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Photo-Fenton oxidation of dichlorophene in aqueous solution: kinetics investigation and effects of operational parameters

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ABSTRACT

Dichlorophene (DCP), a widely detected contaminant in the aquatic environment, was removed under the UV-254 nm irradiations based on advanced oxidation processes. The removal efficiency of DCP from water was enhanced by coupling UV with oxidant (H_2O_2) and/or catalyst (Fe^{2+}), that is, UV/H_2O_2 and UV/H_2O_2/Fe^{2+} owing to the $^{\bullet}OH$ radical generation in the system, which is chiefly responsible for degradation of DCP. Removal of DCP was maximum, that is, 96% degradation after 50 min UV irradiation by UV/H_2O_2/Fe^{2+} at pH 3, with apparent rate constant (k_{app}) of 0.058 min^{-1}. The degradation rate of DCP increased with the increasing initial concentrations of DCP, represented by 0.011, 0.018 and 0.023 ppm min^{-1} at using 3, 4 and 5 ppm initial concentrations of DCP, respectively. The presence of NO_3^- and HCO_3^- deteriorated the degradation proficiency of DCP from 96% to 86% and 74%, respectively, attributed to scavenging of $^{\bullet}OH$ radical.

Keywords: Dichlorophene; Advanced oxidation processes; Photo-Fenton process; Rate constant; Radical scavengers

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1. Introduction

Water is not simply an economic commodity but also an imperative societal commodity. Though, due to cumulative human activities, aqueous environments have been exposed to thrilling microbial, chemical and biological toxins. Polluted water from anthropogenic sources is discharged into fresh water bodies, and is destroying the aquatic system [1]. In most of the developing countries, one of the key environmental problem is water pollution [2]. Dichlorophene (DCP) is one of the harmful substances [3] used as an antihelmintic pesticide product, which enters into the aquatic environment and causes long-term chronic effects in the aquatic organisms, that is, fish, leading to

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disturbed aquatic life; it may also cause fatal diseases [4]. DCP is a non-biodegradable mutagen and has been reported to cause serious health issues directly or indirectly to human populations; it irritates the skin leading to serious skin diseases. It is also very harmful to the eyes and mucous membranes. It has the probability to develop cancer [5]. The removal of such hazardous substances from aquatic environment is necessary [6]. Previously many techniques such as filtration, froth filtration, adsorption, ultra filtration, $KMnO_4$ oxidation, primary, secondary and tertiary treatment for the removal of such kinds of toxic material from water have thoroughly been conducted [7,8]. Most of the organic pesticides used in agriculture and other contaminants present on the surface of soil absorb ultraviolet (UV) radiation, which causes their degradation via molecular bond that in turn causes breaking [9,10]. The above mentioned techniques are more expensive and more complicated as well as the degradation efficiency of contaminant is not too much high [11], Other drawbacks of these stated techniques are that non-biodegradable, mutagenic materials such as DCP may be converted into more toxic by-product; thus DCP is not completely mineralized in aquatic environment [12]. Therefore, new economically practicable and extra effective methods for pollution regulation and prevention are mandatory for environmental safety. Recently advanced oxidation process (AOP), a conventional technique, is utilized for the removal of harmful chemicals from wastewater [11]. AOPs have been found the most effective remediation technologies concerning the removal of non-biodegradable organic pollutants (NBOP) including pharmaceuticals into nontoxic and even complete mineralized constituents [13].

