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DISINFECTION OF WATER CONTAINING E. COLI BY PHOTOCATALYTIC ROUTE USING TiO2/UV/VISIBLE LIGHT SOURCE

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ABSTRACT

Disinfection of water containing E. coli is a major concern. The objective of this research is to disinfect the water containing E. coli by photocatalytic route using TiO2 and Carbon doped TiO2 and comparison of the two. The photocatalytic disinfection was tested under UV light and visible light irradiation. The experiments were carried out using different culture concentrations and different catalyst concentrations. It was examined that 99.94% disinfection occurs at 0.2 grams C-doped TiO2 concentration per 200 ml of solution.

KEYWORDS: *disinfection, E. coli, photocatalysis, TiO2*

I. INTRODUCTION

Conventional methods of disinfection of water are not so effective and there are problems associated with the usage of very expensive instruments [1]. Photocatalysis has appeared as an alternative technology for water disinfection [2]. Photocatalytic disinfection of bacteria by TiO_2 has merited increasing scientific attention [3]. The other disinfection methods like chlorination, reverse osmosis are effective against most pathogens but are too costly to implement. Advanced oxidation technologies, including semiconductor photocatalysis, make available the alternatives for the disinfection of contaminated water in situations. Heterogeneous photocatalysis utilizes light energy along with a semiconductor which produces reactive oxygen species (ROS) which can inactivate bacteria [4].

The capacity of titanium dioxide (TiO_2) to degrade contaminants has been studied for more than 20 years [5]. TiO_2 is non-toxic for humans and is widely used as a self-cleaning material in many applications such as surface coating etc. [6]. TiO_2 occurs as rutile, brookite and anatase phase. Rutile and anatase are the photocatalytic active forms of TiO_2 [7].

The TiO_2 photocatalyst is found as inhibitory agent for bacterial growth. It is used in the form of powder, films and nanocomposits with UV light as well as visible light [8]. When irradiated TiO_2 particles come in direct contact with or close to microbes, the microbial surface becomes the primary target of the initial oxidative attack [9]. The wavelength range of UV-C irradiation is from 100 nm to 290 nm [10].

During the photocatalytic disinfection process, the illumination of semiconductor photocatalyst with UV radiation activates the catalyst and establishes a redox environment [11]. The energy difference between valence band and conduction band is known as band gap. Many semiconductors have band gap energies sufficient for catalyzing chemical reactions. [12].

The holes (h^+) and electrons (e^-) are generated on the surface of TiO_2 when it is exposed to light during photocatalysis [13]. Holes can oxidize and kill bacteria. Extensive work had been carried out to evaluate bactericidal effect of TiO_2 in powder form using UV light [14-18].

The most studies in the field of photocatalysis have been done on bacteria specially e. coli because e. coli is a representative of all the bacteria [19]. The practical application of TiO_2 is limited for several reasons such as low photon efficiency and use of UV as an excitation source. The modifications of this catalyst are made by doping it with various materials to solve these problems [20]

II. EXPERIMENTAL

2.1 Materials and methods

The standard strain of E. coli (ATCC) was procured from department of Microbiology, Bharati Vidyapeeth Medical College, Pune, India. The culture was grown in a nutrient broth at 37^0C for 24 hrs. The required bacterial concentration was adjusted by serial dilution method.

2.2 Reactor set-up

The experiments were conducted in a 0.2 dm^3 Quartz reactor in a 0.04 m^2 dark room as shown in Figure 1. All glass wares were autoclaved at 121^0C for 30 minutes. First different serial dilutions were made and the culture was plated on nutrient agar plates and incubated for 24 h at 37^0C. The desired colonies were obtained when culture was diluted five times where colony forming units (CFUs) were calculated as $2.19*10^7$. The nutrient agar medium was prepared and poured in petri dishes. Then the first set of experiment was carried out by varying catalyst loading as 0.05, 0.1 and 0.2 g. The best results were obtained at 0.2 g. Then the second set of experiment was conducted at optimized catalyst loading i.e. 0.2 g. And the solution was diluted by serial dilution method. Above two sets of experiments were carried out under UV light irradiation (125 Watt). Now, the optimized catalyst loading was kept constant i.e. 0.2 g. And culture concentration was varied and treated under visible light irradiation (125 watt). Above all experiments were performed using Carbon doped TiO_2 catalyst.

