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Process Intensification of Advanced Fenton Process for Degradation of Acid Orange – 7 Dye: A Review

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ABSTRACT: Textile industries use different synthetic dyes and these dyes generate huge volume of textile effluent which contains complex mixture of many polluting substances. These polluting substances are responsible for many human diseases and water pollution. The removal of colour from textile wastewater represents a major environmental concern. In this the removal of Acid Orange 7, a textile dye, from aqueous solution has been studied using Advanced Fenton Process. Basically, development and application of several Advanced Oxidation Processes to destroy many biologically refractory organic contaminants in Industrial wastewater is now a days required. This may include Fenton oxidation method, ozone oxidation method, membrane separation method, activated carbon adsorption method, etc. Among them, Fenton oxidation (H_2O_2 / Fe^{++}) method is considered to be one of the most effective, simple and economical method. Fenton oxidation process is used to produce $\cdot OH$ (hydroxyl radical) and development is made to improved low-sludge wastewater advanced oxidation treatment technology.

KEYWORDS: Aqueous, Effluent, Fenton, Hydroxyl Radical, Oxidation Process, Ozone, Synthetic Dye, Textile Industry.

I. INTRODUCTION

Industrial effluents are one of the most important sources of pollution in the environment (Choi *et al.* 2004). The dye effluents from textile industries are significant sources in environmental pollution. Synthetic dyes have been used in many industries such as textile, paper printing, food, pharmaceutical, leather and cosmetics (Wua *et al.* 2007). Traditionally, synthetic dyes are classified into acid, reactive, direct, basic, vat, disperse, metal complex, mordant and sulphur dyes. Acid and reactive dyes are mostly used. Azo dyes, one of the greatest groups of synthetic dyes, have one or more azo bounds ($-N=N-$) and because of their solubility, low expense, stability and color variety, are widely used in many applications. Removal of azo dyes from colored effluents due to their complex composition, toxicity, poor degradability and high solubility, have attracted great interest in the last few years (Zheng *et al.* 2016). Colored wastewater is one of the most important sources of environmental pollution and because of their visibility and bearing toxic chemicals, it is very important to be treated before released into the environment. Many microbial pathogens in wastewater can cause chronic diseases with costly long-term effects, such as degenerative heart disease and stomach ulcer (Wua *et al.* 2007).

Some microbial pathogens are present in wastewater could causes chronic diseases which are belong term effect and costly, such as degenerative heart disease and stomach ulcer. By considering volume and composition, in the textile industry is the most polluted among all industrial sectors. From the textile industries common effluent are removed it contains high concentration of organic and inorganic chemicals and are characterized as Chemical Oxygen Demand

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(COD), Biological Oxygen Demand (BOD), Total Dissolved Solids (TDS), pH, Total Suspended Solids (TSS) value and low Dissolved Solids (DO) as well as colour. The main concern with the colour is elegant character while discharge point with respect to visibility of the water which is receiving. In the future, measure countries are issues on stricter standards on the colored waste streams. It's similar like textile industries will be force to remove residual dyestuffs form wastewater before discharging them into received water (Zheng *et al.* 2016).

This is great burden in terms of wastewater management and consequently leads to point source pollution problem, which is not only increases treatment cost but also entry for a wide range chemical pollutants and microbial contaminants to water source (Gul *et al.* 2007). This is a great burden in terms of wastewater management and can consequently lead to a point-source pollution problem, which not only increases treatment cost considerably, but also introduces a wide range of chemical pollutants and microbial contaminants to water sources (Gul *et al.* 2007). The using conventional methods like chemical precipitation and biological treatment can't be removed of dyes from effluents, hence new solution should be or technique will be necessary. In recently years, Advanced Oxidation Process, is use because of its toxicity, low cost, effectiveness has been used as reagent for removal of pollutants from environment. (Zheng *et al.* 2016).