So, in the present study, we have applied AOP, which is cheap and easy to construct and also the removal/degradation efficiency of NBOPs from aquatic environment is high as compared with other techniques [4,5]. In AOPs, there are different methods such as homogenous catalysis, heterogeneous catalysis, electrochemical process, photo-oxidative process, etc. [5]. There are different systems present in AOPs such as UV/O_3, UV/H_2O_2, UV/peroxydisulfate, photo-Fenton, and Fenton such as AOPs, etc. In the present study, we used photo-Fenton process (PFP) for the degradation of DCP. In PFP, the $^{\bullet}OH$ radical is created from Fe^{2+} catalyzed activation of H_2O_2, following a chain reaction (i.e., reactions (1)–(13)) [14,15], and as a result, $^{\bullet}OH$ radical attacks on focused pollutant causing its debasement [16]. H_2O_2 may react with Fe^{3+} to regenerate Fe^{2+} as well. The Fe^{2+} may also be regenerated through UV light according to Eq. (12). Meanwhile, the less oxidant radical species, that is, $HO_2^{\bullet}$ may also react with Fe^{3+} to regenerate Fe^{2+} as well as forming additional $^{\bullet}OH$ radical. This Fenton process has the advantage over many other techniques as it causes complete mineralization of the target contaminant through safe and non-toxic route. Although the efficiency of a photocatalytic system was generally reduced by mass transfer from the solution to the photocatalyst surface in fixed film reactors, which may limit the degradation reaction rates. However, mass transfer effect was not significant in Fenton and PFPs using homogeneous photocatalyst. The Fenton's reagents are easily soluble in water, constituting a homogeneous solution in aqueous medium, thereby avoiding the mass transfer limitation effects. Thus, in PFP, the catalyst (Fe^{2+}, Fe^{3+}) may play an essential role in the production of $^{\bullet}OH$ through electron exchange component by utilizing UV light radiation [17].

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

$$Fe^{3+} + H_2O_2 \rightarrow Fe^{2+} + HO_2^{\bullet} + H^+ \quad (2)$$

$$^{\bullet}OH + H_2O_2 \rightarrow HO_2^{\bullet} + H_2O \quad (3)$$

$$Fe^{2+} + {}^{\bullet}OH \rightarrow Fe^{3+} + OH^- \quad (4)$$

$$Fe^{3+} + HO_2^{\bullet} \rightarrow Fe^{2+} + O_2 + H^+ \quad (5)$$

$$Fe^{2+} + HO_2^{\bullet} + H^+ \rightarrow Fe^{3+} + H_2O_2 \quad (6)$$

$$HO_2^{\bullet} + HO_2^{\bullet} \rightarrow H_2O_2 + O_2 \quad (7)$$

$$HO_2^{\bullet} + H_2O_2 \rightarrow {}^{\bullet}OH + H_2O + O_2 \quad (8)$$

$$Fe^{3+} + H_2O_2 \rightarrow Fe(HO_2)^{2+} + H^+ \quad (9)$$

$$Fe(HO_2)^{2+} \rightarrow Fe^{2+} + HO_2^{\bullet} \quad (10)$$

$$Fe^{3+} + H_2O \rightarrow Fe(OH)^{2+} + H^+ \quad (11)$$

$$Fe(OH)^{2+} + h\nu\ (\lambda < 400\text{ nm}) \rightarrow Fe^{2+} + {}^{\bullet}OH \quad (12)$$

$$H_2O_2 + h\nu \rightarrow 2OH^{\bullet} \quad (13)$$

The $^{\bullet}OH$ radical basically assaults chlorinated carbon on benzene ring in DCP molecule. In PFP, the catalyst (Fe^{2+}/Fe^{3+}) decomposes H_2O_2 to deliver $^{\bullet}OH$ through electron exchange component within the nearness of UV (ultra violet). The PFP is relatively cost effective and environmental friendly process, since no supplementary vitality is required when compared with many other AOPs. Similarly, both hydrogen peroxide and iron are moderately conservative and safe [18].

According to the above mentioned discussion, photo-Fenton oxidation (PFO) was adopted for the effective remediation of recalcitrant pollutant DCP. As to the best of our knowledge, no research study is available on the PF-based degradation of DCP. The nitrates and bicarbonates are two of the more commonly inorganic anions found in natural water systems, which might affect the degradation efficiency of the pollutants based on various AOPs [19]. Investigating the effect of those anions on pollutant degradation may be useful on laboratory scale, considering practical applications. The aim of the current study is to remove DCP from the water system through safe and economical route. The concentration of Fe^{2+} and H_2O_2 has been optimized for the effective degradation of DCP besides pH optimization, as pH of the aquatic system greatly affects the degradation. To boost WTPs (water treatment processes), pH is an important factor that significantly influences the efficiency of PFP. Due to the presence of various organic and inorganic ions, natural water impacts on the removal efficiency of DCP by $UV/H_2O_2/Fe^{2+}$ at predetermined ideal conditions. Therefore the influence of HCO_3^- and NO_3^- on the degradation of DCP by PFP has also been conducted in the current exertion.

