Research Article

Evaluation of Contaminated Water Treatment on the Durability of Steel Piles

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The most common effluent created by the oil industry is oily wastewater. This produced water (PW) corrodes the steel piles in the infrastructure of bridges, which shortens their service life. It is important to remove organic content in PW to prevent this outcome. Samples from the Ahdab oil field were used in this study. Two catalysts were selected: zinc oxide (ZnO) and titanium dioxide (TiO₂) with photo presence as an energy source. The results were organic elimination of 96.4% and 93.4% using ZnO and TiO₂, respectively. The experimental conditions were pH = 3 and an irradiation time of 120 min. Due to the ability of ZnO to adsorb high amounts of organic content from PW, there was an increased elimination of organic content. Hence, the maintenance of steel piles durability is a good alternative to approach the goals of this study. The results of the study demonstrated that the organic adsorption on a catalyst agent reinforced in nonappearance of radiation photo is insignificant.

1. Introduction

The major environmental and economic problem caused by oil and gas manufacturing factories is the production of oily wastewater [1, 2]. Usually, the wastewater produced is more than the treated crude oil volume, within 0.4–1.6 folds [3, 4]. The produced water (PW) must be treated properly before being released to reservoirs to avoid damaging the environment. Properly treated water can be used for other purposes and reduce water flooding [5, 6]. The significant quantities of polluted PW that are regularly released into the environment make the treatment methods of great importance, requiring suitable treatments that can remove contaminants that are present in many of these manufacturing streams. These streams are problematic because of the high concentrations of organic content in PW [7]. Furthermore, there are stringent environmental rules that govern how PW is sent into tanks [8]. Some of the chemical compounds released due to human activities are difficult to remove through PW treatments and are eventually deposited in the

environment [9, 10]. Many researchers raise concerns about PW treatment meeting environmental rules and being reused and recycled when possible [7, 11]. Numerous diverse methods exist for oil-water emulsions separation, such as adsorption [12, 13], ultrafiltration [14], biological processes [15, 16], and chemical coagulation [17, 18]. However, these techniques do have some limitations and drawbacks. For example, activated carbon adsorption can change the phase of contaminants without eliminating them, leading to additional contamination problems. In biological treatment processes, there are likewise many disadvantages including slow reaction rates, activated sludge disposal, and temperature control [19]. None of these treatment approaches are sufficient to reduce the most tenacious soil contaminants to satisfactory levels. Contaminated water reduces the service life of steel piles due to the interaction of some compounds with steel that leads to erosion of steel sections. Resultantly, steel piles can be corroded so extensively that the bridge life is significantly affected, as shown in Figure 1 [20].

FIGURE 1: Corrosion of steel piles [20].

Owing to the low permeability of reactive powder concrete [21, 22], corrosion of steel reinforcement can be prevented or substantially minimized by using it in contaminated water.

In order to reduce the factors affecting the durability of the steel piles, an additional treatment stage is frequently needed. Advanced oxidation processes (AOPs) might be performed when PW contains high chemical stability and is not biodegradable. This method can produce CO_2 and inorganic compounds [23]. AOPs are usually applied using two methods: photochemical and nonphotochemical. The photochemical oxidation usually includes homogenous processes such as UV/hydrogen peroxide, vacuum UV photolysis, UV/ozone, photo-Fenton, UV/ozone/hydrogen peroxide, and heterogeneous processes such as photocatalysis. Non-photochemical oxidation comprises ozonation at high pH Fenton and Fenton-like and ozone/hydrogen peroxide processes [24]. The aim of this treatment is the generation of free hydroxyl radical ($\text{OH}\cdot$), a highly reactive, nonselective oxidizing agent that can abolish even the recalcitrant contaminants [25]. The overall aim of this study is to remove organic content from the contaminated soil of the Al-Ahdab oil field in Iraq using photocatalytic oxidation processes. The first aim is to find the optimal catalyst agent dosage. The second is to study the parameters that affect the photocatalytic process performance, including pH and irradiation time.

2. Materials and Methods

2.1. Materials. Titanium dioxide (TiO_2), zinc oxide (ZnO), sodium hydroxide (NaOH), and sulfuric acid (H_2SO_4) from Merck (India) and distilled water were used in this research work. The solution's pH was adjusted with 1 N H_2SO_4 or 1 N NaOH .

2.2. Produced Water. Produced water was collected from the Al-Ahdab oil field in Iraq. The PW was filtrated to eliminate solids and kept at 5°C to maintain PW characteristics (Table 1).

TABLE 1: PW characteristics.

Parameter	Value
Organic	142.51 ppm
Turbidity	110.4 NTU
pH	6.85
Solution oxygen concentration	0.055 ppm
Specific gravity	0.994
Conductivity	72541.64 $\mu\text{S}/\text{cm}$
TSS	21.2 ppm
TDS	46426.65 ppm
Viscosity	1.104 mPa/S
Fe	0.33 ppm
SO_4	55.4 ppm
Manganese	2.5 ppm
Chrome	0.14 ppm

2.3. Logical Measurements. The organic content in PW was measured using a UV-spectrometer (UV-1800 Shimadzu, Japan) at a wavelength of 218 nm, using n-hexane gas. A turbidimeter (Lovibond, SN 10/1471, Germany) was used to measure turbidity. The pH was measured by a pH meter (Model 2906, Jenway Ltd, UK).

2.4. UV/ TiO_2 Bench-Scales Batch Reactor. Photocatalytic procedures squalor tests were performed in a 500 ml glass batch reactor containing 250 mL PW stirred at 200 rpm at different periods ranging between 30 min and 120 min. The pH was adjusted by adding diluted H_2SO_4 or NaOH .