Dyes lead to number of environment and health hazards which are as follow,

1. The greatest environment concern with dyes is their absorption and reflection of sunlight entering the water. Light absorption diminishes photosynthesis activity of algae and seriously influences the food chain.
2. Many dye and their breakdown product are carcinogenic, mutagenic and toxic to life. Dyes are mainly introduced into the environment through industrial effluent.
3. Triple primary cancers involving kidney, urinary bladder and liver of dye workers have been reported.
4. Allergies like contact dermatitis and disease, allergic reaction in eyes, skin irritation to mucous membrane and the upper respiratory tract are causes by textile dyes.
5. Reactive dyes form covalent bond with cellulose, woolen and PA fibers. Certain reactive dyes have caused respiratory sensitization of workers occupationally exposed to them.
6. The presence of very small amounts of dyes in the water, which are nevertheless highly visible, seriously affects the quality and transparency of water bodies like lakes, rivers and others, leading to damage to the aquatic environment.
7. The highly toxic and mutagenic dyes decreases light penetration and photosynthesis activity, causing oxygen deficiency and limiting downstream beneficial uses such as recreation, drinking water and irrigation.

The taste of water is affected by the presence of TDS. Higher hardness with high alkalinity or sulfates causes scale formations. The higher sulfates content is caused by laxative effect. High or low Dissolved Solids can cause osmotic balance of native species. Due to the, Disposal of salt laden effluents to the ground and surface water bodies can cause pollution and that is unfit for domestic, industrial, agricultural use. High salt concentration interference with proper operation is due to the biological wastewater treatment plant. Naturally, sewage also called Municipal wastewater. The reason is because water is used in household sinks and various application which combines with use of toilets. Wastewater is combination of sewer and sanitary sewer. Once it transport to wastewater treatment plant, whatever treated water is discharged to receiving water body by use of effluent pipes. Physical wastewater treatment represent the body of technologies that is solid-liquid separation techniques are used, but filtration plays important role. Filtration techniques are divide into two categories - conventional and non-conventional. This technologies are integral component of drinking water and wastewater treatment applications. It's one one unit process with a modern water treatment plant scheme where multi equipment and technologies option are select depending upon the goals of the

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treatment. To understand the role of filtration, there is other technologies are employee for the cleaning and purification of industrial and municipal water it's important to distinction with the other technologies but also it have objective of different unit process (Umar *et al.* 2013).