2. Materials and methods

2.1. Materials

Dichlorophene ($C_{13}H_{10}Cl_2O_2$, Fig. 1), H_2O_2 (hydrogen peroxide 30%), $FeSO_4 \cdot 7H_2O$ (ferrous sulfate hepta hydrate), HCl (hydrochloric acid 37%), $NaHCO_3$ (sodium nitrate), $NaNO_3$ (sodium bicarbonate), CH_3OH (methanol), CH_3COOH (acetic acid), and CH_3CN (acetonitrile) were bought from Sigma-Aldrich (St. Louis MO, USA). All chemicals were used as received. All the solutions were prepared in Milli-Q water. The pH of the solution was adjusted by adding appropriate amount of 0.1 N HCl or NaOH.

2.2. Degradation experiments

The photo-Fenton experiments were carried out in a bench-scale photochemical reactor comprising of a Pyrex Petri dish covered with a quartz plate. The solution was irradiated by a 15 W low pressure mercury UV lamp, which emitted UV light primarily at 254 nm. The intensity of the UV light was measured as 0.1 mW/cm^2 by using a calibrated radiometer. The reacting solution was constantly stirred using a magnetic bar to thoroughly mix the solution. The experiments were performed in triplicate. The error bars in the figures denote the standard error of the mean. A schematic diagram of PFP is depicted in Fig. 2.

2.3. Chemical analysis

The concentration of DCP was determined by using high performance liquid chromatograph (HPLC, Agilent 1200) with UV detector. An Eclipse (XDB-C18) column (150 × 4.6 mm, 5 micrometer particle size was employed for the separation of the analyte. The UV detection was performed at 280 nm, and the column temperature was maintained at 25°C. The mobile phase comprised of acetonitrile, methanol and acetic acid (50:30:20% v/v) at a flow rate of 1 mL/min.

3. Results and discussion

3.1. Direct UV photolysis of DCP

Fig. 3 depicts the result of direct UV photolysis of DCP in aqueous solution. The results showed that DCP was significantly degraded by direct UV photolysis, represented by 40% DCP removal in 50 min. Furthermore, the results revealed that the degradation efficiency of DCP increased with increasing UV radiation time, represented by 9%, 15%, 27%, 35% and 40% degradation, after 10, 20, 30, 40 and 50 min UV irradiation, respectively. The result was consistent with the studies of Dantas et al. [20] showing 50% and 30% removal of metronidazole and propranolol, respectively, in an 8-h UV-C irradiation. Mondal et al. [21] showed 60% degradation of ciprofloxacin in 120 min, using UV-C light irradiation. Similarly, Xie et al. [22] showed 83% degradation of 4-bromophenol in 20 min, by using direct UV photolysis. A plausible reason was the presence of a chromophore structure, such as unsaturated bond or aromatic ring, which have the capacity of UV light absorption [20].

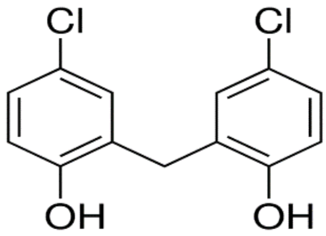

Fig. 1. Chemical structure of dichlorophene.

3.2. Degradation of DCP by UV/H_2O_2

The degradation of DCP by UV/H_2O_2 is shown in Fig. 3, indicating 60% degradation of 5 ppm in 50 min. The results revealed that the UV photolytic degradation of DCP was significantly enhanced by adding H_2O_2, attributed to $^{\bullet}OH$

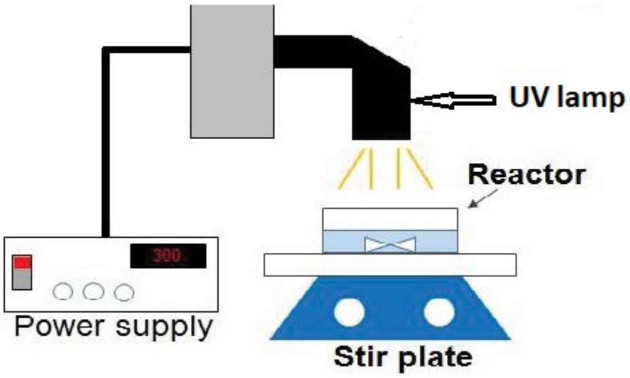

Fig. 2. A schematic diagram of photo-Fenton experimentation.