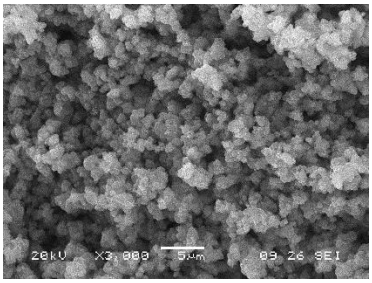
The next three sets of experiment were performed using TiO_2 catalyst under UV light irradiation (125 Watt). The culture concentration of was varied. The optimized catalyst loading was used i. e. 0.2 g. Also three experiments were performed using Carbon doped TiO_2 catalyst under Visible light irradiation (125 Watt). The samples of each experiment were collected every 30 minutes. The best results were obtained at 10^4 dilution factor.

The photocatalysts were characterized by Scanning Electron Microscopy (SEM) and X-ray diffraction (XRD).

Figure1. Experimental Set up.

III. RESULTS AND DISCUSSION

SEM results of TiO_2 and C-doped TiO_2 were obtained using Scanning Electron Microscope as shown in figure 2. SEM is widely used to identify phases based on quantitative chemical analysis or crystalline structure.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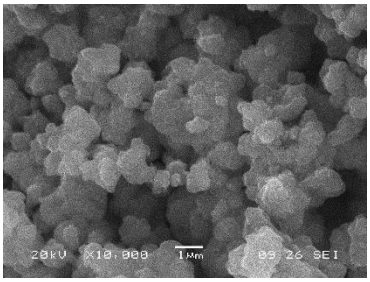
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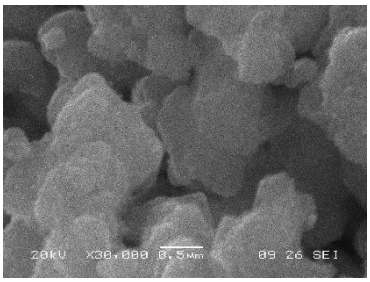
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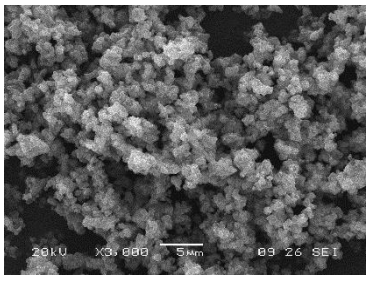
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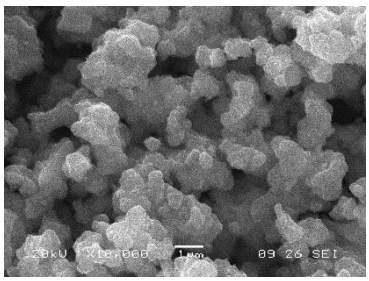
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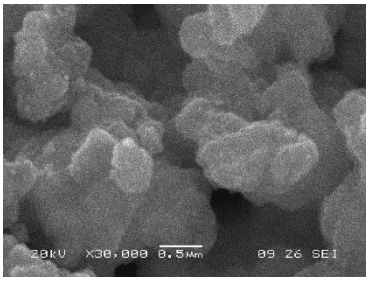
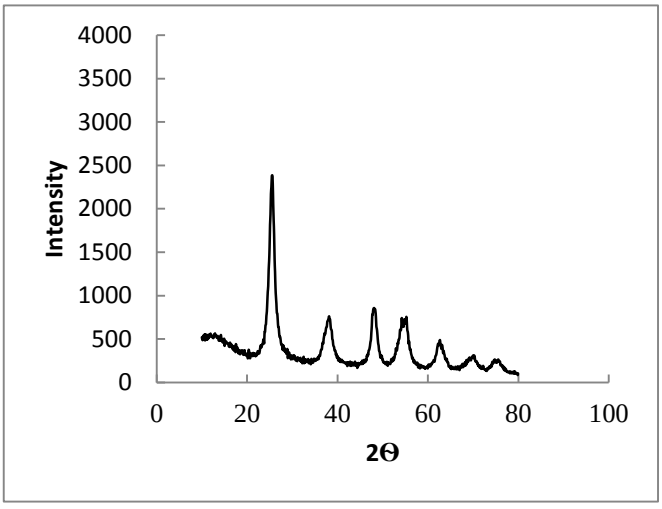
(e)