II. DIFFERENT TYPES OF WASTEWATER TREATMENT METHODS

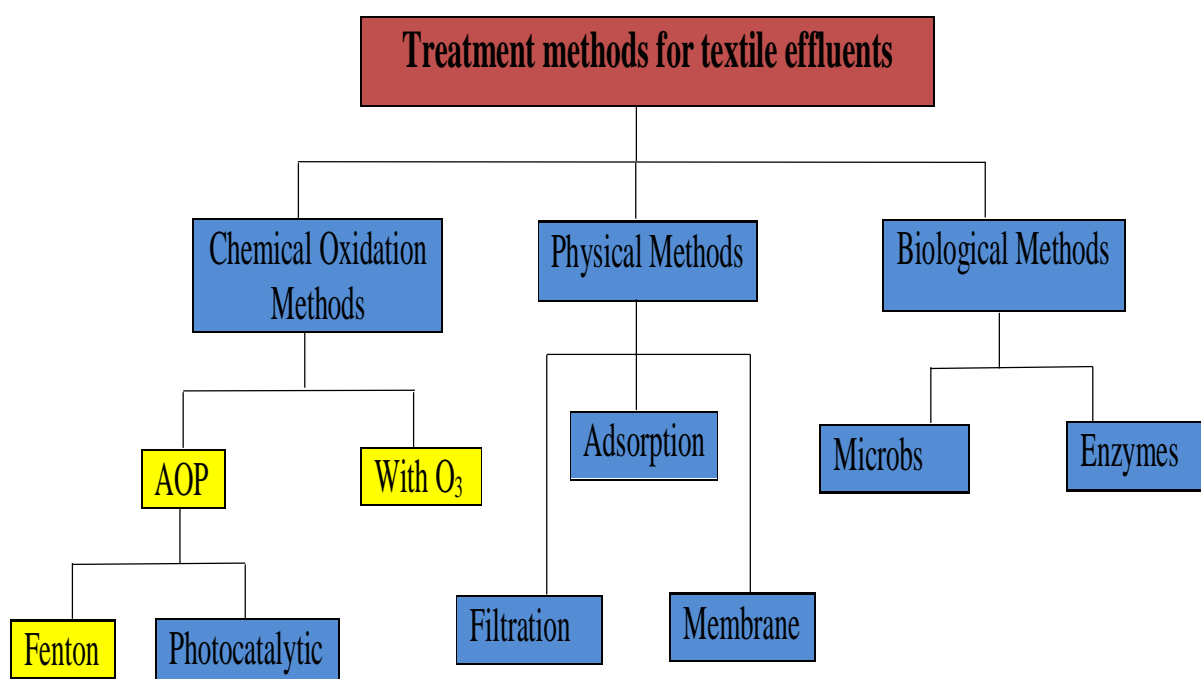


Fig. 1 Different types of wastewater treatment method

Methods to treat wastewater

At a global level, around 80% of wastewater produced is discharged into the environment untreated, causing widespread water pollution. There are numerous processes that can be used to clean up wastewaters depending on the type and extent of contamination. Wastewater can be treated in wastewater treatment plants which include physical, chemical and biological treatment processes (Deborde *et al.* 2008).

Treatment methods are:

1. Preliminary treatment
2. Primary treatment
3. Secondary treatment
4. Tertiary treatment

1. Preliminary treatment:

It consists of removal of floating material (like dead animals, tree branches, papers, plastics, wood pieces, vegetables peels etc.) and also the heavy settleable inorganic solids (grit etc.). Preliminary treatment of wastewater includes:

- Screening
- Comminutors
- Grit Chamber
- Detritus Chamber
- Skimming Tank

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2. Secondary treatment:

Secondary treatment of sewage and other wastewater is the stage of wastewater treatment designed to substantially degrade the biological content of the sewage. This usually uses biological processes.

- Activated sludge
- Trickling filter
- Oxidation ponds

3. Tertiary treatment:

Tertiary treatment comes after the secondary treatment in the wastewater treatment process. This treatment is also called as the final or advanced treatment. Its work is to remove the organic load left after secondary treatment for removal of nutrients from sewage. It particularly kill the pathogenic bacteria. The effluents from secondary sewage treatment plants contain both nitrogen (N) and phosphorus (P). The purpose of tertiary treatment is to provide a final treatment stage to raise the effluent quality before it is discharged to the receiving environment such as sea, river, lake, ground, etc., or to raise the treated water quality to such a level to make it suitable for intended reuse. This step removes different types of pollutants such as organic matter, SS, nutrients, pathogens, and heavy metals that secondary treatment is not able to remove (Debordeaet al. 2008).

Why to treat wastewater

If wastewater is not properly treated, then the environment and human health can be negatively impacted. The reasons to treat wastewater are:

1. Good quality influent water.
2. Effluent water quality must meet rules and regulations.
3. Recover high value material in wastewater
4. To remove pathogenic organics in order to protect environment and human health
5. To remove organic and inorganic matter this would otherwise cause pollution.
6. Other substances such as some pharmaceutical and personal care products, primarily entering the environment in wastewater effluents, may also pose threats to human health, aquatic life and wildlife.

Advanced Oxidation Process

AOPs is the technology used for the oxidation of wide range of organic contaminants in polluted water. For getting clean water for human consumption drinking and household purpose. AOP methods involve generation of highly chemical oxidants such as the hydroxyl radical (.OH). Hydroxyl radicals are used to treat the water means they are the only source of bringing the contamination levels in water up-to their permissible limits (Wuaet al. 2017).Advanced Oxidation Processes (AOPs) are efficient methods to remove organic contamination not degradable by means of biological processes. AOPs processes produces very reactive oxygen species which are able to destroy a wide range of organic compounds. AOPs are more expensive than the conventional biological wastewater treatment since external energy sources (electric power, ultraviolet radiation (UV) or solar light electric power, ultraviolet radiation (UV) or solar light) are required the driven AOP's. AOP systems are not more expensive than well establish technologies for pollutants abatement (Andreozziet al. 1999)

