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UV/O_3 Aided Advanced Oxidation Process in Wastewater Treatment Technology

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ABSTRACT

Wastewater treatment for industrial effluent can be carried out by various physical, chemical and biological treatment methods. For removal of various organic and inorganic pollutants various advanced methods are used with good effect. The general strategy of this study was based on applying Advanced Oxidation Process (AOP) of (UV/O_3) for reduction of COD of effluent wastewater. Various parameters affect the oxidation process such as pH, Ozone dose and exposure time of UV. The optimized conditions were found to be pH: 7, the ozone dose of 4gm/hr and 60 min UV exposure. Finally, chemical oxygen demands (COD), before and after oxidation process was measured to ensure the entire destruction of organic load.

INTRODUCTION

One of the basic requirements for all living organism including human beings is clean and non-polluted water. Nowadays its availability is major problem [1]. Advances in technology have resulted in greater water demands for industry [2-4]. Generation of wastewaters in industrial processes is sometimes unavoidable and in most cases a process to reduce the organic load and other contaminants must be employed before water discharge. [5] This wastewater contains a variety of suspended solids, oils, metals, and organics. The successful cleaning of these new wastewaters prior to discharge, using existing treatments, has yet to be improved comparatively [2-4]. In some cases, however, due to the high organic load, toxicity or presence of bio-recalcitrant compounds, biological processes cannot be used, since no chemical oxygen demand (COD) removal is achieved biologically. Among chemical processes, the advanced oxidation process (AOP) has been used to reduce the organic load or toxicity of different waters and wastewaters [5-7]. AOPs are based on the generation of hydroxyl free radicals, which have a high electrochemical oxidant potential. The generation of hydroxyl radicals involves the combination of classical oxidants, such as hydrogen peroxide (H_2O_2) or ozone (O_3) with UV radiation or a catalyst. The formed radicals react with organic materials breaking them down gradually in a stepwise process. The generation of hydroxyl radicals can be achieved by a variety of reactions, such as ozone/UV [8], hydrogen peroxide/UV [9], Fenton oxidation [10], photo-Fenton [9, 11] or titanium dioxide/hydrogen peroxide/solar radiation [12]. The advantage of AOPs is that they effectively destroy the organic compounds, converting them mainly to carbon dioxide and water. Advanced oxidation processes (AOPs) are technologies based on the intermediary of hydroxyl and other radicals to oxidize recalcitrant, toxic and non-biodegradable compounds to various byproducts and eventually to inert end-products [13,14].

In view of above, this work aims at studying the effect of select UV/O_3 AOP process for waste water treatment containing high organic content so as to achieve reduction in total organic load measured in terms of chemical oxygen demand (COD). In this study, O_3 was used in combination with UV under varying conditions for the treatment of wastewater.

MATERIALS AND METHODS

Effluent water used in this study was obtained from the effluent treatment plant of Ankleshwar, Gujarat, India. Effluent water was analyzed for its characteristics. Various physicochemical parameters were estimated as per the Standard Methods for examination of water and wastewater [15]. For the COD estimation; sample (20 ml) was refluxed on Gerhardt assembly with a known volume (10ml) of potassium dichromate (0.25N) for 2 hrs, after digestion it was titrated against Standard Ferrous Ammonium Sulphate (0.1N). Chemicals used in the study were supplied by Fisher Scientific (Qualigence fine chemicals), Mumbai, India. All the reagents were of analytical grade and the solutions were prepared with deionized water. The reactor used in the study is detailed as given in Fig. 1 and its experimental conditions are depicted in Table 1. All the experiments were performed in the completely cylindrical photo-reactor made of the glass with a total volume of 2L and water column height of 30cm. The UV irradiation source was 15W (TUV 15W/G15 model Phillips) low-pressure mercury vapor lamp (maximum emission 254nm) placed in quartz tube. A novel air cooling system was introduced instead of commercially available water cooling jacket; which is very parsimonious compared to available treatment system. The reactor was covered with an aluminum foil to avoid the light leakage to the outside. The effluent sample (1.5 liters) was uniformly mixed by an aerated pump of 10.5 liters/min capacity.

Sample was then exposed to the UV lamp of 15W for a specified period of time. The experiments were started by turning the UV lamp on after the addition of reagents. After the completion of the experiment, the sample was withdrawn from its outlet pipe and stirred well on magnetic stirrer. The sample was then analyzed for COD. Samples were removed from the reactor at predetermined time intervals for the immediate analysis of COD. ELTECH Ozone Generator was used to generate ozone. Varying doses of ozone (1 – 10 gm/hrs) were introduced individually and COD reduction was found out. A bench scale pH meter (Orion plus) was used for pH measurement. COD analysis was carried out on Gerhardt assembly. The COD analysis was followed [15]. Similar procedure was performed with varying exposure time of UV light (15-280 min), O_3 dose (1-10gm/hrs) and pH (4-10) so as to optimize these parameters. The removal efficiency of each set of samples was estimated by applying following formula:

$$\text{Photocatalytic degradation efficiency } (\eta) = \frac{\text{Initial COD} - \text{Final COD}}{\text{Initial COD}} \times 100$$

RESULTS AND DISCUSSION

Wastewater effluent from Ankleshwar, Gujarat is highly organic in nature with high COD, total organic carbon (TOC) and phenol content. The conventional treatment methods cannot be completely degrade or remove the pollutants from the wastewater released from treatment plants. In the present study, the optimum experimental parameters for photocatalytic treatment of wastewater effluent are determined for effective degradation of organic pollutants in the effluents.

