Advanced Oxidation Processes are recognized in the early 1970s as the promising field of study for pollutant degradation, and much research and development work is being undertaken to commercialize some of these processes. AOPs have shown great potential in treating wastewater for the reason that the organic components that are thermodynamically unstable to the oxidation are not transferred from one phase to another. AOPs have found applications as diverse as ground water treatment, municipal wastewater sludge destruction and VOCs control.

Munter, 2001 (29) observed Advanced Oxidation Processes to be suitable for destroying dissolved organic contaminants such as halogenated hydrocarbons (trichloroethane, trichloroethylene), aromatic compounds (benzene, toluene, ethylenzene, xylene), pentachlorophenol (PCP), nitrophenols, detergents, pesticides, etc. They are also used to oxidize inorganic contaminants such as cyanide, sulphide and nitrite.

Andreozzi et al., (2000) (30) studied advanced oxidation processes (O3/UV and O3/H2O2) for the treatment of mineral oil-contaminated wastewater using a 17W UV lamp. The results of their investigation showed O3/UV system to be capable of achieving high levels of COD removal ranging from 80 to 90% within 30 min.

Idil Arslan et al., (2000) (31) studied advanced chemical oxidation of reactive dyes in simulated dye house effluents by ferrioxalate-Fenton/UV-A and TiO2/UV-A processes. They found ferrioxalate-photo-Fenton oxidation to be three times faster in decolorizing the dyes compared to photocatalytic process.
Photochemical advanced oxidation processes (AOPs) utilizing the combinations of UV/H₂O₂ and the photo-Fenton reaction are investigated in lab-scale experiments for the degradation of p-chlorophenol by Montaser Ghaly et al., (2001) (32). They observed photo-Fenton process to be the most effective treatment process for the degradation of p-chlorophenol at a very short radiation time. Finally, they made a rough comparison of the specific energy consumption and found that the photo-Fenton process reduced the energy consumption by at least 73 to 83% compared with the UV/H₂O₂ process.

Zwiener et al., (2000) (33) studied the oxidative treatment of pharmaceuticals like clobric acid, ibuprofen and diclofenac. With ozone alone they found negligible degradation of the compounds. However, they observed that the degradation efficiency improved with combined application of ozone and hydrogen peroxide and achieved almost more than 98% degradation at a concentration of 5.0 mg/l ozone and 1.8 mg/l hydrogen peroxide.

Anna Goi et al., (2001) (34) compared different oxidation processes such as hydrogen peroxide photolysis, the Fenton treatment, photo-Fenton treatment, and ozonation combined with hydrogen peroxide and UV radiation for the destruction of 2,4-dinitrophenol. Among all the processes studied, they found Fenton to be effective in the degradation of 2,4-dinitrophenol and concluded that advanced oxidation led to complete detoxification of 2,4-dinitrophenol.

Esplagas et al., (2002) (35) found Fenton’s reagent to be one of the evaluated advanced oxidation processes for phenol degradation. He used pseudo-first order kinetics for the analysis of the experimental data.

Hug et al., (2003) (36) investigated the oxidation of arsenic (As(III)) applying Fenton’s reagent in the pH range 3.5-7.5. They used ferric and ferrous iron with
hydrogen peroxide in aqueous solutions and found As(III) to be completely oxidized in solutions of Fenton’s reagent (Fe(II)/H₂O₂) at the studied conditions.

Effect of hydrogen peroxide using a continuous photochemical reactor on decolorization of three dyes, namely Acid Orange 8 (AO8), Acid Blue 74 (AB74) and Methyl Orange (MO) is studied by *Aleboyeh et al., (2003)* (37). They found that the rate of decolorization increased with increasing initial dosage of H₂O₂ up to a “critical” value at which it is maximum and beyond which it is inhibited. Their results confirm the pseudo–first order kinetic model to be in good agreement with the experimental data.

The oxidation potentiality of simulated aqueous solution of 2-chlorophenol (2-CP) by Fenton’s reagent is assessed for wastewater treatment by *Kavitha and Palanivelu (2003)* (38). In both Fenton and photo-fenton processes, they observed a maximum concentration of free chloride ion generating from 2-CP degradation process. They achieved only 39% DOC removal in Fenton’s process (i.e.,) only 2/5th of compound is mineralized. However, improvement in the efficiency of mineralization from 95–97% is observed in Photofenton process.