Fenton Process

The Fenton process is used for the treatment of both organic and inorganic substances under laboratory conditions using synthetic effluents as well as real effluents from different sources like chemical, refinery and fuel terminals, engine and metal cleaning etc. Fenton Process is based on the production of highly reactive hydroxyl radicals (OH[•]). Fenton's reagent is a result of the reaction between hydrogen peroxide (H₂O₂) and ferrous ions (Fe²⁺) under acidic conditions. Based on the oxidation system fenton's reagent can be employed to treat a variety of industrial wastes containing a wide range of organic compounds like phenols, formaldehyde, pesticides, wood preservatives, plastic additives, and rubber chemicals. The waste water treatment using Fenton process results in reduction of toxicity, improvement in biodegradability, odour and colour removal (Zheng et al. 2016).It has been demonstrated that Fenton's reagent is able to destroy toxic compounds in waste waters such as dyes, phenols and herbicides. Hydroxyl radical

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production by fenton reagents occurs by adding H_2O_2 to Fe_2^+ salts. The special reactants and apparatus are not required for reaction because this is a very simple way of producing OH radicals hence. The fact is that iron is available abundantly and hydrogen peroxide is environment friendly and easy to handle hence the system is attractive (Andreozzi *et al.* 1999).

Ozonation Process

Ozonation has excellent potential in decolorization due to the following reasons. (i) Decolorization and degradation occur in one step; (ii) danger to humans is minimal; (iii) no sludge remains; (iv) all residual ozone can be decomposed easily into oxygen and water; (v) little space is required and (vi) ozonation is easily performed. Two possible degradation ways are available for oxidation of organics (i) at basic Ph, it decomposes rapidly to yield hydroxyl and other radical species in solution, according to Eqs. (1)–(3), and (ii) at acidic Ph, ozone is stable and can react directly with organic substrates. UV radiation can decompose ozone in water, generating highly reactive hydroxyl radicals. The hydroxyl radicals oxidize organics more rapidly than ozone and it is known to be powerful oxidizing agents. The effects of dye concentration, ozone dose, Ph, the presence or absence of UV and UV intensity in ozone-based systems have been evaluated (Shen *et al.* 2017).



Many studies have provided evidence that ozone can decolorize synthetic dyes which are soluble in water. There are two different primary reaction pathways for oxidation are direct attack of ozone molecule on the pollutants and generation of free radicals due to decomposition of ozone and subsequent attack of these two radicals on the pollutants. The combination of ozone with UV light, H_2O_2 and MnO_2 increases more oxidizing efficiency. Ozone with UV light process is more efficient than the ozone process alone, because UV radiation promotes ozone decomposition and as a result yielding additional hydraulic radicals and hence decolorization rate increases (Chen *et al.* 2009).

Advantages and disadvantages of AOP'S

Advantages:

- Rapid reaction rates
- Small foot print
- Potential to reduce toxicity of organic compounds
- Mineralization of organics, i.e. conversion to salt and CO_2
- Does not concentrate waste for further treatment, such as membranes
- Does not produce “spent carbon” such activated carbon absorption
- Easily Automated and Controlled
- Reduced Labor Input

Disadvantages:

- Capital Intensive
- The reactions are efficient at low Ph-levels (<6) – which is difficult to maintain.
- The advanced oxidation processes require high electricity demand for devices such as UV-lamps, ozonators, etc.
- The requirement of large amount of oxidants and catalysts.
- The low operating Ph condition for Fenton process is difficult to obtain.

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III. RECOMMENDATION

The presence of organic compounds in water have a direct effect on the human health, animals, aquatic life. Many organic pollutants are toxic in nature and hazardous when present even in very small quantity. Hence removal of contaminations from water is very important task. In certain cases conventional methods such as biological treatment methods are not effective due to the recalcitrant nature of the contaminants present. Hence advanced oxidation processes like Fenton process, Ozonation process are used to degrade. By using this advanced oxidation process high degradation is possible. However pollution load, process limitations, operating conditions are the key factors to be consider during the selection. Advanced oxidation process are the alternative processes which are able to degrade bio refractory organic compounds. And this process typically operates with less energy requirements.

Common AOPS and the reactive species produced and the reactive species produced in each process.