Table 2 depicts the physicochemical parameters of the effluent wastewater. pH was found to be in the range of 7.1-8.3, COD was found in the range of 848-1380mg/lit and phenol concentration was 0.59-1.89mg/lit.

Optimization of UV exposure

A set of experiments were carried out to optimize exposure time of UV radiation for wastewater (1.5 L) in the reactor. The intensity of 15W UV lamp was in the range of 200-280nm which remained constant for all the experiment. In this experiment, radiations time was varied and samples were collected and analyzed. The result in COD reduction in raw wastewater samples with variable time exposure of UV radiation is shown in Table 3.

It was observed in Fig. 3 that there was increase in COD reduction found up to 60 min whereas further exposure with time did not show considerable reduction irrespective of original COD concentration. UV exposure to wastewater samples with an initial COD of 600mg/lit showed a reduction of 21% at 15 minutes exposure time and increased to 40% COD reduction with increase in UV exposure time to 60 min.

Optimization of pH

In the experiments, the pH of the samples was varied in the range of 4-10 in order to arrive at optimized pH. Finally, experiments were conducted at the optimized pH and COD reduction was determined. The results are presented in Table 4. In Fig 4, it was observed that with the initial

COD concentration of 620 mg/lit there is gradual reduction in COD at pH 7 (70% reduction) with the UV exposure of one hour and further reduction in increase in pH did not show considerable results. It was also observed that after UV exposure there was no considerable change in pH at neutral stage (pH 7.0).

Optimization of Ozone dose

Raw effluent was introduced into the lab scale AOP reactor consisting UV lamp (15W) and varying doses of ozone (1-10gm/hrs) were introduced individually and COD reduction was found out. The results are presented in Table 5. Fig 5 shows COD reduction occurs at the ozone dose of 4gm/hr.

Reduction in COD of effluent wastewater at optimized conditions

Table 6 shows the reduction in COD at the optimized conditions of AOP of ozone dose and UV exposure.

CONCLUSION

From the above experiments, we can conclude that Advance Oxidation process is very effective in the wastewater treatment process. Reaction at optimized conditions of UV exposure of 15W lamp for one hour and O_3 dose of 4gm/hr at pH of 7 shows the effective reduction in COD of effluent wastewater. It can be concluded that proper choice of treatment method and suitable combination of treatment methods can make the wastewater treatment more economical, effective and acceptable.

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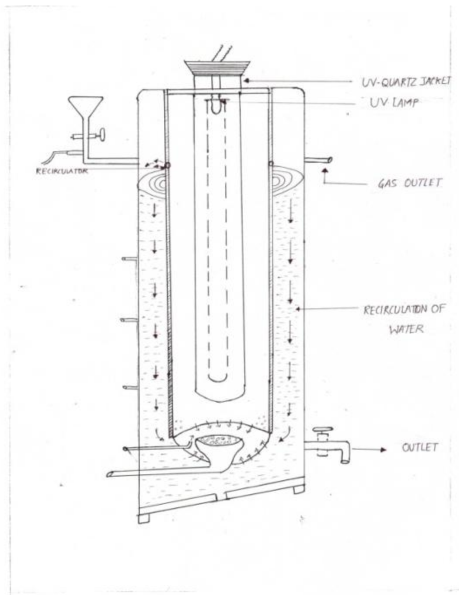