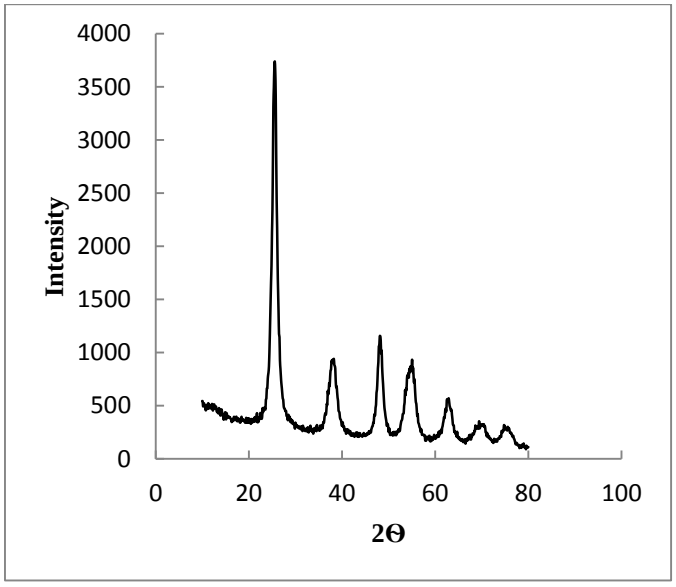
(f)

.**Figure2.** SEM analysis of catalyst: (a), (b), (c) for TiO_2 and (d), (e), (f) for C-doped TiO_2

The XRD pattern of both the catalysts is as shown in figure 3. X ray diffraction is most widely used for identification of fine-grained materials that are difficult to determine optically. Both the phases rutile and anatase .were found in X ray diffraction.



(a)



(b)

Figure3. XRD pattern of TiO2 (a) and C-doped TiO_2 (b)

The treated solution was plated on nutrient agar plate every 30 minute. The plates were incubated for 24 h at 37^0C. The colonies were counted by standard plate count method. The % disinfection was calculated. The solution having total dilution factor 10^4 got the best results at 0.2g catalyst loading which was optimized as shown in table 1. The results are shown in graphical form as shown in figure 4.

Table 1: % Disinfection of solution having dilution factor 10^4

Time (min)	**% Disinfection**		
	0.05 g TiO_2	0.1 g TiO_2	0.2 g TiO_2
0			
30	36.67	64.38	97.72
60	95.43	69.40	98.17
90	96.80	79.45	99.08
120	98.83	89.49	99.54

The solution was serially diluted and was treated with 0.2g C-doped TiO_2 under UV light irradiation. The 99.94% disinfection was obtained after 120 minutes of the solution having 10^4 total dilution factor as shown in table 2. The disinfection achieved is because of combined action of TiO_2 with UV. The graphical results are as shown in figure 5.

Table 2: % Disinfection using C-doped TiO_2 under UV light irradiation

Time (min)	**% Disinfection**		
	DF 10^2	DF 10^3	DF 10^4
0			
30	8.37	14.05	15.67
60	11.37	30.65	25.22
90	19.63	94.35	99.42
120	93.93	99.4	99.94

In next set the solution containing e. coli was treated using TiO_2 under UV light irradiation. The samples were taken every 30 minutes. Very negligible disinfection occurred in the solution having 10^2 and 10^3 dilution factor. 96.08% disinfection occurred in solution having 10^4 dilution factor using 0.2 g catalyst loading as shown in table 3 and the graphical representation is as shown in figure 6.

Table 3: % Disinfection using TiO_2 under UV light irradiation

Time (min)	**% Disinfection**		
	DF 10^2	DF 10^3	DF 10^4
0			
30	-	-	83.1
60	-	-	84.67
90	-	-	89.53
120	-	-	96.08

In last set of experiment the solution containing e. coli was treated with 0.2g C-doped TiO_2 under Visible light irradiation. The disinfection went up to 99.1% after 120 minutes of solution having 10^4 dilution factor as shown in table 4. The disinfection was achieved due to the combined action of TiO_2 and UV radiation [21]. The graphical results of % disinfection are as shown in figure 7.

