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Advanced Oxidation Process for Wastewater Treatment Using H_2O_2 and UV Method

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Abstract

Advanced oxidation processes (AOPs) are being identified as potential technologies for wastewater treatment and improvement of conventional biological treatment processes, especially for wastewater with highly toxic and poorly biodegradable organic compounds. In the present work, wastewater samples were obtained from Kala Odha in Ichalkaranji. Several parameters of the wastewater, such as pH, turbidity, total dissolved solids (TDS), total suspended solids (TSS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total Kjeldahl nitrogen (TKN), total phosphorus, and total alkalinity, were determined by standard methods. The best dose of hydrogen peroxide (H_2O_2) and the best treatment time were established by using a photochemical reactor in batch mode. The research revealed that the highest COD removal efficiency of 74.41% was obtained with a concentration of 300 mg/L of H_2O_2 after a reaction time of 90 minutes, from an initial COD of 1720 mg/L.To further optimize the treatment process, COD tests were also performed at different time intervals. The results showed that a reaction time of 75 minutes produced the maximum COD removal efficiency of 76.27% at the optimum dose of 300 mg/L of H_2O_2 with an initial COD of 2360 mg/L. Based on the findings, it is clear that the combined application of H_2O_2 and UV methods is a promising solution for efficient removal of COD from wastewater.

Introduction

Advanced oxidation processes evolved initially in the 1960s when scientists first started to treat wastewater with powerful chemicals such as hydrogen peroxide(H_2O_2) and ozone (O_3) Techniques using the term came to describe methods for degrading difficult to-break-down pollutants that generate hydroxyl radicals (•OH) in the 1980s; meanwhile, methods like Fenton's reagent became much more widely known. The 1990s saw AOPs become incorporate techniques, including UV/ H_2O_2 systems and photocatalysis, mostly due to the much tighter environmental regulations and the need to address complex contaminants. In the 2000s and 2010s, it started integrating with biological treatments as well as the latest breakthroughs in nanotechnology as AOP technology became more practical. The AOP based on H_2O_2 and UV started in the late 1980s, when researchers noticed that irradiation from UV light together with hydrogen peroxide, H_2O_2, produced hydroxyl radicals, •OH, which could potentially result in degradation of persistent organic pollutants. Pursuing pilot-scale implementation of the method sparked the method's wide public acceptance in the course of the 1990s. An increasing number of studies came forth from research proving the effectiveness of the AOP technology for removing dyes and chlorinated chemicals from water. H2O2/UV systems were marketed in the early 2000s and typically have been used in combination with other treatment processes to produce greater effluent than usual for conventional treatment and to provide efficiencies of a higher order. More recent innovation has focused attention on energy efficiency and optimization of process parameters, including the use of solar UV light. It is known to be one of the most effective technologies for decomposing newly identified pollutants today; therefore, it is an essential technology in contemporary water treatment. AOP using hydrogen peroxide in combination with UV light is relatively relevant for removing emerging contaminants in wastewater, because it can significantly degrade the complex organic pollutants that traditional treatment methods often missed. Emerging contaminants, such as pharmaceuticals and personal care products, persisted in wastewater and posed significant risks to aquatic ecosystems and human health. AOPs produced hydroxyl radicals with extremely high reactivity, enabling the treatment of such persistent compounds into less harmful by-products. This route also expanded the range of treatable contaminants and well responded to the growing regulatory pressure for cleaner water. AOP treatment technique employs strong oxidizing chemicals to break down pollutants in wastewater. Among several AOPs, the H2O2/UV technique, also known as the Hydrogen Peroxide/Ultraviolet Light, is most frequently used. Organic pollutants such as pesticides, industrial chemicals, medicines, and colors are easily treated using this technique, which are usually insoluble using conventional techniques such as coagulation, filtration, or biological treatment. Hydrogen peroxide is a strong oxidizing agent that decomposes complex organic molecules into less harmful ones. H2O2 added to water decomposes into hydroxyl radicals, which are highly reactive and can attack a range of pollutants. Hydrogen peroxide photolyzes when it is exposed to UV light, which increases its capacity to produce hydroxyl radicals. The typical range of wavelengths for UV radiation is between 200 and 400 nm. Because UV-C (200 280 nm) contains the maximum amount of energy and facilitates easier breakdown of hydrogen peroxide, it is the most commonly used. Hydrogen peroxide is activated by light and broken into hydroxyl radicals (•OH), which are necessary for the oxidative processes. The principal mechanism of the decomposition of organic pollutants in water is the photolysis process of hydroxyl radicals generated by UV.