AOP's	Reactive Species
Ozone treatment: O ₃	HO•, HO ₂ •, HO ₃ •, O ₂ -•, O ₃ -•
O ₃ /H ₂ O ₂	HO•, O ₂ -•, O ₃ -•
Fenton processes: H ₂ O ₂ /Fe ₂ ⁺	HO•, HO ₂ •
Photo-Fenton processes	HO•
UV/O ₃ , UV/H ₂ O ₂ , UV/O ₃ /H ₂ O ₂	HO•, HO ₂ •/ O ₂ -•, O ₃ -•
Photocatalytic treatment	HO•, h ⁺ , O ₂ -•, HO ₂ •, HOO•

Table 2. Common AOP'S and their reactive species

Mechanism of Fenton Process

Kinetic Schemes Fenton's reagent is a mixture of H₂O₂ and ferrous iron, which generates hydroxyl radicals according to the reaction



The ferrous iron (Fe²⁺) initiates and catalyzes the decomposition of H₂O₂ resulting in the generation of hydroxyl radicals. The generation of the radicals involves a complex reaction sequence in an aqueous solution.



Moreover, the newly formed ferric ions may catalyze hydrogen peroxide, causing it to be decomposed into water and oxygen. Ferrous ions and radicals are also formed in the reactions. The reactions are as shown in Equations (7) – (11).



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The reaction of hydrogen peroxide with ferric ions is referred to as a Fenton-like reaction



As seen in reaction [11], H_2O_2 can act as an OH^\bullet scavenger as well as an initiator {reaction [5]}

Hydroxyl radicals can oxidize organics (RH) by abstraction of protons producing Organic radicals (R^\bullet), which are highly reactive and can be further oxidized



If the concentrations of reactants are not limiting, the organics can be completely detoxified by full conversion to CO_2 water and in the case of substituted organics, inorganic salts if the treatment is continued.



This equation suggests that the presence of H^+ is required in the decomposition of H_2O_2 , indicating the need for an acid environment to produce the maximum amount of hydroxyl radical.

IV. LITERATURE REVIEW

Literature Survey on Fenton and Ozonation Process for Degradation of Textile Dye Effluent:

Textile industries' production of dyestuffs creates huge volumes of wastewater. It is estimated that over 15% of the total world production of dyes is lost in the textile effluents. Azo dyes constitute the largest and the most important class of synthetic dyes for industrial applications. The discharge of azo dyes into water streams is undesirable not only because of their colour but also their toxicity, non-biodegradability, and potential carcinogenic characteristics. Therefore, the urgent removal of azo compounds from wastewater has attracted worldwide attention.

(Zheng *et al.* 2016) reported that AOPs, including ozonation Fenton reaction and photo catalysis have been applied to the degradation of azo dyes. Among them, Fenton process has its own unique advantages, including high degradation efficiency, simple operation, environmentally benign property, and low cost. The classical Fenton reagent consists of a homogeneous solution of iron ions and hydrogen peroxide. However, its practical application in dealing with industry waste water has some disadvantages. It is efficient only at low pH ($\text{pH} < 4$), and it is costly to remove the iron ions from the system after the treatment). In order to overcome the above shortages, developing heterogeneous Fenton-like catalysts such as iron-containing solid compounds, iron-coated particles, and supported iron compounds, is necessary. For heterogeneous processes, main oxidative reactions occur at the solid liquid interface where the iron remains substantially in the solid phase, either as a mineral or as an adsorbed ion.

We found that the factors that affect the advanced oxidation process are as follows:

1. Effect of Initial Concentration
2. Effect of pH
3. Effect of Ferrous Ions loading
4. Effect of Hydrogen Peroxide loading

