H.J.H. Fenton an outstanding chemist discovered the Fenton's reagent in 1894. Fenton's reagent is defined, as a mixture of hydrogen peroxide and iron (II) ion ($\text{H}_2\text{O}_2 + \text{Fe}^{2+}$). This is one of the most effective oxidizing agents for destroying organic compounds. The extraordinariness of Fenton chemistry results from the fact that it is very common in chemical, biological, and natural environmental systems. Nowadays, Fenton reagent plays a very important role in free radical biology and medicine. A very important role it also plays in natural environmental systems, and environment protection engineering (for example in wastewater treatment and remediation of groundwater). Therefore, it can be assumed, that the Fenton’s discovery has played a very important role in all aspects of our life [1].

Literature survey reveals that in the past two decades, advanced oxidation processes (AOPs) have been proven to be powerful and efficient treatment methods for degrading recalcitrant materials or mineralizing stable, inhibitory, or toxic contaminants in waste waters. Advanced oxidation processes are those groups of technologies that lead to hydroxyl radical (.OH) generation as the primary oxidant (second highest Powerful oxidant after the fluorine), Hydroxyl radicals are non-selective in nature and they can react without any other additives with a wide range of contaminants. These hydroxyl radicals attack organic molecules by either abstracting a hydrogen atom or adding hydrogen atom to the double bonds. It makes new oxidized intermediates with lower molecular weight or carbon dioxide and water in case of complete mineralization.

Oxidation is defined as the transfer of one or more electrons from an electron donor (reductant) to an electron acceptor (oxidant), which has a higher affinity for electrons. These electron transfers result in the chemical transformation of both the oxidant and the reductant, in some cases producing chemical species with an odd number of valence electrons. These species, known as radicals, tend to be highly unstable and, therefore, highly reactive because one of their electrons is unpaired. Oxidation reactions that produce radicals tend to be followed by additional oxidation reactions between the radical oxidants and other reactants (both organic and inorganic) until thermodynamically stable oxidation products are formed. The ability of an oxidant to initiate chemical reactions is measured in terms of its oxidation potential. The most powerful oxidants are fluorine,
hydroxyl radicals (OH), ozone, and chlorine with oxidation potentials of 2.85, 2.70, 2.07 and 1.49 electron volts, respectively. The end products of complete oxidation (i.e., mineralization) of organic compounds can be easily biodegradable.

AOP Technologies:
AOPs can be divided into established and emerging technologies based on the existing literature and the waste water treatment industry’s experience with the technology. The Advanced Oxidation Processes (AOPs) appear as interesting tools, in comparison with the well-established techniques like activated carbon adsorption, air stripping, reverse osmosis, combustion. Emerging technologies are defined here as technologies that have very limited, if any, full-scale applications in waste water treatment. Each of the AOP technologies is evaluated on the basis of its performance reported in the engineering literature, results of manufacturer or vendor studies, and the industry’s experience with the technology.

Established Technologies:
• Hydrogen Peroxide/Ozone (H₂O₂/O₃)
• Ozone/Ultraviolet Irradiation (O₃/UV)
• Hydrogen Peroxide/Ultraviolet Irradiation (H₂O₂/UV)

Emerging Technologies:
• High Energy Electron Beam Irradiation (E-beam)
• Cavitation (Sonication & Hydrodynamic)
• TiO₂-catalyzed UV
• Fenton’s Reaction

Strategies for the choice of the appropriate treatment process depend upon below said points.
1. Possibility of recycling and reuse of the treated waste water (pollution prevention).
2. If the recycling of the waste water constituent is not suitable for any reason biological process are preferred because of low cost compared to other process.
3. If the waste water contains non-biodegradable organic pollutants, micro-organisms cannot degrade the main part of the organics, biological process is not suitable.
Advanced oxidation process (AOP’S) are suitable alternatives for the treatment of the waste water containing toxic or non-biodegradable pollutants. Ms Chatterji et.al. (2003) [2]