A. Abbreviations and Acronyms

AOP- Advanced oxidation process H2O2- Hydrogen peroxide
UV- Ultra-Violet
BOD- Biochemical oxygen demand COD – Chemical oxygen demand TKN- Total kjendal nitrogen
PO4- Phosphate
TDS- Total dissolved solids TSS- Total suspended solids W- Watt
•OH - Hydroxyl radicals

Methodology

- Location of sample collection: - The untreated wastewater samples analyzed in this study were obtained from Kala Odha, a natural drain at Ichalkaranji, Maharashtra. This location was chosen based on its uniform wastewater flow and suitability to represent common municipal and industrial effluents available in the area.
- Sampling method and frequency: - Grab sampling was employed to obtain wastewater samples, in which a sample is taken once at a single point in time and space. This will reflect the water quality at that time of collection. Sampling was performed weekly to account for temporal changes and maintain consistent sample quality and analysis.
- Sample analysis: The wastewater samples taken from the selected sites were analyzed for different physico-chemical parameters to find out their behavior and the degree of pollution. The parameters like Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), pH, Total Kjeldahl Nitrogen (TKN), Total Phosphorus, turbidity, total Alkalinity and Total phosphorus were analyzed. Each analysis was done using standard methods as given by the IS:3025 guidelines to verify accuracy and validity of results.
- Reactor setup: - For the treatment process, a 5-liter capacity cylindrical reactor was used. In the center of the reactor, a 13-watt UV lamp enclosed in a protective quartz sleeve was placed as the source of ultraviolet light. The employment of quartz ensures maximum transmission of UV and guards the lamp from direct exposure to wastewater. To provide for homogeneous exposure of the wastewater to UV radiation and avoid sedimentation of suspended matter, the reactor content was mixed constantly with a magnetic stirrer and a magnetic bead. The configuration provided good contact between the wastewater components and UV radiation to allow for effective

treatment.

Experimental Work

A) Test Procedures

Different parameters of wastewater samples such as pH, turbidity, chemical oxygen demand (COD), biochemical oxygen demand (BOD), total suspended solids (TSS), total kjendal nitrogen (TKN), and phosphate (PO_4) were determined by using standard methods. pH was determined with multiparameter, whereas turbidity was determined with portable turbidity meter. COD was found by open Reflux method (IS 3025, part-58) in which 20 ml wastewater sample was digested in a reflux open digester for 2 hours at temperature of 150ºC. The sample was then cooled and titrated against Ferrous Ammonium Sulphate (FAS) of strength 0.1 N. BOD was found by Winkler's method and BOD track method by using IS 3025, part-44 and BOD track manual. Total suspended solids were found by filtration method and total kjendal nitrogen was found by TKN analyzer. To find TKN, test tubes were cleaned with distilled water, added concentrated H_2SO_4, 25 ml of wastewater sample, and Cupric Sulphate and Potassium Sulphate mixture. Test tubes were put into digesters at 300ºC and 410ºC, cooled, and put into distillation units. Two to three drops of mixed indicator were added to the conical flask after completion of distillation and the sample was titrated with 0.02 N H_2SO_4. Concentration of phosphate was found by spectrophotometer and Ascorbic acid method; calibration curves were drawn on spectrophotometer for various concentrations of phosphate. The sample of wastewater was then transferred to cuvettes in order to find out the concentration of PO_4.