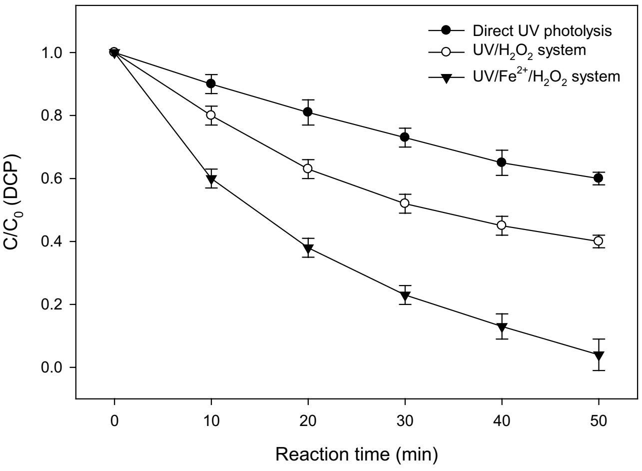

Fig. 3. Degradation of DCP with (i) direct UV photolysis, (ii) UV/H_2O_2 and (iii) UV/Fe^{2+}/H_2O_2 processes. $[H_2O_2]_0$ = 3 mM; $[Fe^{2+}]_0$ = 7 µM; $[DCP]_0$ = 5 ppm; pH = 3.0.

radical generated in Eq. (13). Furthermore, the results showed that the degradation efficiency of DCP by UV/H_2O_2 increased with the increasing concentration of H_2O_2, indicated by 47%, 55% and 60% degradation of DCP in 50 min at using 1, 2 or 3 mM H_2O_2, respectively (Fig. 4). The result was attributed to the elevated concentration of $^{\bullet}OH$ at using high concentration of H_2O_2. This result was consistent with the literature studies regarding the degradation of organic pollutants by UV/H_2O_2 system. Mondal et al. [21] showed the degradation of ciprofloxacin by UV-C light irradiation increased from 60% in 120 min to 100% in 40 min, by adding 100 mM H_2H_2 to the system, attributed to the generation of $^{\bullet}OH$ radicals. Khan et al. [23] found the degradation efficiency of lindane by UV/oxidant system increased from 58% to 92%, 98% and 100% after 180 min UV irradiation, by increasing the oxidant concentration from 125 to 250; 500 and 1,000 μM, respectively. Gu et al. [24] reported the apparent rate constants (k_{obs}) of ketamine and methamphetamine increased radically from 0.001 min^{-1} to 0.027 and 0.049 min^{-1} by increasing the H_2O_2 concentration from 0 to 1,000 μM, respectively.

3.3. Degradation of DCP by PFP (i.e., UV/Fe^{2+}/H_2O_2)

The degradation of DCP by PFP (i.e., UV/Fe^{2+}/H_2O_2) is shown in Fig. 3, indicating 96% removal of DCP (C_0 = 5 ppm) in 50 min, at using $[Fe^{2+}]_0$ = 7 μM and $[H_2O_2]_0$ = 3 mM. The enlarged degradation of DCP was attributed to enhanced $^{\bullet}OH$ radical generation owing to the involvement of Fe^{2+} according to reactions (1)–(13). Furthermore, the results showed that the degradation efficiency of DCP by UV/Fe^{2+}/H_2O_2 increased with the increasing concentration of H_2O_2, indicated by 80%. 90%, 93% and 96% degradation of DCP at using 0.5, 1, 2 or 3 mM H_2O_2, respectively, in 50 min (Fig. 4). The results also showed that the degradation efficiency of DCP by UV/Fe^{2+}/H_2O_2 increased with the increasing concentration of Fe^{2+}, indicated by 45%, 58% and 96% DCP removal in 50 min at using 2, 5 and 7 μM Fe^{2+}, respectively (Fig. 5). This was attributed to the elevated concentration of $^{\bullet}OH$ at high concentration of Fe^{2+}. This result was consistent with the literature about the degradation of organic pollutants by using UV/Fe^{2+}/H_2O_2 systems. Lucas and Peres [25] reported that the decolorization of the azo dye Reactive Black 5 by Fenton and PFO increased with the increasing concentration of Fe^{2+}. In case of Fenton process, by increasing the $[Fe^{2+}]_0$ from 5.0×10^{-5} to 2.0×10^{-4} M, the discoloration of Reactive Black 5 was enhanced from 72% to 95% after 7.5 min UV irradiation, while PFP enhanced the discoloration efficiency from 75% to 96% within the same reaction time. Khan et al. [26] also found the degradation of atrazine by UV/H_2O_2/Fe^{2+} dramatically increased by increasing the concentration of Fe^{2+} from 1.79 to 35.81 μM.