In the dry process wood industry and their activities, these industries generate lower volumes of highly polluted wastewaters after cleaning activities. Advanced oxidation processes such as Fenton and photo-Fenton, are potentially feasible options for treatment of these wastewaters. Constraint of iron sludge formation that might be overcome with the use of nanoscale zero-valent iron (nZVI) powder. The supply of the reactants in more than one dose during the reaction time had significant and positive effects on the treatment efficiency. According to the results, Fenton and mostly photo-Fenton are promising treatment options for these highly recalcitrant wastewaters. Future investigations should focus on optimizing treatment processes and assessing toxic effects that residual pollutants and the nZVI might have. The feasibility of combining advanced oxidation processes with biological treatment is also recommended. Hansson et.al. (2012) [3]

A novel modified Fenton process using heterogeneous catalyst (swarf) was developed to catalyze the oxidation reaction of azo dye Acid Red 18. It was found that swarf could be used to replace iron salts as a catalyst for the Fenton reaction. The examined continuous Fenton process proved to be very efficient for decolorization of simulated wastewater containing 100 mg/dm3 Acid Red 18. Performance of the Fenton reactor and regeneration method of the catalyst was discussed. The simplified mechanism of hydroxyl radical production in the presence of swarf as a catalyst also was proposed. Barbusiński et.al. (2005), [4]

Spent DIPA is routinely generated from natural gas absorption columns. It is generated from periodic cleaning of absorption and regeneration columns and during a process upset. The liquid waste containing these absorbents is characterized of having high chemical oxygen demand (COD) in the range of 5,000 to 25,000 mg/L. Based on such loading, the waste is not suitable to be treated via biological treatment. Fenton’s reagent was found to be a suitable chemical treatment method. Among the parameters that will affect the treatment efficiency are temperature and pH. Thus for this study, the experimental ranges for temperature and pH: $30^\circ$C $\leq T \leq 60^\circ$C and $2 \leq$ pH $\leq 4$. The molar
ratio of reagents, $\text{H}_2\text{O}_2$: $\text{Fe}^{2+}$ used was 95. The treatment efficiency increases with increasing temperature. The best pH for treatment was 2.5. *Khamaruddin et al. (2012)* [5]

The present study is focused on a Common Effluent Treatment Plant (CETP) located at Umaraya, District Baroda. Waste water from about thirty five small and medium scale industries majorly comprising of chemical manufacturing and pharmaceutical industries are treated in this CETP. The incoming wastewater was collected and segregated into three groups as per their BOD/COD ratio. They were then oxidized independently by two oxidants Fenton’s reagent ($\text{Fe}^{2+}/\text{H}_2\text{O}_2$) and Sodium Hypochlorite (NaOCl) and reduction in COD and BOD were observed at different chlorine, $\text{H}_2\text{O}_2$, $\text{FeSO}_4$ doses, different pH values and contact time for determining the optimum values. COD and BOD values at optimized conditions for the two oxidants were compared and observed that maximum reduction of 64.35% and 68.57% respectively was achieved by Fenton’s reagent. The results clearly indicate that conventional system should be replaced by advanced oxidation process and Fenton’s reagent is a suitable choice.*Prashant et al.(2013)*[6]

Advanced oxidation processes (AOPs) constitute a promising technology for the treatment of wastewaters containing non-easily removable organic compounds. Chlorophenols (CPs) are a group of special interest due to their high toxicity and low biodegradability. Data concerning the degradation of CPs by means of AOPs reported during the period 1995–2002 are evaluated in this work. Among the AOPs, the following techniques are studied: processes based on hydrogen peroxide ($\text{H}_2\text{O}_2$ + UV, Fenton, photo-Fenton and Fenton-like processes), hotolysis, photocatalysis and processes based on ozone ($\text{O}_3$, $\text{O}_3$ + UV and $\text{O}_3$ + catalyst). *Pera-Titus et al. (2004)*[7]

The aim of our work was to study the biotreatability of heavily polluted pharmaceutical fermentation broth (COD value of 124,500 mg·L$^{-1}$) as well as application of Fenton oxidation for effective pretreatment. Because waste broth expressed biodegradability ($\text{BOD}_5$/COD ratio was 0.40), biological treatment was the first choice. At the same time, in preliminary ready biodegradability assessment test, diluted broth degraded 65% as well it was not toxic to mixed bacterial culture of activated sludge. Further experiments in pilot laboratory biological treatment plant confirm acceptable treatment efficiency up to 0.01 vol% of the broth added (76%). However, we had considered additional
pretreatment method to be able to enhance biotreatability. Fenton procedure was optimized in batch reactor using different concentrations of \( \text{Fe}^{2+} \), \( \text{H}_2\text{O}_2 \), temperatures (40/45 °C), as well as different retention times (up to 30 minutes). The highest treatment efficiency reached only 44% according to COD, but ready biodegradability of the sample increased (82%). Fenton oxidation was confirmed as possible method for pretreatment of broth, because it slightly enhanced biodegradability, it reduced organic pollution and formed products were non-toxic. Žgajnar Gotvajn et.al.(2005) [8]