Table 4: % Disinfection using C-doped TiO_2 under visible light irradiation

Time (min)	**% Disinfection**		
	DF 10^2	DF 10^3	DF 10^4
0			
30	5.37	7.32	2.5
60	67.97	77.28	78.6
90	89.46	92.04	94.45
120	95.8	95.12	99.1

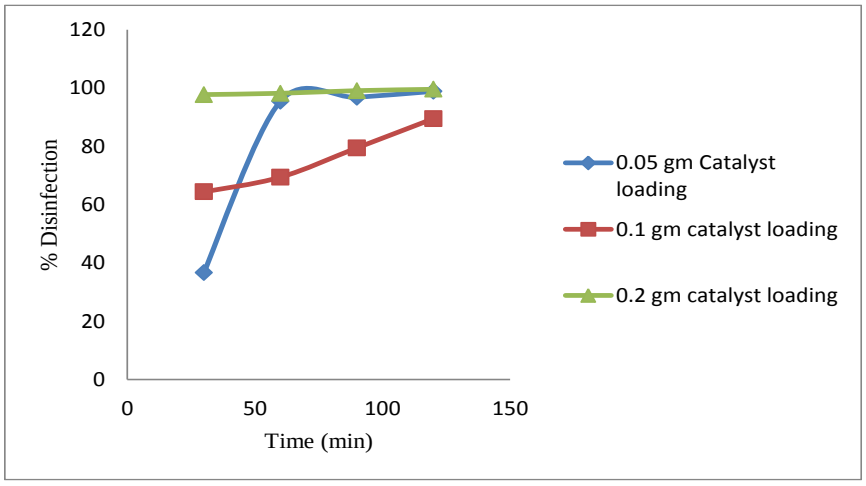


Figure4: C-doped TiO_2 under UV/Visible light irradiation (10^4 dilution factor)

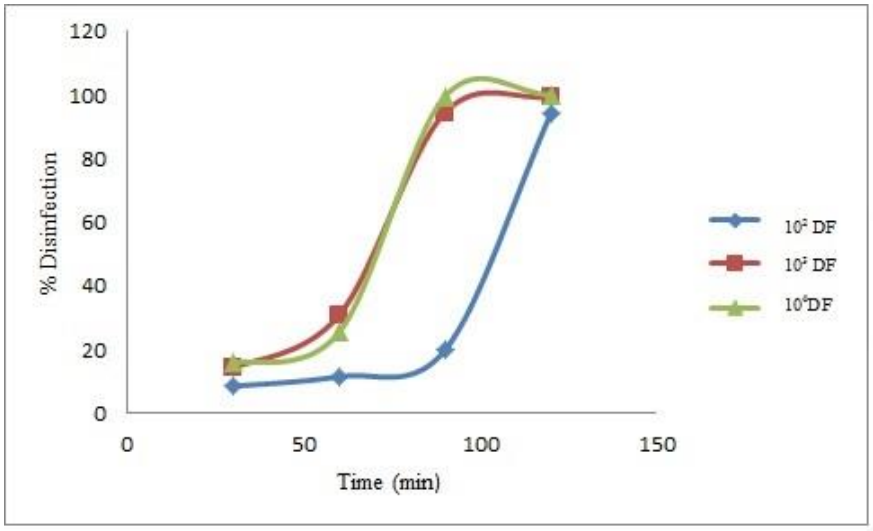


Figure5. C-doped TiO_2 under UV/Visible light irradiation (0.2 g catalyst loading)

