduction was spoken by ratio way of remaining oil in time t (Cₜ) to (C₀) as initial oil. Extra teachings were accepted out via mutable the current, time and H₂O₂ dosage. Proceeding to practice in Electro- process of Fenton, very electrodes were systematically cleaned with H₂O to remove wreckage. Previously saturated electrodes were in 1N hydrochloric acid for 1 h shadowed by 1M sodium hydroxide for another hour. The electrodes were put in distilled H₂O when not in practice. Afterward each usage, the electrodes were worn in 1M NaOH and 1N HCl to eradicate whatever imaginable contamination.
Figure 2. Electro Fenton reactor Scheme

In the meantime consumption of energy (kWh/m$^3$) is definite significant feature in this treatment methods kind, thus, it was intended by means of equation as follow [20]:

$$ E = \frac{U \times I \times t}{(1000 \times V)} $$

(1)

Since $U$ is voltage applied (volt), $I$: current applied (Amps.), $t$: electrolysis time (h), and $V$ is the produced $H_2O$ volume (m$^3$).

2.4. Rational measurements: content of oil in PW was assessed finished meter of UV–spectra (UV-1800 Shimadzu, Japan) linked to a PC at all-out wavelength of absorption (218 nm) heading for n-hexane. The pH measure was whole finished meter of pH (Model 2906, Jenway Ltd, UK). Turbidity was lethargic by meter of turbidity (Lovibond, SN 10/1471, and Germany) and declaim turbidity.

2.5. Tested oil by using a UV–spectra meter: 50 mL PW in the closed cylinder through the sense of trouble oil emulsion. 5 ml of n-hexane was more underneath the acidic condition (pH=2) and shadowed thru energetic shaking meant at 3 min. Then 10 min, produced H2O solution unglued hooked on two layers being distinct, oil layer overhead was engaged heading for dimension of absorbance, and subsequently that from curve of calibration, content of oil in PW was originate.

2.6. Design of Experiment: In such education, the untried circumstances optimization for produced H2O via process of electro-oxidation was presented through design of central compos-ite (CCD) technique under RSM. Design as Expert Minitab-17software was rummage-sale aimed at design as untried, statistics examination, removal of quadratic model, and plotting of graph. Variables as self-governing of $H_2O_2$ concentration ($X_2$), current ($X_1$), and electrolysis time ($X_3$). They were coded via high and low levels in the CCD by exposed means at Table 2. Table 3 demonstrations operational variables of coded and natural by Minitab software Design for untried systems.

| Parameters | Ranges  |
|------------|---------|
| $X_1$: current (Amps) | 0.2-1 |
| $X_2$: $H_2O_2$ concentration (ppm) | 10-60 |
| $X_3$: electrolysis time (min) | 10-30 |

| Variable as Natural (Xi) | -2 | -1 | 0 | 1 | 2 |
|--------------------------|----|----|---|---|---|
| $X_1$: Current (mA)      | 0.2| 0.4| 0.6| 0.8| 1 |
| $X_2$: $H_2O_2$ concentration (ppm) | 10 | 25 | 35 | 50 | 60 |
| $X_3$: Electrolysis time (min.) | 10 | 15 | 20 | 25 | 30 |
3. Results and discussion

3.1. Models of regression: In such study, relations between independent variables and the responses were got via the following model as second-order finished method of least-squares [18]:

\[ Y = B_0 + \sum_{i=1}^{q} B_i X_i + \sum_{i=1}^{q} B_{ii} X_i^2 + \sum_{i}^{q} \sum_{j}^{q} B_{ij} X_i X_j + \varepsilon \]  

(2)

Anywhere Y is responses as deliberate; X₁, X₂, to Xq are the variables employed; B₀ is a constant as regression, Bi is constant of linear regression, Bᵢᵢ is the squared constant regression and Bᵢⱼ is the cross-product constant regression; ε is error as random. Table 4 demonstrates the working variables values, studied responses % removal, i.e. Oil removal, final pH and consumption of energy.

### Table 4: Variables results

| Run | X₁: Current (Amps) | X₂: H₂O₂ concentration (ppm) | X₃: Electrolysis time (min) | Oil removal (%) | Final pH | E (kWh/m³) |
|-----|-------------------|-----------------------------|-----------------------------|-----------------|----------|------------|
| 1   | 0.2               | 10                          | 20                          | 93.24           | 3.51     | 12.81      |
| 2   | 1                 | 10                          | 20                          | 94.62           | 4        | 21.36      |
| 3   | 0.2               | 60                          | 20                          | 94.85           | 4.2      | 12.81      |
| 4   | 1                 | 60                          | 20                          | 96.46           | 3.26     | 21.36      |
| 5   | 0.2               | 35                          | 10                          | 96.92           | 3.27     | 23.81      |
| 6   | 1                 | 35                          | 10                          | 98.07           | 3.57     | 39.67      |
| 7   | 0.2               | 35                          | 30                          | 94.85           | 3.42     | 23.80      |
| 8   | 1                 | 35                          | 30                          | 96.46           | 3.25     | 39.67      |
| 9   | 0.6               | 10                          | 10                          | 95.31           | 3.76     | 12.20      |
| 10  | 0.6               | 60                          | 10                          | 96              | 4.1      | 36.62      |
| 11  | 0.6               | 10                          | 30                          | 95.77           | 3.27     | 24.42      |
| 12  | 0.6               | 60                          | 30                          | 93.93           | 3.51     | 24.41      |
| 13  | 0.6               | 35                          | 20                          | 91.4            | 3.2      | 9.77       |
| 14  | 0.6               | 35                          | 20                          | 98.07           | 3.41     | 39.06      |
| 15  | 0.6               | 35                          | 20                          | 96.46           | 3.48     | 24.41      |