B) Photochemical Reactor

A photochemical reactor was installed for batch mode experiments. It consists of a monochromatic UV lamp with light output at 254 nm and power of 13 watts. The lamp is fitted inside a quartz sleeve with an outer diameter of 2 cm and length of 27 cm, and placed at the center of a 5-liter cylindrical reactor. The plastic reactor has an outer diameter of 20 cm and a length of 32 cm. Proper mixing of the content is ensured by the use of a magnetic stirrer with a magnetic bead. A thermometer is placed within the reactor to monitor temperature continuously. When the temperature reaches 22ºC, a water bath will be employed to keep the sample at a constant temperature. Shown in figure 1.

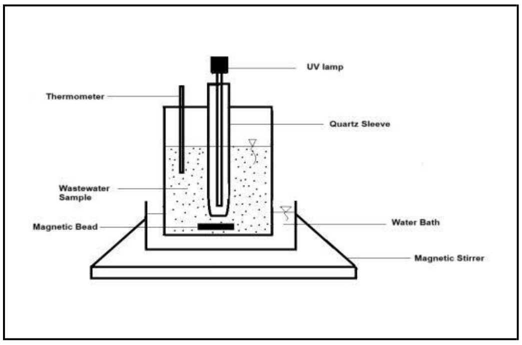

Figure 1. Photochemical Reactor

Results And Disscussion

1) Raw wastewater sample analysis

Table 1 gives the general wastewater parameters for the wastewater used in this study. This wastewater has an average Total dissolved solids (TDS) of 1875 mg/L, Total suspended solids (TSS) of 600 mg/L, Turbidity of 200 NTU, Conductivity of 3.73 mS/cm, Biochemical oxygen demand (BOD) of 562 mg/L, Chemical oxygen demand (COD) of 1790 mg/L, Total kjendal nitrogen (TKN) of 8.03 mg/L, Phosphate of 1.95 mg/L, Total Alkalinity of 450 mg/L, and was at pH 7.09.

Table 1: Average results of raw wastewater sample analysis

Sr. No	Parameters	Results
1	pH	7.09
2	TDS	1875 mg/L
3	TSS	600 mg/L
4	Turbidity	200 NTU
5	Conductivity	3.72 ms/cm
6	BOD	560 mg/L
7	COD	1790 g/L
8	TKN	8.03 mg/L
9	Phosphate	1.95 mg/L
10	Alkalinity	450 mg/L

When raw wastewater sample was analyzed, it was observed that wastewater has average BOD/COD ratio of 0.32 and it indicates that wastewater contains negligible amount of biodegradable organic matter as compare to non- biodegradable organic matter.

2) Optimum Dose of Hydrogen peroxide

A 30% hydrogen peroxide solution was used to generate reactive hydroxyl radicals. It has been demonstrated through research that the production of these radicals is affected by the pH level of the solution. According to several studies conducted where hydrogen peroxide and UV light were used, the optimal operating pH should be 3 since this has been identified as the best pH for the process when using sulfuric acid or sodium hydroxide.

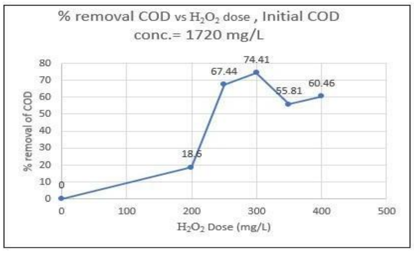

Figure 3 (a) Reduction of COD by various H2O2 concentration (COD influent = 1720 mg/L)

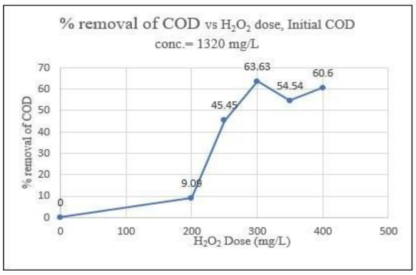

Figure 3 (b) Reduction of COD by various H2O2 concentration (COD influent = 1320 mg/L)