The occurrence and fate of pharmaceutically active components in the aquatic environment has been recognized as one of the emerging issues in environmental chemistry. One key component, which is found in considerable concentrations in European natural waters and is only partially eliminated during biological wastewater treatment, is ibuprofen (IBU). This paper studies the application of classic Fenton, photo-assisted Fenton, \( \text{H}_2\text{O}_2 \)/UV and peroxymonosulphate (POMS) oxidation for degrading IBU from wastewater. It is seen that the applied advanced oxidation processes are capable of effectively degrading the IBU, with the photo-assisted Fenton oxidation having the highest efficiency. The IBU in the mixture (at an initial concentration of 22 mg/L) is completely removed by a \( \text{H}_2\text{O}_2 \) concentration of 0.024 and 0.03 mg/L for the photo-assisted Fenton and classic Fenton oxidation, respectively. A POMS concentration of 37 mg/L is required to remove all IBU. No complete mineralization is obtained: a chemical oxygen demand (COD) removal by 89 and 88% was obtained for a \( \text{H}_2\text{O}_2 \) concentration of 0.023 and 0.03 mg/L for photo-assisted Fenton and classic Fenton, respectively. A POMS concentration of 37 mg/L resulted in 86% reduction of COD. Scheersa et.al.(2012) [9]

This paper investigated the application of advanced oxidative processes – Fenton’s reagent - in wastewater disinfection. The treatments included the variation of the hydrogen peroxide and ferrous ions concentrations (\( \text{Fe}^{2+}/\text{H}_2\text{O}_2 \)) and pH values. The sewage samples were collected at Ilha do Governador Wastewater Treatment Plant (ETIG) in Rio de Janeiro, Brazil, before the biological treatment with activated sludge. The average pH fluctuated from 6.5 to 7.2 and the most common value was 6.7. The reactions with the Fenton´s reagents, as well as the beginning of the analysis occurred within 24 hours after the sewage sample´s collection. The oxidative process, its behavior
and the treatment effectiveness have been monitored by micro-organism counting, COD, BOD, ammonical nitrogen and others. Cláudio de O et.al.(2011) [10]

Oxidation by Hydrogen peroxide (H$_2$O$_2$) alone is not effective for degradation of heterocyclic nitrogenous pharmaceutical compounds in water containing pyridine derivatives, because of low rates of reaction at reasonable H$_2$O$_2$ concentrations. Transition metal salts e.g. iron salts and V-light can activate H$_2$O$_2$ to form hydroxyl radicals, which are strong oxidants. Pyridine derivatives like (2-AP) 2-aminopyridine can be toxic to certain life forms and are rated as priority pollutants by (USEPA) United States Environmental Protection Agency. In the present study degradation of 2-AP using Fenton’s reagent (iron salt and hydrogen peroxide) in combination with UV light (Photo-Fenton) is used to maximize percent 2-AP and Chemical Oxygen Demand (COD) removal. Also effect of pH, H$_2$O$_2$ concentration and iron concentration on 2-AP degradation efficiencies were investigated at different doses of 2-AP ranging from10-80mg/L using +: [30-47]:1 for Fenton process and [H$_2$O$_2$]: [Fe$^{2+}$]: [27-40]:1 for Photo-Fenton process, maximum 2-AP and COD removal was obtained. 2-AP removal of 95.3% and 100% respectively for Fenton and Photo- Fenton was obtained at pH= 3 corresponding to 10 mg/L initial concentration. The degree of mineralization achieved was 89% and 94% COD removal. Karale et.al.(2013)[11]