2.5. Organic Content Tested by a UV-Spectrometer. 50 mL of PW and 5 ml of n-hexane were added at pH = 2, shaken for 2 min. Subsequently, after 10 min, the PW solution was separated into two layers. The organic layer was not within the absorbance range; so, the organic content in PW was determined using a calibration curve.

2.6. Analytical Analysis and Kinetic Study. The organic removal percentage in PW was calculated using the following equation:

$$\eta = \frac{C_{\text{initial}} - C_{\text{treated}}}{C_{\text{initial}}} \times 100\% \longrightarrow, \quad (1)$$

where η is the organic removal efficiency; C_{initial} is the initial organic concentration (ppm); and C_{treated} is the final organic concentration (ppm).

The kinetics of the photocatalytic degradation rate of organic elimination were performed using the Langmuir-Hinshelwood kinetics model, according to the following equation, where a plot of $\ln(C_0/C)$ against time was drawn for each experiment to determine a straight-line relationship with slope (K_1) of the pseudo-first-order rate constant, k_1 (min^{-1}) [26, 27].

$$\ln\left[\frac{C_0}{C}\right] = K_1 t. \quad (2)$$

FIGURE 2: TiO₂ effect on removal of PW at pH = 6.5.

FIGURE 3: ZnO effect on removal of PW at pH = 6.5.

3. Results and Discussion

3.1. Catalysts Agent Effect. To examine the role of catalyst concentration on the photodegradation of PW, experiments were carried out at a wavelength less than visible light irradiation with different catalysts as shown in Figures 2 and 3 for TiO₂ and ZnO, respectively. The results indicate that TiO₂ exhibits lower photocatalytic activity than ZnO. A similar trend has been shown in previous findings with Biebrich scarlet dye as mentioned in [28]. Therefore, ZnO is better than TiO₂, due to the higher band gap and superior quantum competence.

3.2. pH Effect. The photocatalytic technique is significantly affected by pH values. The pH effect on the degradation of organic content in PW by photocatalytic processes is presented in Figure 4 for TiO₂ and ZnO, correspondingly. Increasing pH from 3 to 9 reduced the organic elimination from 96.4% to 65.4% by using ZnO and from 93.4% to 55.4% by using TiO₂, respectively, which is in agreement with prior research [29]. As shown in Figure 4, that low pH causes higher organic degradation and increases the catalyst's active area and irradiation area [30]. Consequently, catalyst surface charge can be diverse at different pH levels, which will affect the particles adsorption on the catalyst surface which leads to degradation rate variation efficiently. Hence, the experiments succeeded in getting the optimum pH of the reaction mixture to approach the best decomposition of organic content in PW. The results were in contrast with [31] because

the photodegradation rate decreased as pH increased for PW.

3.3. Irradiation Time Effect. This experiment focused on the effect of irradiation time influenced by the photocatalytic treatment to reach the highest possible elimination of organic content. Batch experiments were adopted to achieve the equilibrium by studying the relationship between organic elimination percentage and irradiation. Figures 5 and 6 elucidate that the process of organic elimination is slow and directly relative to the time for both agents TiO₂ and ZnO. This is due to free radicals that cause organic oxidation and increase removal of organic content, which is in agreement with the observations described in [10].

3.4. Kinetic Study. The pseudo-first-order models on catalytic agent tests are shown in Figures 7 and 8. Different concentrations of TiO₂ (50, 100, and 150 ppm) and initial PW concentration of 142.5 mg/L were chosen to study the effect of TiO₂ concentration on the kinetic coefficients of organic elimination percentage. According to appropriate experimental data rendering to equation (2), the k_1 (min⁻¹) value was significant. Figure 7 shows $\ln(C_0/C)$ against lighting time using TiO₂. The same trend is shown in Figure 8 using ZnO.

The rate coefficients values in the model are provided in Table 2 using zinc oxide. R^2 is the pointer of how the equation can predict the results. The closer the value is to 1,

FIGURE 4: pH effect on removal of PW using TiO_2 (150 ppm) and irradiation time (120 min).

FIGURE 5: Irradiation time effect on removal of PW by adding 150 ppm TiO_2 at pH = 6.5.

FIGURE 6: Irradiation time effect on removal of PW by adding 150 ppm ZnO at pH = 6.5.

FIGURE 7: Pseudo-first-order model for degradation of PW using TiO_2 at pH = 6.5.

FIGURE 8: Pseudo-first-order model for degradation of PW using ZnO at pH = 6.5.

TABLE 2: Rate constants using ZnO.

ZnO	First-order $K_1 \text{ min}^{-1}$	R^2
50	0.0017	0.7987
100	0.0021	0.9
150	0.0029	0.91

the better and more appropriate the model is. From Figures 7 and 8, it is clear that ZnO is more effective than TiO₂.

Figure 8 shows that the rate constant K_1 increases gradually to a maximum of $2.9 \times 10^{-3} \text{ min}^{-1}$ at an optimum concentration of 150 mg/L ZnO, which coincides with [28].

4. Conclusion

The organic degradation in PW is affecting the durability of steel piles. Different catalysts of TiO₂ and ZnO were tested in the presence of an energy source. ZnO showed a high absorption property that is good enough to absorb organics. Therefore, it is preferred to TiO₂.

The degradation kinetics of organic content in PW follow first-order kinetics. However, photocatalytic processes can be adopted for the degradation of organic content from PW. This study indicates that the service life of the steel piles in the contaminated soil can be maintained using the catalyst.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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