

The impact of environmental matrices on the degradation of chlorazol black by photoactivated acetone

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Abstract— In this study we investigate the effect of acetone on the batch photolytic degradation at 253.7 nm of chlorazol black (CB) azo dye in different matrices basically deionized water and mineral water. It was found that acetone (50 mM) assisted-UV treatment of CB (20 mg/L) resulted in 5.6-fold increase in the initial degradation rate, as compared with UV alone for both systems. Radical scavenger tests using oxygen saturation have showed that methyl radical was probably the main species responsible for the efficient degradation of CB in UV/acetone system. The obtained results show that CB degradation is also effective in mineral water. For both matrices, the initial amount of CB was nearly removed after about 30 min, but the degradation rate proceeds much quickly in deionized water.

Key-Words— Advanced oxidation; acetone; Ultraviolet irradiation UV/acetone process; Chlorazol black (CB); methyl radical.

I. INTRODUCTION

Water quality is currently threatened by textiles dyes detected at trace levels in water bodies and whose impact in the environment is of growing concern(1). The effective decolorization of colored effluents has become an important problem in the treatment of wastewater originating from the textile industry. Conventionally, physical (adsorption, filtration, and flotation), chemical (coagulation, oxidation, reduction, and electrolysis) and biological methods have been employed to treat wastewater containing organic dyes and pigments. However, it is difficult to find a convenient method which can effectively treat all types of dyestuff wastewater (2). The dye pollutants taken from various industries play an important role in the environmental contaminations because of their resistance to biological degradation. It is

evaluated that 1–15% of the dye is lost during dyeing processes and released into wastewater (3). Due to the large degree of aromaticity and stability of the molecules which results a serious issue for the industry and create an important threat to the environment (4).

Advanced oxidation processes (AOPs) are applicable to the degradation of a wide range of pollutants and are especially useful as pretreatment steps before biological treatment for the degradation of dye in wastewater that is resistant to biodegradation(5). Most AOPs rely on the generation of hydroxyl radical (6). However, other chemical oxidation techniques may result in faster wastewater treatment than traditional AOPs, such as photolytic ozonation (ultraviolet [UV]/O₃), UV /hydrogen peroxide (H₂O₂), Fenton's Reagent [H₂O₂/Fe(II)], and titanium dioxide photocatalysis (TiO₂/UV)(7). Oxyanions such as periodate (IO₄⁻), hydrogen peroxide (H₂O₂) and persulfate (S₂O₈²⁻) can be reductively converted into highly reactive radical intermediates such as iodyl (IO₃[•]) periodyl (IO₄[•]), hydroxyl ([•]OH) and sulfate (SO₄^{•-}) radicals through various activation ways for AOPs applications(8).

Lately, photoactivation of acetone with UV irradiation at 254 nm has become an emerging approach for the removal of organic compounds (10-11). Due to the absorption of ultraviolet light, acetone molecules decompose either by rearrangement into the two principal products ethane and carbon monoxide or by fission into methyl and acetyl radicals which in turn give ethane, biacetyl, and carbon monoxide (12).

Acetone photolysis may enhance the degradation of pollutants through two

mechanisms: (i) involvement of methyl radical and (ii) acetone photosensitization.

Some experimental reports showed that irradiation at 253.7-270 nm efficiently decomposes acetone in aqueous solution (13.14). The data available indicate quite strongly that the photochemical decomposition of acetone proceeds mainly by a free radical mechanism (15)

The free radical attack, via methyl radical, may be a potential alternative to the photosensitization process toward the oxidation of organic pollutants by UV/acetone process. This may be supported by the fact that CH_3^\bullet has shown a strong reactivity to some compounds in aqueous solutions (16-17). Similar to other reactive radicals, methyl radical may react with substrates through addition and atom abstraction (18-19)

The results of a previous study (20) showed that the photodegradation of CB azo dye was strongly accelerated by acetone, due to the involvement of methyl radical generated upon UV photolysis of acetone in the degradation process .

The main objective of the present investigation was to explore the impact of environmental matrices on the photodegradation of chlorazol black (CB) using acetone

II. MATERIALS AND METHODS

All solutions were prepared in deionized water. The azo dye chlorazol black (CB) and acetone (Acet.) were purchased from Sigma-Aldrich.

Photochemical experiments were carried out in a cylindrical glass water-jacketed reactor with the overall volume of 500 mL. The middle of the reactor was occupied

with a quartz tube in which a low pressure mercury lamp (Oriel 6035, 15 mW cm^{-2} , predominately emits at 253.7 nm) was placed vertically. The treated solution (250 mL) was agitated by means of a magnetic stirrer. The temperature of the tank was controlled through the cooling jacket and displayed by a thermocouple immersed in the reacting medium. Samples were withdrawn at different time intervals and the concentration of the dye was determined using a UV-vis spectrophotometer (Jenway 6405) at $\lambda_{\text{max}} = 578 \text{ nm}$. The pH of the solution was adjusted using NaOH or H_2SO_4 .