3.4. Factors affecting the degradation efficiency of DCP

3.4.1. Effect of solution pH

The pH of the solution is an important factor affecting the efficiency of Fenton and PFPs. The pH effects on Fenton and PFPs could be related to several reasons, for example, varying the solution pH may change the oxidation state of Fe^{2+}, etc. [27]. pH is also marked as an effective parameter in the optimization of WTPs, as it considerably affects the efficiency of many AOPs as well [28]. At both very low and high pH, iron is not soluble rather precipitates as manifested by Eq. (9); thereby hindering the degradation efficiency of the pollutants. In the current study, optimization of pH was done by studying DCP degradation at various pH, that is, ranging from acidic to basic conditions, including neutral pH, that is, investigating pH 2, 3, 6 and 9, while keeping other parameters constant, such as concentration of DCP, H_2O_2 and Fe^{2+}.

Table 1 shows the effect of pH on degradation efficiency of DCP by UV/Fe^{2+}/H_2O_2, represented by 65%, 96%, 91% and 59% DCP removal in 50 min, at pH 2, 3, 6 and 9, respectively. Based on experimental findings, pH 3 was selected as ideal pH for the degradation of DCP by photo-Fenton

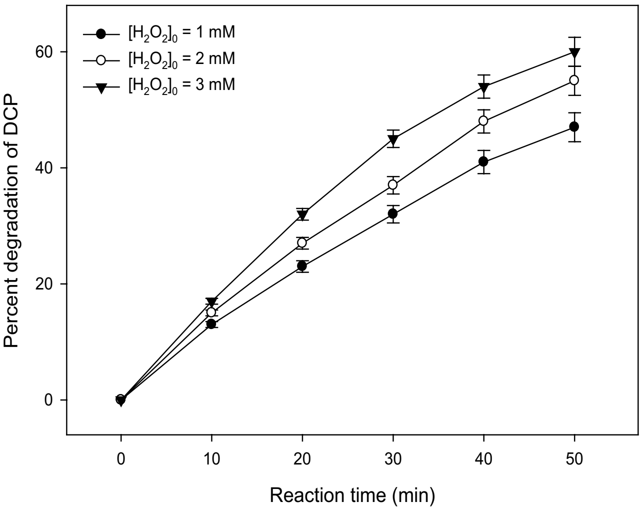

Fig. 4. Effect of initial concentration of H_2O_2 on DCP degradation by UV/H_2O_2 process. $[Fe^{2+}]_0$ = 7 μM; $[DCP]_0$ = 5 ppm; pH = 3.0.

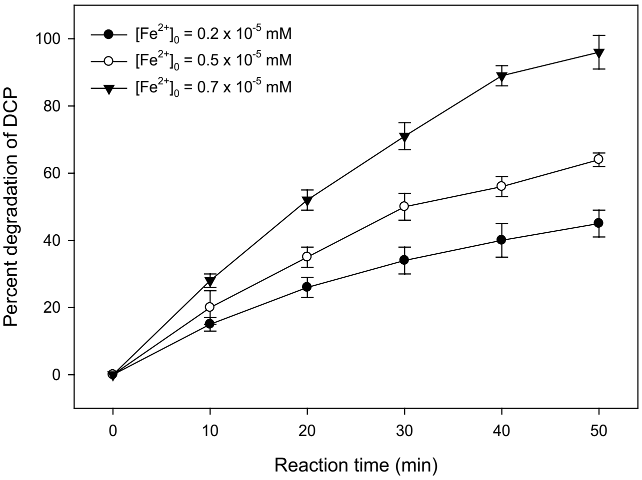

Fig. 5. Effect of initial concentration of Fe^{2+} on DCP degradation by UV/H_2O_2 process. $[H_2O_2]_0$ = 3 mM; $[DCP]_0$ = 5 ppm; pH = 3.0.