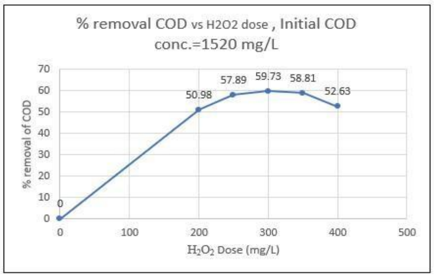

Figure 3 (c) Reduction of COD by various H2O2 concentration (COD influent = 1520 mg/L)

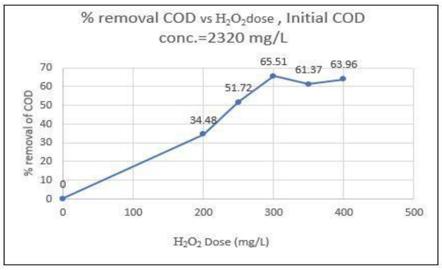

Figure 3 (d) Reduction of COD by various H2O2 concentration (COD influent = 2320 mg/L)

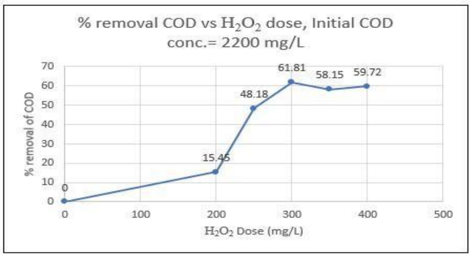

Figure 3 (e) Reduction of COD by various H2O2 concentration (COD influent = 2200 mg/L)

The effect of the concentration of hydrogen peroxide (H_2O_2) on the performance of the UV process was investigated by changing the concentrations of H_2O_2 from 200 mg/L to 400 mg/L, as presented in Fig. 3 (a) to (e). The findings indicated that the maximum mean chemical oxygen demand (COD) removal efficacy of 65% was obtained using a concentration of 300 mg/L of hydrogen peroxide.Notably, raising the concentration of hydrogen peroxide past this threshold did not result in more efficient removal of COD. Past research has shown that too much hydrogen peroxide has a detrimental effect on removal efficiency. This can be attributed to the production of less reactive hydroxyl radicals when hydroxyl radicals interact with excess hydrogen peroxide. Although extremely high levels of hydrogen peroxide can still have some desired effects such as producing more radicals from the decomposition of H_2O_2 or increasing oxidative capacity to degrade especially recalcitrant compounds their benefits are not greater than their detriments at excessive levels of hydrogen peroxide. Additionally, at very high doses, some reactions that were previously incomplete might proceed further, leading to improved COD removal efficiency which was previously dropped. Fig 3 (c) shows the continuous decrease in COD removal efficiency it might be because of the utilization of •OH radicals for neutralization of excess hydrogen peroxide, at high concentration of H2O2, H2O2 could absorb UV light, which competes with wastewater and organic matter for photons. This reduces the generation rate of •OH radicals and reduce photolytic efficiency. At higher H2O2 concentration, concentration of •OH radicals were also high, there was also a higher chance of radicals combining with each other instead of attacking organic matter present in wastewater.

3) Optimum time of treatment

In order to determine the optimum time for the treatment, COD tests were carried out at different time intervals and at constant dose of H2O2 of 300 mg/L shown in Fig.4 (a) to (e). Fig.4 (a) shows that initial COD concentration of 2360 mg/L has removal efficiency of 76.27 % at 75 min reaction time. Fig 4 (b) shows that initial COD concentration of 1440 mg/L has removal efficiency of 62.5 % at 75 min reaction time. Fig 4 (c) shows that initial COD concentration of 1600 mg/L has removal efficiency of 67.5 % at 75 min reaction time. Fig 4 (d) shows that initial COD concentration of 920 mg/L has removal efficiency of 58.69 % at 75 min reaction time. Fig 4 (e) shows that initial COD concentration of

1100 mg/L has removal efficiency of 56.36 % at 75 min reaction time. From fig.4 it was observed that initial COD concentration did not influences the reaction time. For the different initial COD concentration, optimum reaction time was same at optimum dose of H_2O_2. It was noted that, 75 min reaction time showed maximum COD removal efficiency of 65 % (average) at 300 mg/L optimum dose of H_2O_2.