III. RESULTS AND DISCUSSION

A. Preliminary tests

Preliminary experiments were carried out to test the extent of CB (20 mg L^{-1}) degradation for both matrices mineral water and deionized water under two different systems: (i) photolysis and (ii) photolysis in the presence 50 mM of acetone. Fig-2 shows the obtained concentration-time profiles. The degradation yield by UV alone was determined as approximately 34% after 30 min in deionized water face to 40% for mineral water . However, in the case of UV/acetone, a rapid degradation of CB occurred, i.e. 97% of CB was removed after 30 min with mineral water face to 98% in deionized . This notable increase was attributed to the involvement of free radical species in the degradation process

B. Mechanism of acetone-induced intensification of CB photodegradation

In order to appreciate the contribution of mechanism in the degradation of CB, chemical probes technique has been adopted, therefore Oxygen is a strong scavenger (oxidizer) of methyl radical in both gas and liquid reaction phases

We investigate the effect of oxygen saturation on the UV-degradation of CB in the presence of 50 mM of acetone. As seen Fig-1, O₂ saturation completely quenched the positive effect of acetone toward the degradation rate of the dye. The effect of acetone was completely nullified and the degradation rate becomes as that obtained under UV alone. Therefore, the main mechanism of CB destruction in UV/acetone system is chemical oxidation by methyl radicals

C. The impact of environmental matrices :

the performance of the photoactivated process was checked in real environmental water. Degradation of CB by UV/acetone process was studied in a natural mineral water of the characteristics: pH 7.2, Ca²⁺ = 81 mg/L, Mg²⁺ = 24 mg/L, Na⁺ = 15.8 mg/L, Cl⁻ = 72 mg/L (2 mM), SO₄²⁻ = 53mg/L(0.55 mM), HCO₃⁻ = 265 mg/L (4.34 mM). The obtained results, presented in Fig. 2 show that CB degradation is also effective in mineral water. For both matrices, the initial amount of CB was nearly removed after about 30 min, but the degradation rate proceeds much quickly in deionized water. In view of the relative high concentration of bicarbonate in the mineral water (4.34 mM), it is suspected that bicarbonate is the main species responsible for lowering the degradation of CB in mineral water. It should be noted that cations, i.e. K⁺ and Na⁺, have not any reactivity with methyl radical .

III. CONCLUSION

The results of this study showed that the photodegradation of CB azo dye was strongly accelerated by acetone, due to the involvement of methyl radical. The experimental result that there is no impact of nature of matrices on degradation

of CB using UV/acetone processes that making UV/acetone a promising processes to treat polluted water in different natural matrices.

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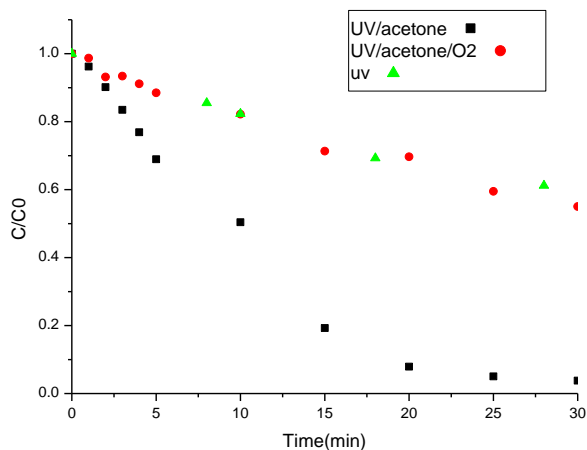


Fig. 1. Effect of O₂-saturation on the removal kinetics of CB upon UV/acetone treatment in deionized water (conditions : volume: 250 mL, initial CB concentration: 20 mg/L (25.5 μM), initial acetone concentration: 50 mM, pH 7, temperature: 25 ± 1 °C).

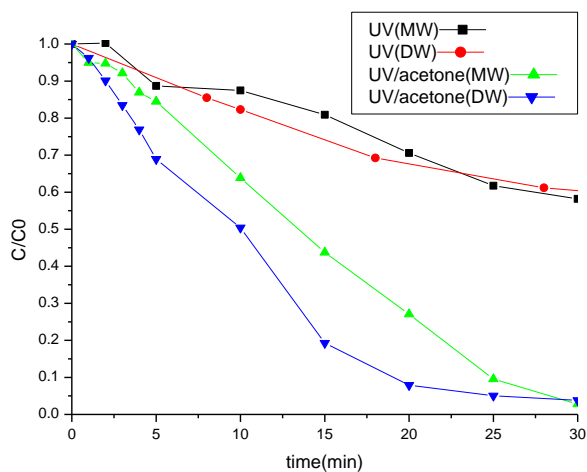


Fig.2. Degradation kinetics of CB with UV and UV/acetone processes in deionized water (DW) and mineral water (MW) (conditions – volume: 250 mL, initial CB concentration: 20 mg L⁻¹ (25.5 μM), initial acetone concentration 50 mM, pH 7, temperature: 25 ± 1 °C).