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Photolysis System Performance in Petroleum Hydrocarbons Removal from Wastewater and its Modeling

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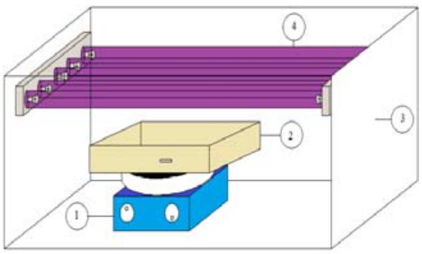
1-Introduction

Due to high amounts of toxic multi-cyclic aromatics, wastewaters contaminated with petroleum compounds are generally considered to be harmful. They may cause significant damages to water resources and human health and should be treated before discharging them to the environment. So far, different methods have been employed for treatment of wastewater contaminated by petroleum compounds. In this study, the photolysis process is investigated.

During recent years, use of UV technology for water and wastewater treatment processes has noticeably increased. UV photolysis and photo-initiated oxidant ions have a potential for inactivation of microorganisms and destruction of a wide variety of contaminants in aqueous medium. Current research works confirm this claim. In this research, the capability of photolysis system, its optimum conditions, its use as pretreatment in destruction of hard-degradable petroleum hydrocarbons, and preparation of its effluent for the main treatment unit are investigated. Also, the time required for maximum COD removal is modeled.

2- Experimental Program

In this study, a plastic rectangular cube pilot (L: 24 cm, W: 17 cm, H: 9 cm) was applied as the photolysis system (Fig. 1).



1- Stirrer
2- Reactor
3- UV Fluorescent light
4- Foil

Fig. 1: Pilot and Schematic: Photolysis system

To have a composition similar to that of the Tehran Refinery's effluent, a mixture of gasoline (C_{16}-C_{20}) and crude oil (C_8-C_{37}) with a ratio of 1 to 2 was prepared and aerated for 48 hours. So, the lighter compounds with water vapors were stripped and removed from the medium and the heavier hydrocarbons (heavier than C_{35}) remained on the reactor walls.

In the photolysis system the same wastewater that has been prepared earlier was directly exposed to UV-C ray. Concentration parameters (50, 100, 250, 350 and 500 mg/L), radiation power (60, 80, 100 and 120 W) were also examined. First, optimum concentration was determined given radiation power of 60 W and later optimum radiation power was determined given the optimum concentration. The parameters of radiation power and concentration were optimized based on the minimum energy consumption as determined by the industry earlier. Reactor temperature was monitored as a controlling parameter. Some insignificant vaporization from the surface of the sample was observed and it was compensated by adding distilled water prior to sampling.

3- Conclusions

In this study, contact surface of radiation and the distance of the sample from lamps were assumed to be constant and the effect of UV radiation alone and the effect of concentration on the efficiency of contaminant removal in Photolysis process have been examined.

3.1- Determination of Optimum Concentration

The results obtained during investigation of the effect of UV light at different CODs and radiation power of 60 W are given in Fig. 2. Initially, an increasing trend of COD level was observed which can be attributed to the nature of hydrocarbon-rich contaminant. Then in about a couple of days for each COD concentration the chart reached a maximum value of COD corresponding to the input concentration.

As shown in the chart, the radiation period of UV rays to meet constant removal efficiency is increased by increasing the concentration of the contaminant. So, given the CODs of 50, 100, 250, 350 and 500mg/L, the radiation period of UVs are 5, 6, 9, 11 and 14 days, respectively. Furthermore, the removal efficiency under steady state declined upon increasing the concentration of the contaminant. Maximum values of removal efficiency of the contaminant due to 60W radiation of UV for the above-mentioned CODs are 50, 37, 28, 25 and 16%, respectively. Increasing the COD value as shown in the chart may be attributed to degradation of hard degradable petroleum compounds into other petroleum compounds.

For the purpose of determination of optimum concentration, the period of tests and consumed energy should be cost-effective. Energy consumption against removal of each unit of COD are presented in

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Fig. 3. As shown, the least values of energy consumption, i.e. COD equal to 350mg/L, are related to the stirrer and the lamp. This is considered as the optimum concentration in this research.

3.2- Determination of Radiation Power of Optimum UV

The effect of radiation power on COD removal is indicated in Fig. 4. By increasing the radiation power and the numbers of photons emitted, the efficiency remained almost constant after a long time as shown in Fig. 4.

To determine the optimum power, the variations of energy consumption per COD at different UV powers are shown in Fig. 5. According to the Figure, radiation power of 80W with energy consumption of 0.24kWh/mg/L was considered as optimum amount because of insignificant difference with the results of 100W.