The pre-oxidation of an extremely polluted pharmaceutical wastewater (chemical oxygen demand (COD) value of 362,000 mg/l) using the Fenton’s reagent has been systematically studied using an experimental design technique. The parameters influencing the COD removal of the waste water, namely temperature, ferrous ion and hydrogen peroxide concentrations have been optimized to achieve a COD global reduction of 56.4%.The total range of the proposed experimental design, however, could not be tested because under some conditions (hydrogen peroxide concentration over 5 M) the Fenton’s reaction became violent and could not be controlled, probably due to the high exothermic effect associated with COD oxidation. For the tested conditions, the optimal values of hydrogen peroxide and ferrous ion concentration were 3 and 0.3 M, respectively, whereas temperature only showed a mild positive effect on COD removal. In addition, during the first 10 min of Fenton’s reaction, more than 90% of the total COD removal can be achieved. Fenton’s reaction has proved to be a feasible technique for the
pre-oxidation of the wastewater under study, and can be considered a suitable pre-treatment for this type of wastewaters. San Sebastian Martínez et al. (2003) [12]

Due to their insufficient removal in conventional wastewater treatments, advanced drinking and wastewater treatment options should be considered for the removal of pharmaceutically active compounds (PhACs) from urban, hospital and industrial wastewaters. This paper summarizes the current state-of-the-art in two often applied advanced oxidation processes (AOPs), namely TiO$_2$ assisted photocatalysis and photo-Fenton process. Their possibilities in removing PhACs are discussed, giving examples for several most studied compounds. Mira et al. (2011) [13]

Biodegradation of azo dyes is difficult due to their complex structures and low BOD to COD ratios. In this paper, the efficiency of using Fenton’s reagent (H$_2$O$_2$ + Fe$^{2+}$) as a pretreatment process to enhance microbial transformation of reactive black 5 (RB5) in an aqueous system was evaluated. The RB5 with an initial concentration of 250 mg/L was decolorized up to 90% in 60 h by using a bacterial consortium. Fenton’s reagent at a Fe$^{2+}$ concentration of 0.5 mM and H$_2$O$_2$ concentration of 2.9 mM (molar ratio, 1:5.8) was most effective for decolorization at pH = 3.0. The extent of RB5 removal by the combined Fenton–biotreatment was about 2 times higher than that of biotreatment alone. The production of some aromatic amines intermediates implied partial mineralization of the RB5 in Fenton treatment alone; in addition, decreasing of GC-MS peaks suggested that dearomatization occurred in Fenton-biological process. Fenton pretreatment seems to be a cost–effective option for the biotreatment of azo dyes, due mainly to the lower doses of chemicals, lower sludge generation, and saving of time. Bahmani et al. (2013) [14]

Advanced oxidation processes (AOPs) are widely used for the removal of recalcitrant organic constituents from industrial and municipal wastewater. The aim of this study was to review the use of titanium dioxide/UV light process, hydrogen peroxide/UV light process and Fenton’s reactions in wastewater treatment. The main reactions and the operating parameters (initial concentration of the target compounds, amount of oxidation agents and catalysts, nature of the wastewater etc) affecting these processes are reported, while several recent applications to wastewater treatment are presented. Stasinakis et al. (2008) [15]
The process of pesticide removal from industrial wastewater using chemical, vacuum-chemical and Fenton's reactions have been analyzed. Fenton process is attractive alternative to conventional oxidation processes in effluent treatment of recalcitrant compounds. The aim of this study is to evaluate the efficiency of chemical, vacuum and Fenton processes for the reduction of chemical oxygen demand in wastewaters from pesticide industry. In this study wastewater from pesticide industry was used. Whereas in the chemical procedure [Ca(OH)2 and KMnO4], the chemical oxygen demand removal efficiency is 94.9 %; in the vacuum-Ca(OH)2 + KMnO4 system (with 250 mg/L KMnO4, 1 mL H2SO4, 5 mg/L polyelectrolyte and 2000 mg/L CaOH application) this efficiency was 97.8 %; and a 99.8 % KOI removal efficiency was obtained by the Fenton process (the optimum ratio of [Fe^{2+}] to [H2O2] was 1:1.56 (mM/mM), at pH 3.0). Özdemir et.al(2008)[16]

The public demand for color free waste discharge to receiving waters and tougher color standards have made decolorization of a variety of industrial waste to top priority. Unfortunately, with the completed color causing compound, the decolorisation of these wastes is a difficult and challenging task. This article first describes the background information of dye molecules and dye waste characteristics. The methods for color measurements and standards are discussed. Hoa et.al(2000)[17]