process, which led to 96% DCP removal in 50 min. The results obtained were supported by the literature studies [29,30]. Ghaly et al. [31] reported the degradation of p-chlorophenol by photo-Fenton process varied from 83% to 96%, 82% and 72% by increasing the pH from 2 to 3, 4 and 5, respectively. In our previous study, it was shown that the removal efficiency of lindane by photo-Fenton-like process was 98.2%, 42.5% and 36.4% after 40 min UV irradiation, when the initial pH was 3.0, 6.0 and 9.0, respectively [14], indicating pH 3 as the best pH condition. The maximum efficiency of DCP at pH 3 was attributed to the solubility of Fe^{2+} catalyst in the aqueous medium. Furthermore, Table 1 also depicts that the degradation efficiency of DCP at natural pH (i.e., pH 6) was also comparatively high, suggesting that the current process was an efficient approach for treating natural water and wastewater systems.

3.4.2. Effect of initial concentration of DCP

For conducting the kinetic studies, the photo-Fenton degradation of DCP was investigated at using different initial concentrations of DCP (i.e., 3, 4 and 5 ppm) at using constant concentrations of Fe^{2+} (7 μM) and H_2O_2 (3 mM) at pH 3. The results showed that degradation rate of DCP (calculated by the concentration change in the first 20 min) by photo-Fenton process under the optimized situation increased with the increasing initial concentrations of DCP, represented by 0.011, 0.018 and 0.023 ppm min^{-1} at using initial DCP concentrations of 3, 4 and 5 ppm, respectively (Fig. 6). Fig. 6 suggests that the degradation rate of DCP enhanced with increasing DCP concentration, imitating direct relationship of degradation rate with DCP concentration [29]. Meanwhile, it was shown that the apparent rate constant (k_{obs}) of degradation of DCP decreased with increasing concentration of DCP (Fig. 6). The observed rate constant (k_{obs}) of DCP was found to be 0.058, 0.043 and 0.034 min^{-1}, respectively, at initial DCP concentrations of 3, 4 and 5 ppm, respectively (Fig. 6). Khan et al. [14] found that the degradation rate of lindane by photo-Fenton-like process increased from 0.023 to 0.175 μM min^{-1} by varying initial lindane concentrations of lindane from 0.5 to 5.0 mM, respectively. A probable reason was the greater number of DCP molecules being exposed to the •OH radicals, which might led to an enhanced degradation rate of DCP [14]. Degradation of pollutants by Fenton and photo-Fenton based advanced oxidation processes generally followed first order kinetics [13]. In this study, the degradation of DCP was carried out at using three different concentrations of DCP, that is, 3, 4 and 5 ppm, and the graphs of $-\ln C/C_0$ vs. k were plotted at different time intervals (t) that gave straight lines with R^2 values greater than 0.95 in each case (Fig. 7). These graphs were successfully explained by first order kinetics equation, as shown by reaction (14) [14]. Table 2 presents a comparative degradation analysis of various contaminant by conventional methods with our established system, which clearly signifies the superiority of our approach.