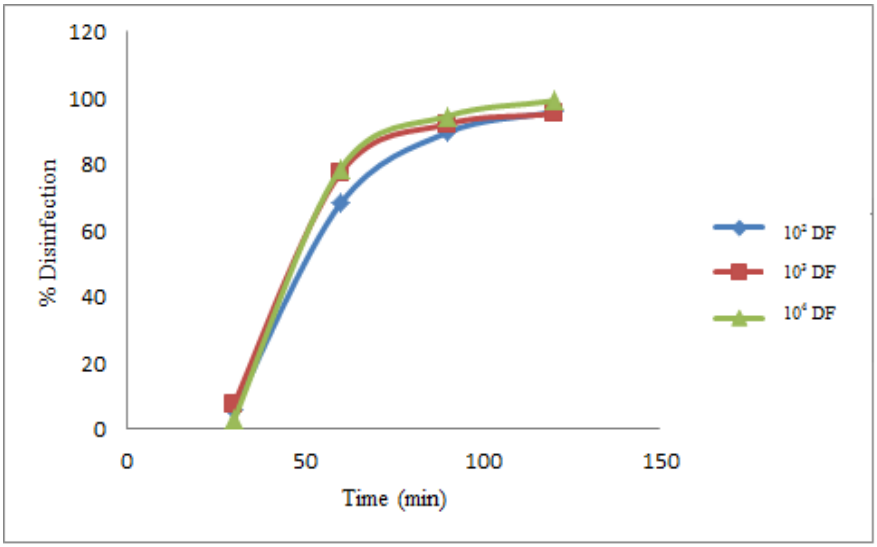


Figure6. C-doped TiO_2 under visible light irradiation (0.2 g catalyst loading)

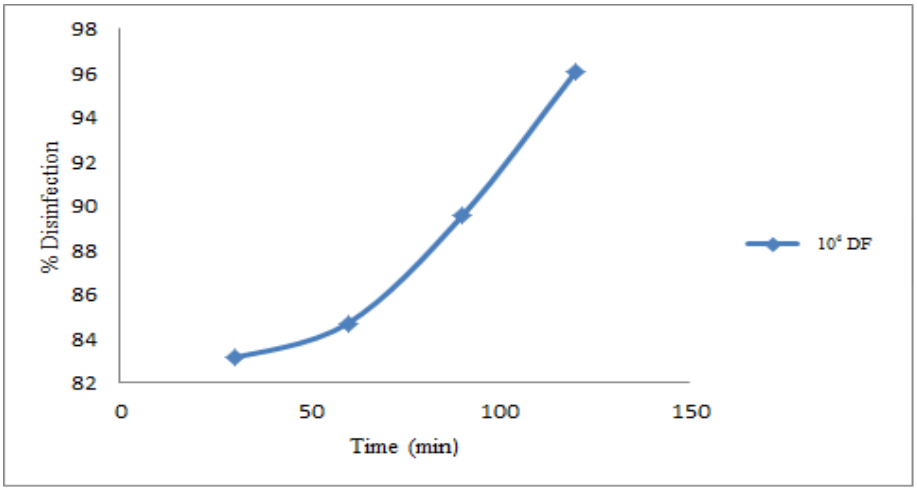
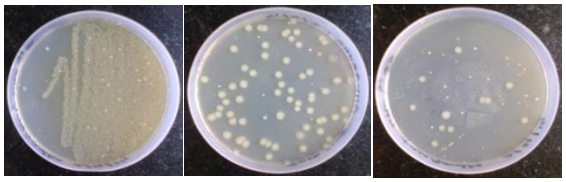
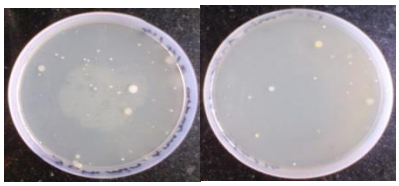


Figure7. TiO_2 under UV light irradiation (0.2 g catalyst loading)



(a) (b) (c)



(d) (e)

Figure8. E. coli population during photocatalytic disinfection: (a) initial population, and population after (b) 30 min, (c) 60 min, (d) 90 min, (e) 120 min of treatment

Another experiment was carried out to treat natural water containing E. coli. The sample was taken from Mula-Mutha River, Pune, India. The analysis was done for E. coli test and the standard plate count method. The CFU per 100ml were found >1600 by IS 5887 method. The sample was treated using C-doped TiO_2 under both UV and Visible light irradiation for 240 minutes. 95.6% disinfection was obtained after 240 min under UV/visible light irradiation and 91.65% disinfection was obtained after 240 min under visible light irradiation.

IV. CONCLUSION

This work shows that photocatalysis can be used for disinfection of water. The C-doped TiO_2 performed well and disinfected 99.94% E. coli after 120 min of irradiation under UV light whereas it disinfected 99.1% E. coli under visible light irradiation after 120 min which may be combined effect of UV and TiO_2 However there is need of suitable reactor configuration so as to implement this system on commercial scale.

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