The photochemical decolourisation of chlorotriazine reactive azo dye Reactive Orange 4 (RO4) has been carried out by Fenton and photo-Fenton processes. The effects of solution pH, applied H2O2, Fe^{2+} dose, UV light intensity have been studied. The increase of initial dye concentration decreases the removal rate. Under optimum conditions the photo-Fenton process is found to be more efficient than Fenton process. About 2% of colour resurgens was observed at the end of the reaction. Muruganandham et.al.(2004)[18]

The requirement of color removal has promoted the research in this field. However, there is still a lack of understanding of colour problems. In this paper a literature review is made to assess the information on color removal and need for systematic evaluation of the results is emphasized. Experimental studies are conducted on the textile dyeing wastewaters applying chemical precipitation, chemical oxidation, adsorption and their
combination. Results of the study are evaluated and discussed within the context of a systematic approach. APHA(1995)[19]

A two stage sequential Fenton's oxidation followed by aerobic biological treatment train was used to achieve decolorization and to enhance mineralization of azo dyes, viz. Reactive Black 5 (RB5), Reactive Blue 13 (RB13), and Acid Orange 7 (AO7). In the first stage, Fenton's oxidation process was used while in the second stage aerobic sequential batch reactors (SBRs) were used as biological process. Study was done to evaluate effect of pH on Fenton's oxidation process. Results reveal that pH 3 was optimum pH for achieving decolorization and dearomatization of dyes by Fenton's process. Degradation of dye was assessed by COD reduction and reduction in aromatic amines (naphthalene chromophores) which was measured by reduction in absorbance at 200 nm. More than 95% of color was removed with Fenton's oxidation process in all dyes. In overall treatment train 81.95, 85.57, and 77.83% of COD reduction was achieved in RB5, RB13, and AO7 dyes, respectively. In the Fenton's oxidation process 56, 24.5, and 80% reduction in naphthalene group was observed in RB5, RB13, and AO7, respectively, which further increased to 81.34, 68.73, and 92% after aerobic treatment. Fenton's oxidation process followed by aerobic SBRs treatment sequence seems to be viable method for achieving significant degradation of azo dye. Tunay et.al (1996) [20]

The applicability of Fenton's oxidation to improve the biodegradability of a pharmaceutical wastewater to be treated biologically was investigated. The wastewater was originated from a factory producing a variety of pharmaceutical chemicals. Treatability studies were conducted under laboratory conditions with all chemicals (having COD varying from 900 to 7000 mg/L) produced in the factory in order to determine the operational conditions to utilize in the full-scale treatment plant. Optimum pH was determined as 3.5 and 7.0 for the first (oxidation) and second stage (coagulation) of the Fenton process, respectively. For all chemicals, COD removal efficiency was highest when the molar ratio of H$_2$O$_2$/Fe$^{2+}$ was 150–250. At H$_2$O$_2$/Fe$^{2+}$ ratio of 155, 0.3 M H$_2$O$_2$ and 0.002 M Fe$^{2+}$, provided 45–65% COD removal. Hsueh et.al. (2007) [21]

The removal efficiency of activated carbon Filtrasorb 400 (F-400) towards three highly used reactive dyes in the textile industry was investigated. In this work, the adsorption capacities for the anionic reactive dyes, namely; Remazol Reactive Yellow, Remazol
Reactive Black and Remazol Reactive Red were determined. The adsorption capacity data showed high removal ability for the three reactive dyes and a distinguished ability for R. Yellow. The high adsorption capacities for F-400 were attributed to the net positive surface charge during the adsorption process. Surface acidity, surface basicity, H⁺ and OH⁻ adsorption capacities and pH_ZPC for F-400 were estimated and compared with other reported values. Mass et.al.(2005) [22]

The proposed research aims at studying the effect of the operating conditions (pH, H₂O₂/Fe⁺² ratio, reaction time) of the advanced oxidation Fenton process using H₂O₂/Fe⁺² for the different waste water streams containing API Molecule and API Molecule spiked water. The H₂O₂/Fe⁺² will be used as the oxidant. The optimum conditions of the Fenton process will be tried for different API in water.