3.3- Time Modeling of COD_{max}

Modeling the system by examining performance in different CODs under light intensity of 60 watts and also best-fit values of COD_{max}/COD_0 for each concentration in terms of time are shown in Fig. 6.

As shown in Fig. 6-a, variations in COD/COD_0 over time in different CODs follow a similar trend. Connecting maximum points of these trends concludes an appropriate linear relation (Fig. 6-b). This relation is a logarithmic regression (Eq. 1 and Eq. 2) with correlation coefficients of 0.99 and 0.96, respectively.

$$COD_{max}/COD_0=0.6594\ Ln(t)+0.7014 \quad (1)$$

$$COD_{max}/COD_0=0.4164\ Ln(COD_0)+1.2458 \quad (2)$$

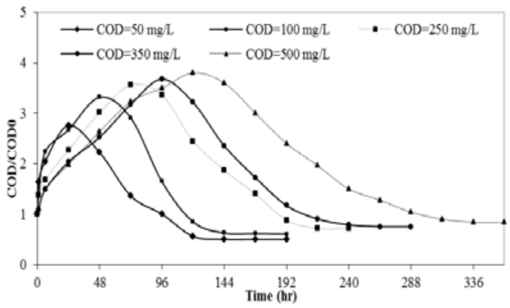

Fig. 2. Variation of COD removal in photolysis system (COD_0= 50, 100, 250, 350 and 500 mg/L; P_{uv}= 60 W)

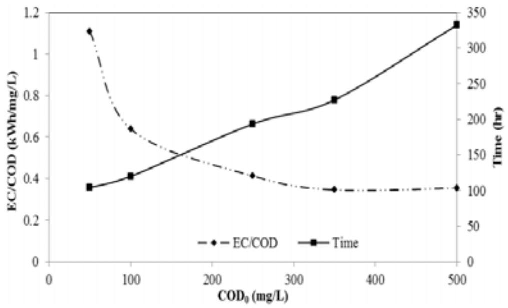

Fig. 3. Energy consumption at different initial CODs (COD_0= 50, 100, 250, 350 and 500 mg/L; P_{uv}= 60 W)

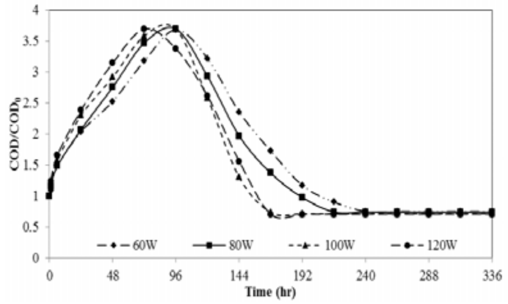

Fig. 4. The effect of different UV radiation powers at COD of 350 mg/L (COD_0 = 350mg/L; P_{UV}= 60, 80, 100 and 120 W)

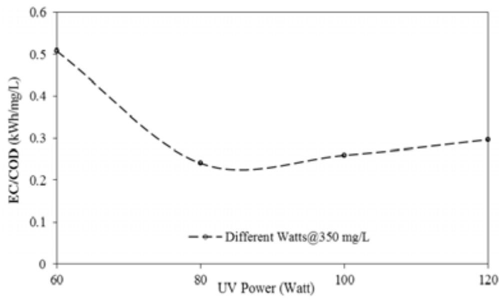

Fig. 5. Energy consumption level against different powers (COD_0 = 350mg/L; P_{UV}= 60, 80, 100 and 120 W)

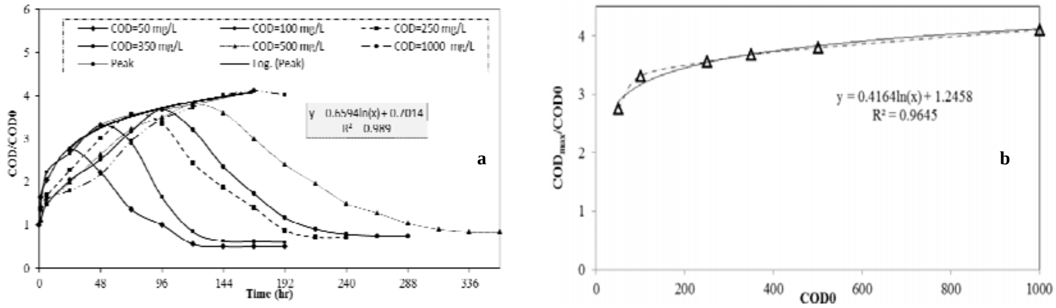

Fig. 6. Variations of COD removal and logarithmic regression COD_{max}/COD_0 amounts according to a) Time and b) COD_0 (P_{UV}=60W)