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Sr.No	TITLE	AUTHOR	METHOD	REAGENTS	PARAMETERS	RESULT
1	Efficient degradation of Acid Orange 7 in aqueous solution by iron ore tailing Fenton-like process.	JianmingZheng, ZhanqiGao, Huan He, Shaogui Yang, Cheng Sun (2016)	Fenton Process	Acid Orange 7 dye, H ₂ O ₂ , Fe ²⁺ , Methanol, 5-5 Dimethyl Pyrrolime-N-Oxide	Effect of Catalyst Loading, Effect of H ₂ O ₂ Dosage , Effect of pH, Initial AO7 concentration	Removal of colour was 96.5% after 60 min. Removal of TOC was 56.3%. Optimum pH 3.
2	Ozonation of C.I. Reactive Red 194 and C.I. Reactive Yellow 145 in aqueous solution in the presence of granular activated carbon.	D. Mendez-Paz, Omil, J.M. Lema, ANNA GOI, Cao, Wei Huang (2007)	Fenton Process	Sulfuric acid, Iron powder, Acid orange7, Liquid hydrogen peroxide	Effect of the amount of Granular activated carbon on color reduction.	The rate of ozone depletion increased when amount of GAC increased in both dye solutions. Decolourization efficiency was 96%.
3	Oxidation rates of two textile dyes by ozone: Effect of pH and competitive kinetics Oxidation rates of two textile dyes by ozone: Effect of pH and competitive kinetics.	Arlindo C. Gomes, Luis R. Fernandes, Rogério M.S. Simoes	Oxidation Processes	Acid Green 27, AO-7, Acros Organics	Effect of pH on decolorization.	Decolourisation efficiency was 96%.
4	Application of ozone on the decolorization of reactive dyes - Orange-13 and Blue-19	T.Y. Chen, C.M. Kao, A. Hong, C.E. Lin, S.H. Liang	Oxidation Processes	Ozone, Orange-13, Blue-19, KI Solution	Effect of pH , Effect of Ozone dosage	The effect that more extensive reactions of O ₃ with OH ⁻ occur at higher pH. More hydroxyl radicals are produced at higher pH.
5	Reduction of COD and Color of Acid and Reactive Dye stuff Wastewater Using Ozone	Jae-Wook Choi, Hyung Keun Song, Whun, Kee-Kahb, ChoonHaa, Byung-Ki Na	Oxidation Processes	Ozone, Bromamine acid dyestuff, Reactive dyestuff	Effect of pH, Effect of Ozone Flow rate, Effect of Ozone Concentration, Effect of Reaction Time	Reduction of COD was 228 mg/l at pH 11 and 153mg/l at pH 12). COD Reduction was 93% at 12.5 lpm ozone gas flowrate. COD reduction was upto 89mg/l at 82.7 g/Nm ³ of ozone concentration.
6	Decolorization of Azo dyes using Catalytic Ozonation	Chung-HsinWua, Chao-Yin Kuob, Chung-Liang Chang	Oxidation Processes	Reactive Red 2, Acid Orange 6, Ozone, MnO ₂	Effect of O ₃ and O ₃ /MnO ₂ dosage	Decolourisation efficiency was 95%.
7	Decolorization of mono azo dyes in wastewater by advanced oxidation process: a case study for acid red 1 and acjid yellow 23.	Hung-Yee Shu, Ching-Rong Huang , Ming-Chin Chang	Fenton Process	Hydrogen peroxide, Acid Red 1, Acid Yellow 23, HPLC grade solvents, Methanol, Acetic acid	Hydrogen peroxide, Acid Red 1, Acid Yellow 23, HPLC grade solvents, Methanol, Acetic acid	The pH, initial dye concentrations, and hydrogen peroxide dosage significantly influence the reaction rates. Optimum hydrogen peroxide concentration for the maximum decolorization of both dyes was between 7.081 to 9.472 mM.

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Factors affecting to degradation of dye:

1. Initial dye concentration

Influence of initial concentration on the oxidation removal of dye was also studied, since pollutant concentration is an important parameter in wastewater treatment it is possible to see that the extent of degradation decreases with the increase in the initial dye concentration.

Song, Qui, Yao, CAO, Chen (2010) where carried out an experiment with Reactive Yellow 84 dye. They studied the experiments for initial concentrations of 100, 200, 400 and 800 mg/l. and they observed that the colour removal efficiency did not change significantly with an increased in initial concentration. Thus the effect of dye concentration was small. However, they observed that beyond the concentration, the colour removal efficiency falls from 90% to 69% at 10min reaction time with increased in concentration of dye 400 to 800 mg/l. (Song and Qui *et al.* 2010).

2. Effect of pH on the degradation

Deshannavar, Murgod and Molangadecarried out an experiment by maintaining H_2O_2 and catalyst dosage as 20 mg/l and 2.5g/l, respectively. And they varied pH value in the range of 2 to 6. They investigated that the maximum decolourization of 86% was achieved at pH value 3 and with increasing pH the decolourization decreases. They investigate that in alkaline environment, H_2O_2 is unstable and easily decompose to produced water and oxygen rather than forming hydroxyl radicals. But at acidic environment pH value less than 4, ferrous ions decompose H_2O_2 catalytically yielding hydroxyl radicals most directly. However, at pH value greater than 4 ferrous ions decompose H_2O_2 and form ferric ions, which have a tendency to produce ferric hydroxo complexes (Deshannavar, Murgod, Molangade *et al.* 2012).