Table 1
Parameters for degradation of DCP (5 ppm)/H_2O_2 (3 mM)/Fe^{2+} (7 μM) at various pH

pH	% Degradation at reaction time of 50 min	k_{app} (min^{-1})	R^2
2	65	0.054	0.985
3	96	0.057	0.982
6	91	0.047	0.987
9	59	0.053	0.917

$$\ln\frac{C}{C_0} = kt \tag{14}$$

3.4.3. Effect of inorganic anions, that is, NO_3^- and HCO_3^-

Depending upon the anthropogenic and ecological conditions, natural water bodies are abundant in a variety of inorganic anionic species, especially nitrates and bicarbonates, in unpredictable levels ranging from 0.00005 to 0.003 [34]. These inorganic anionic species are reported to have elevated rate constants with •OH radical and hence can act as scavengers of •OH radical, which may affect the degradation kinetics of the pollutants [35,36]. Fig. 8 shows the effect of NO_3^- and HCO_3^- on the degradation efficiency of DCP by PFP, while keeping all other parameters constant, that is, $[DCP]_0$ = 5 ppm, $[H_2O_2]_0$ = 3 mM and $[Fe^{2+}]_0$ = 7 μM, at pH 3. The results showed that in the presence of 1 ppm NO_3^- and HCO_3^- ions, the degradation efficiency of DCP decreased from 96% to 86% and 74%, respectively. The corresponding apparent rate constant (k_{app}) also decreased from 0.058 min^{-1} to 0.035 and 0.033 min^{-1}, in the presence of 1 ppm NO_3^- and HCO_3^-, respectively. The retarding effect due to the presence of NO_3^- and HCO_3^- was attributed to the scavenging of •OH radical by these anions according

Table 2
Comparative degradation analysis of various contaminants by conventional methods

Compound	Methods/material	% Degradation	Reference
Methylene blue	ZnO reduced grapheme, oxide-carbon composites	96%	[32]
DCP	Photoelectrocatalytic mechanism by using TiO_2 and active polytetarafluroethylene	91.1%	[33]
Phenol	In the presence of hydrogen peroxide	48%	[8]
Carbamazapine	Photo-Fenton process	90.6%	[11]
DCP	$UV/H_2O_2/Fe^{2+}$	95.5%	Present study

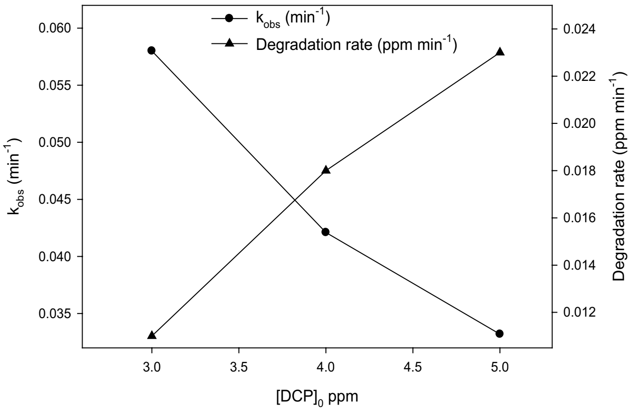

Fig. 6. Variation of k_{obs} and degradation rate with different initial concentration of DCP by UV/Fe^{2+}/H_2O_2 process. $[H_2O_2]_0$ = 3 mM; $[Fe^{2+}]_0$ = 7 μM; pH = 3.0.

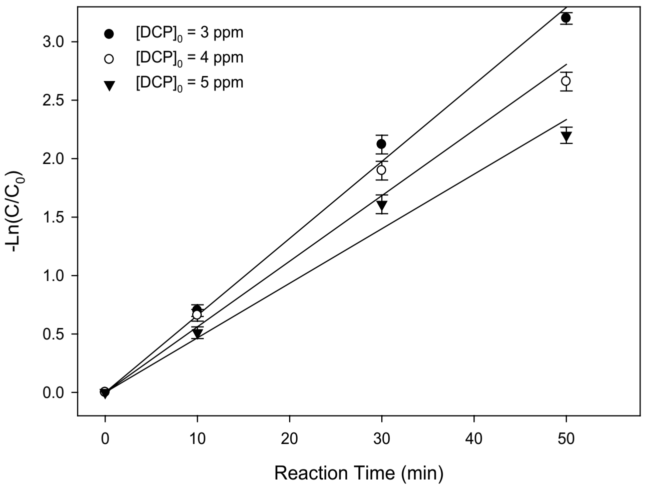

Fig. 7. Plot of $-\ln(C/C_0)$ vs. time for degradation of DCP with UV/Fe^{2+}/H_2O_2 processes. $[H_2O_2]_0$ = 3 mM; $[Fe^{2+}]_0$ = 7 μM; $[DCP]_0$ = 3, 4 and 5 ppm; pH = 3.0.