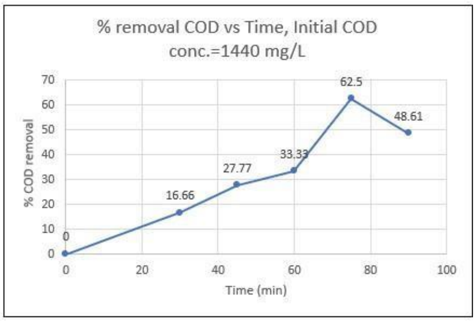

Figure 4 (a) Reduction of COD at various time intervals (COD influent = 2360 mg/L)

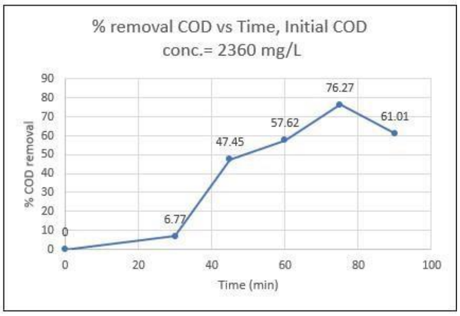

Figure 4 (b) Reduction of COD at various time intervals (COD influent = 1440 mg/L)

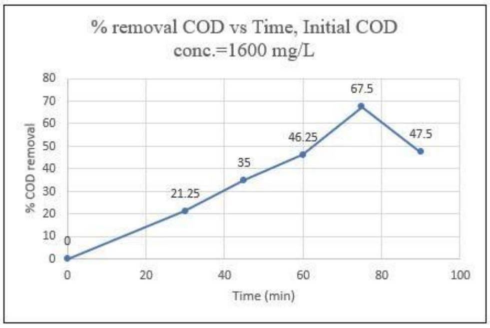

Figure 4 (c) Reduction of COD at various time intervals (COD influent = 1600 mg/L)

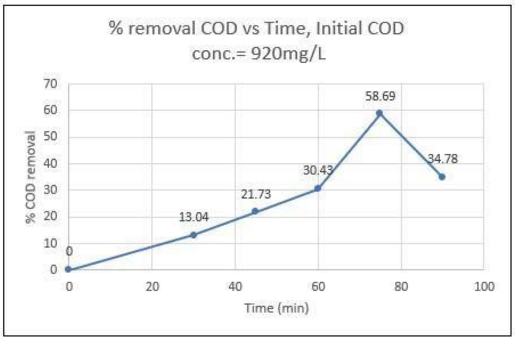

Figure 4 (d) Reduction of COD at various time intervals (COD influent = 920 mg/L)

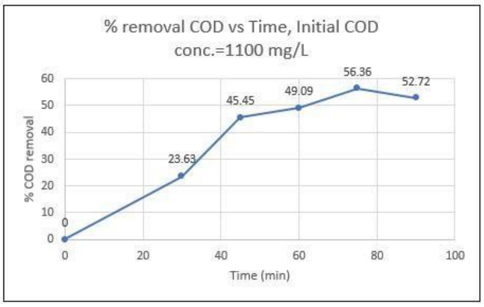

Figure 4 (e) Reduction of COD at various time intervals (COD influent = 1100 mg/L)

Conclusion

H_2O_2 and UV process for the treatment of wastewater was carried out for determination of optimum dose of optimum dose and optimum time for treatment in batch mode. Concentration of H_2O_2 influence the rate of generation of hydroxyl radicals for H_2O_2 and UV method. H_2O_2 and UV system worked effectively at 300 mg/L dose of H_2O_2 at reaction time of 75 minutes with average COD removal efficiency of 65 %. according to CPCB guidelines, the present quality of the wastewater is not at all suitable for disposal into the environment; therefore, tertiary treatment is essential before its disposal.

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