Zheng, Gao, Yang studied the fenton like process they use acid orange 7 dye for degradation and investigated that at acidic pH values 3,4 and 5 the decolourization of dye was completed within 60 min. They observed that rates of reaction were relatively slow and the conversions of AO7 were 66.7% and 21.6% at pH 6.8 and 8.1, respectively. The degradation of AO7 at pH 3.0 was faster than that at other pH. In homogenous systems 3 is also known to be the optimal value for organic pollutant degradation by H_2O_2 /iron. The higher pH with more OH will move the reaction backwards and reduce the activity of Fenton reagent. However, when the pH is below 3, generation of OH will be constrained as shown in the reaction H_2O_2 . When they increase the pH from 5 to 9 degradation efficiency decreased from about 100% to 65% within 120 min (Zheng, Gao, Yang *et al.* 2016).

3. Effect of reaction time

Reaction time is one of the important parameter which can affecting the design and operation of an oxidation process. It is the required time for to attain the desired goals and treatment.

Moussavi and Mahmoudihad done the experiment with Reactive Red 198 dye with Ozonation process. In this they studied colour and COD removal by using catalytic Ozonation as a function of reaction time, under the optimum pH value of 8. Color removal of RR198 increased from zero at the beginning of the experiment so around 78% and 20% COD reduction after 10 min of Ozonation process. By increasing the reaction time to 30 min. colour removal also increased to 98% and COD reduction increases to 50%. But when they carried out same experiments with Catalyst the process is term as catalytic Ozonation process and the colour and COD removal also increased. As observed, the COP could achieved 83% colour removal after a reaction time of 2 min. and the percent of colour removal increased to 99% after 5 min and 100% after 9 min. of the reaction time. In addition, the COP achieved 61% removal of COD from the solution after 10min of the reaction. MgO is the promising catalyst for finding the presented result and the reactivity and the surface area of the catalyst is also high (Moussavi and Mahmoudi *et al.* 2009).

4. Effect of Hydrogen peroxide

Concentration of hydrogen peroxide plays very important role in the increasing efficiency of the degradation process. Usually it has been observed that the degradation of the pollutants increase with an increase the hydrogen peroxide

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dosage. But if excess hydrogen peroxide is used then critical problems like high COD and hydrogen peroxide is harmful to the many of the organic organisms. Another disadvantages of hydrogen peroxide is scavenging of generated hydroxyl radicals, which occurs at large quantities of hydrogen peroxide. Hence dosage of hydrogen peroxide is adjusted in such a way that more quantity is utilized (Babuponnusami and Mutukumaret al. 2013).

V. CONCLUSION

Advanced oxidation process is becoming more and more popular in the wastewater treatment industry. The main focus of this process is the hydroxyl radical, which once generated aggressively attacks virtually all organic compounds. Thus far Fenton process, fenton's reactions have been studied and extensively used for the removal of recalcitrant organic chemicals thus reducing the COD, TOC and phenolic compounds that are commonly found in industrial and municipal wastewater. Major factors affecting these processes are the initial concentration of the pollutant, the quantity of oxidizing agents, catalysts, and the nature of the wastewater's solution. Furthermore, one should clearly see the importance of AOPs as a technological tool for environmental management, and they must be developed from this firm scientific and engineering basis.

In addition, the application of the Fenton catalyst will not add secondary pollution into the environment, and the toxicity of the treated Acid orange 7 solution was reduced effectively. The Fenton process can be applied to remove dyestuff from wastewaters cost-effectively. Moreover, the products of AO7 degradation from the Fenton processes with different $\bullet\text{OH}$ generations were identified by COD analysis. In this study we observed decrease in COD reduction with an increase in dye concentration may be due to the fact that presence of higher concentration of pollutant reduces the efficiency of formation of OH radicals in the solution. It is observed to note that the though the rate of COD reduction increases with a decrease in the concentration. The maximum degradation occurs as optimum pH value 3. Degradation increases with increasing reaction time.

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