3.1.1 The current effect: along study intention of current on the electro-oxidation process presentation result, experiments showed at current of 0.2, 0.4, 0.6, 0.8, 1 Amps. The oil elimination augmented along current increasing that touched of 91.1% at 30 minutes at the 1 Amps current (Fig. 3). Eliminations of Inferior oil were touched current ≤0.8 mA that were 89.1% at 0.6 Amps, 87.2% at 0.4 Amps and 86.2% at 0.2 Amps as exposed in Fig. 3. Current being higher would lead to higher H₂O₂ production rate on cathode surface. By way of results, extra free radicals would accumulate in solution as bulk, foremost to more oil degradation in produced H₂O. Though, cumulative the current outside 0.8 mA did not upsurge the oil elimination prominently throughout 20-30 minutes. Comparable consequences are experiential in the ibuprofen electro-Fenton treatment [21].
Figure 3. The current effect on the oil removal in produced H2O (electrolysis time= 30 min).

3.1.2 Hydrogen peroxide effect: The levels of H2O2 is very significant in the squalor of oil contaminant such as oil content in PW. It is a source of free radical generation in the Fenton’s reagent [22]. Fig.4 specifies the H2O2 concentration effects from 10-60 (mg/L) on the produced H2O at pH 3. Frequent studies have recognized such correlation. Furthermore, unutilized hydrogen peroxide portion with ability of reduction able to consume oil oxidant via electro–oxidation consequently principals toward over oil content estimate, and the error extent is comparative to concentration of hydrogen peroxide. Consequently, the additional H2O2 portion is likely to reason oil reduction, also, the extra H2O2 amount is poisonous to many creatures and histrionically decreases general capability in such cases where knowledge of Fenton. A suitable hydrogen peroxide supplies considered as strong-minded to do competence as greatest in system as electro-oxidation though reducing attendant disadvantages [23], [17]. Therefore, an extra quantity of H2O2 may reason to lively oxidizing consumption of free radicals through a reaction additional than the reaction of oil degradation. Thus, it all decreases the latter reaction rate. Owing to that, a balance was reached between low levels of hydrogen peroxide and extra quantities all the time. These observations are the same as that found by Haider et.al, 2018 [24].

Figure 4. The H2O2 effect on oil removal in produced H2O.
3.1.3 Electrolysis time effect: In the direction of assess the electrolysis effect time, experiments were showed with operating conduct circumstances which were dependable with 104.5 (mg/L) oil content in PW and 3 pH. All-out elimination was reached by 28.7 (mg/L) concentration of H2O2 and 1 Amps at lowest 10 minutes, removal capability of oil content is increase along upsurge time of electrolysis as showing in Fig 5. Such was rendering along M. Gaber et al [25]. The higher time of electrolysis, the higher oil content competences removal from PW solution because adsorption process important activity of the occurred through the electro-Fenton reactor through lengthy way of time of electrolysis [26]. Also, lengthy times of oxidation principal to a step-by-step detoxication incomplete the inorganic tin and carbon dioxide creation [27], consequently mineralization as comprehensive was developed.

![Scatterplot of Oil Removal vs Electrolysis Time (min)](image)

**Figure 5.** The electrolysis time effect on oil removal in produced H2O.

3.2 Operational variables Optimization: The finest current values, concentration of hydrogen peroxide and electrolysis time were got via program of statistical software means (Minitab-17). Fig. 6 elucidates D-optimization measurement consequences. The best content efficiencies elimination oil values were more than 98 %.

![Optimal D: 0.9195 Predict](image)

**Figure 6.** The best the operational variables values and the validated deliberate responses values aimed at the produced H2O treatment.
3.3 Consumption energy estimation: electro-oxidation familiarity receipt as waste necessity treatment reproduces few topographies in order for branding its request likely (anode material performance, consumption of energy and working cost). Fig. 7 protests the significances consumption energy, by current and electrolysis function time way, thru in PW treatment electro-oxidation oil content. It is empirical, for all H₂O kinds where values are relative to the useful time and current thru electro-oxidation treatment, [28].

Figure 7. The operational variables effect on consumption of energy for the produced H₂O treatment

Rendering to the finest electrolysis time and current values which had acquired previous, the electrodes and energy values ingesting are 39.11 kWh/m³. Fig. 7 elucidated the consumption of energy by lively variables function way through the electro-Fenton exclusion of the pollutants. As empirical, the energy consumption upsurge along current is sharply supplementary compared to the increase with time of electrolysis that specifies that the current is additional significant in the energy consumption measurement that is so famous in texts [16].

4. Conclusions
The viability of electro-oxidation process in the oil content squalor existing in the PW was showed. Optimization of the active circumstances in relative to oil elimination, current efficiency, H₂O₂ and electrolysis time was industrialized by RSM based on CCD attaining high oil elimination and low energy. In adding there was good arrangement among experimental values and predicted that approves the model cogency. Consequently, electro-oxidation might be careful as an effective treatment being environment-friendly which able to achieve oil elimination in produced H₂O.
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