to reactions (15) and (16), respectively. Khan et al. [37] found that the apparent rate constants (k_{obs}) of degradation of antipyrine by UV/H_2O_2 decreased from 1.99 to 1.96 h^{-1} and 1.34 h^{-1}, in the presence of 100 mM of NO_3^- and HCO_3^-, respectively. Keen et al. [15] reported that UV (λ < 200 nm) photolysis may generate additional •OH radical from NO_3^-; however, in the current study, the reaction is not likely to be efficient owing to the low quantum yield of •OH from NO_3^- under the UV-C (λ = 254 nm) light. Tan et al. [38] found the degradation of the pharmaceutical compounds, such as ibuprofen, diphenhydramine and phenytoin was reduced in the presence of NO_3^- and HCO_3^-, attributed to the scavenging of •OH radicals by these anions.

4. Conclusions

Dichlorophene (DCP), a widely detected contaminant in the aquatic environment was removed under the UV-254 nm irradiations based on AOPs. The removal efficiency of DCP from water is enhanced by coupling UV with oxidant (H_2O_2) and/or catalyst (Fe^{2+}), that is, UV/H_2O_2 and UV/H_2O_2/Fe^{2+} process. The •OH radical generated under UV/H_2O_2, UV/H_2O_2/Fe^{2+} or UV/H_2O_2/Fe^{3+} systems was mainly responsible for the substantial removal proficiency of DCP. The degradation of DCP was high in indirect photolysis due to the ample production of •OH radicals, which could attack DCP molecules. The degradation rate of DCP increased with the increasing concentration of DCP from 3 to 5 ppm, since large number of DCP molecules get exposed to •OH radicals resulting in enhanced degradation rate of DCP. Optimization studies by fixing other parameters constant ratified that degradation of DCP increased with increasing concentration of H_2O_2 till 3 mM H_2O_2 and then suffers decline with further increase in H_2O_2 till 5 mM suggesting its role as •OH radicals scavenger. Optimization of Fe^{2+} catalyst at DCP (5 ppm)/H_2O_2 (3 mM) suggested 7 μM concentration as a best dose resulting in 96% degradation in 50 min, with 0.051 min^{-1} apparent rate constant. The most competent degradation of DCP after 50 min of irradiation time under ideal PF environment, that is, DCP (5 ppm)/H_2O_2 (3 mM)/Fe^{2+} (7 μM) was achieved in acidic media at pH 3 with 96% degradation efficacy and 0.058 min^{-1} suggesting our present system an economic, rapid and effective tool for environmental reclamation. Studies of scavenger effect elucidated that the presence of NO_3^- and HCO_3^- ions decreased the degradation efficiency of DCP from 96% to 86% and 74%, respectively.

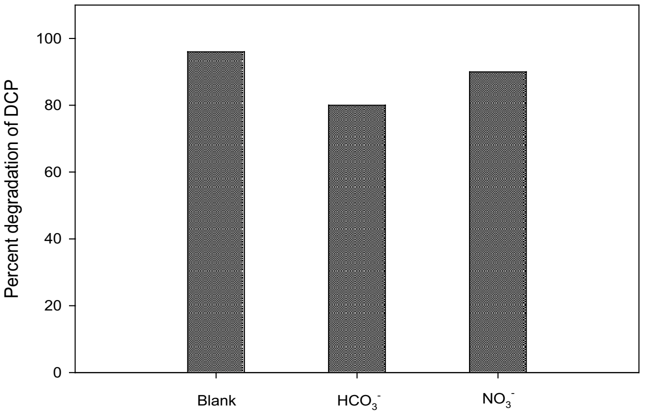

Fig. 8. Effect of NO_3^- and HCO_3^- on percentage removal of DCP in 30 min. $[H_2O_2]_0$ = 3 mM; $[Fe^{2+}]_0$ = 7 μM; $[DCP]_0$ = 3 ppm; $[NO_3^-]_0$ = 1 ppm; $[HCO_3^-]_0$ = 1 ppm; pH = 3.0.

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