*Ajay Mandal et al., (2004)* (39) made a comprehensive experimental investigation on the removal of catechol from aqueous solution by advanced photo-oxidation. The effect of different process parameters, such as initial substrate concentration, H₂O₂ to substrate concentration ratio, addition of a solid catalyst (ferrous sulfate) are all studied. They achieved approximately 90–95% degradation of catechol within 60 min of reaction and showed that the degradation reaction of catechol with UV/H₂O₂ followed a pseudo second-order reaction.

The degradation of 4-chloro-2-methylphenol (PCOC) in aqueous solution by UV irradiation in the presence of TiO₂ is studied by *Sibel Irmak et al., (2004)*
They found that only 51.4 % of PCOC is degraded by this process. Improvement in degradation is achieved using various oxidants as electron scavenger and, periodate ion is found to be the most efficient oxidant. Moreover, they found that addition of metal ions to UV/TiO₂/H₂O₂ system increased the photo degradation rate of PCOC.

_Sivalingam et al., (2004)_(41) studied the kinetics of the photodegradation of substituted phenols by solution combustion synthesized TiO₂. They investigated the photocatalytic degradation rates of o-chlorophenol, p-chlorophenol, dichlorophenol, trichlorophenol, pentachlorophenol, o- and m-methylphenol (cresol) using the combustion synthesized TiO₂ and compared the degradation rates with commercial Degussa P-25. They found that chlorophenols degraded much faster than the methylphenols, which in turn degraded much faster than phenol. They also observed the photocatalytic activity of combustion synthesized TiO₂ to be significantly higher than that of Degussa P-25 under similar conditions.

_Marc Pera-Titus et al., (2004)_(42) reviewed the degradation of chlorophenols by means of advanced oxidation processes. Among the AOPs, processes based on hydrogen peroxide (H₂O₂ + UV, Fenton, photo-Fenton and Fenton-like processes), photolysis, photocatalysis and processes based on ozone (O₃, O₃ + UV and O₃ + catalyst) are studied. Half-life times and kinetic constants for CP degradation are also reviewed and the different mechanistic degradation pathways are taken into account.

_Idil Arslan et al., (2004)_(43) applied a variety of advanced oxidation processes (O₃/OH⁻, H₂O₂/UV, Fe²⁺/H₂O₂, Fe³⁺/H₂O₂, Fe²⁺/H₂O₂/UV and Fe³⁺/H₂O₂/UV) for the oxidative pre-treatment of real penicillin formulation effluent. They found alkaline ozonation and the photo-Fenton oxidation to be the
most promising AOPs in terms of COD (49–66%) and TOC (42–52%) abatement rates.

The effect of hydrogen peroxide (H$_2$O$_2$) on photocatalytic oxidation of phenol and monochlorophenols (CP) in aqueous suspensions of commercial TiO$_2$ rutile is investigated by Barakat et al., (2005) (44). They found that the combination of TiO$_2$ and H$_2$O$_2$ under UV illumination greatly enhanced the degradation rates of the phenol and chlorophenols. The photocatalytic oxidation with the H$_2$O$_2$/UV/TiO$_2$ system was found to be much more effective than either UV/TiO$_2$ or UV/H$_2$O$_2$ alone.

Yuan Song-hu et al., (2005) (45) made a comparative study on the degradation of various chlorophenols by electro-Fenton method. Under the optimal conditions, electro-Fenton method was used to treat various chlorophenols including PCP, 4-chlorophenol (4-CP), 2,4-dichlorophenol (2,4-DCP), 2,4,6-trichlorophenol (2,4,6-TCP) and their mixture aqueous solutions. Their pseudo first-order degradation rate constants gave the following sequence: 2,4-DCP > 2,4,6-TCP > PCP > 4-CP.

Zazo et al., (2005) (46) studied the chemical pathway and kinetics of phenol Oxidation using Fenton’s Reagent. In their study, they identified a series of intermediates like catechol, hydroquinone, and p-benzoquinone. Certain organic acids like maleic, acetic, oxalic, and formic with substantially lower amounts of muconic, fumaric, and malonic acids are also identified. Finally, the time evolution of the intermediates and TOC are fitted to a simple second-order kinetic equation.