Figure 1: Representative Sketch of the photochemical reactor used in the study

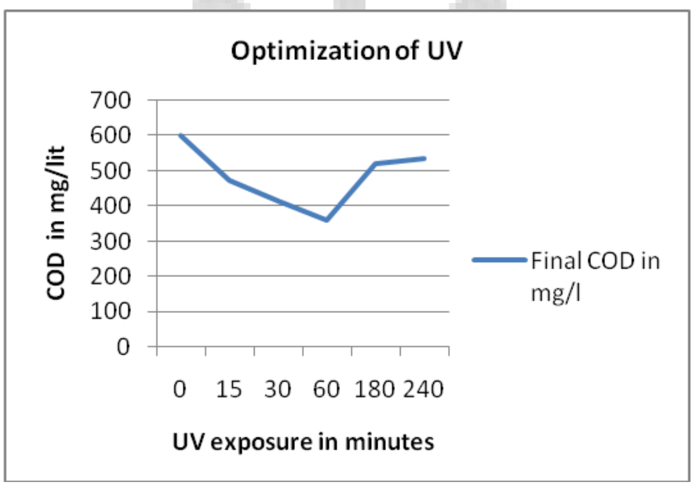

Figure 2: Optimization of UV Exposure

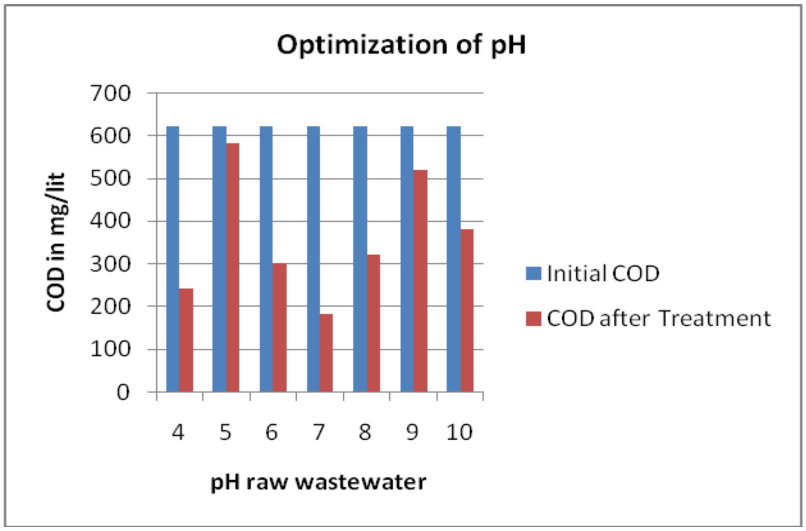

Figure 3: Optimization of pH at 1hr UV Exposure

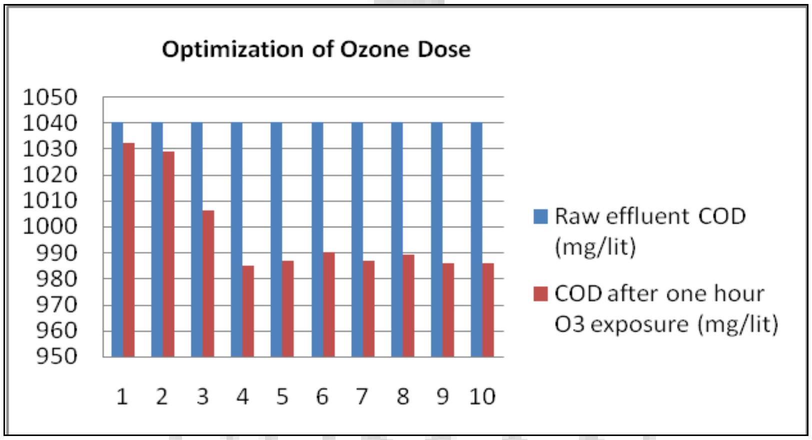

Figure 4: Optimization of Ozone Dose at 1hr UV Exposure

Table 1: Experimental Conditions for AOP Photo-reactor

Parameter	Value
Temperature	25 ± 2^{0}C
Water Column Height	30 cm
UV lamp (irradiation)	15 W UV-C (200-280 nm)
Capacity of Photo-reactor	1.5 L

Table 2: Physicochemical parameters of raw wastewater

Parameters	Range
pH	7.1-8.3
Alkalinity (mg/L)	350-518
TOC (mg/L)	191.4-274
BOD (mg/L)	200-500
COD (mg/L)	848-1380
Total nitrogen (mg/L)	89-294
Phenol (mg/L)	0.59-1.89
Total Hardness (mg/L)	728-908

Table 3: Optimization of UV exposure

Initial COD 600 mg/l

Time of Exposure (minutes)	Final COD in mg/l	% Reduction
15	473	21
30	416	30
60	360	40
180	520	13
240	535	10

Table 4: Optimization of pH at 1hr UV exposure

Initial COD 620mg/lit

pH	Initial pH	Final pH	Exposure time (hour)	COD in mg/l Treated	% Reduction
4	4	4.83	1	240	61
5	5	5.23	1	580	6.4
6	6	6.46	1	300	51
7	7	7.56	1	180	70
8	8	7.89	1	320	48
9	9	8.75	1	520	16
10	10	9.45	1	380	38

Table 5: Optimization of Ozone dose

Ozone Dose (gm/hour)	Raw effluent COD (mg/lit)	COD after 1 hr O_3 exposure (mg/lit)
1	1040	1032
2	1040	1029
3	1040	1006
4	1040	985
5	1040	987
6	1040	990
7	1040	987
8	1040	989
9	1040	986
10	1040	986

Table 6: Reduction in COD at optimized conditions

Initial COD of Effluent mg/lit	Advance Oxidation Process (AOP)		COD of effluent after treatment	% Reduction in COD
	Ozone dose (gm/hr)	UV (Watt)		
1040	04	15	630	39

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