Photodegradation of o-cresol in water is investigated using hydrogen peroxide as an oxidant by Wataru Minamidate et al., (2006) (47). They observed that the efficiency of o-cresol degradation increased as initial o-cresol
concentration decreased and concluded that for an initial o-cresol of 0.93mM, optimal H₂O₂ dose required is found to be around 150mM. Further, they inferred that the degradation of o-cresol with UV-C lamps (wavelength of 254 nm) is more significant than that with near-UV black light lamps (wavelength of 352 nm).

**Ivan Munoz et al., (2006) (48)** assessed different advanced oxidation processes applied to a bleaching Kraft mill effluent. The application of the selected AOPs all resulted in a considerable decrease in dissolved organic carbon (DOC) content with UV/TiO₂/Fenton to have the lowest environmental impact accompanied with a moderate-to high DOC removal rate. On the other hand, heterogeneous photocatalysis appeared to be the worst AOP both in terms of DOC abatement rate and environmental impact.

**Olga Gimeno et al., (2005) (49)** studied the remediation of phenol and two substituted phenols (4-nitrophenol and 4-chlorophenol) using different AOPs. Amongst the technologies investigated, those combining ozone and radiation showed the best efficiency in terms of phenols elimination and also COD and TOC decay rates. They concluded that addition of Titania powder resulted in a slight inhibition of the parent compound degradation rate; although a positive effect is experienced when measuring the chemical oxygen demand (COD) and total organic carbon (TOC) removals.

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 by **Nora San et al., (2003) (50)** using an experimental design technique. They have optimized the parameters influencing the COD removal of the wastewater, namely temperature, ferrous ion and hydrogen peroxide concentrations and achieved more than 90% removal of the
total COD. For the tested conditions, they observed the optimal values of hydrogen peroxide and ferrous ion concentration to be 3 and 0.3 M, while temperature showed only a mild positive effect on COD removal.

The efficiency of advanced oxidative processes (AOPs) towards the degradation of aqueous solutions containing benzene, toluene and xylenes (BTX) and gasoline-contaminated waters is investigated by Elaine Regina et al., (2005) (51). They found that near UV-assisted photo-Fenton process effectively oxidized and almost completely degraded BTX. They also achieved more than 80% removal of the phenolic intermediates within 30 min of reaction time. However, heterogeneous photocatalysis and H$_2$O$_2$/UV system showed lower degradation efficiency.

Andrew J. Poole et al., (2004) (52) studied the treatment of biorefractory organic compounds in wool scour effluent by hydroxyl radical oxidation. They found many compounds in wool sour effluent imparting a high chemical oxygen demand of 500–3000 mg/L and dark color. They treated such compounds with H$_2$O$_2$/UV process and achieved a maximum of 75% COD, 85% total organic carbon, and 100% removal of color.

Humic acid (HA) removal using advanced oxidation processes (AOPs) particularly, UVA/H$_2$O$_2$ and Photofenton-like process (UVA/Fe(III)/H$_2$O$_2$) is investigated by Sanly et al., 2007 (53). They found UVA/Fe (III)/H$_2$O$_2$ process to be effective in removing more than 80% DOC and 90% UV254 absorbance.

Kansal et al., (2007) (54) optimized the photocatalytic process parameters for the degradation of 2,4,6-Trichlorophenol in aqueous solutions. They observed the percent degradation and COD reduction of 2,4,6-TCP to increase with increase
in the catalyst dose up to 1.1 g/L, pH in the range of 4 – 4.5, and oxidant concentration of 9.95 - 10.6M.

The photocatalytic degradation of catechol, resorcinol, m-cresol, o-cresol and phenol is investigated by Arana et al., (2007) (55). They found that in the presence of hydrogen peroxide, degradation rates are determined by the localization of specific adsorption centres than by the amount of adsorbed molecules or the number of aromatic ring activating positions generated by substituents. In addition to this, they also observed that the interaction of catechol with the hydroxyls (responsible for the formation of the more photoactive \( \cdot \text{OH} \) radicals) slows down the degradation of the other phenolics.

Wu et al. (2007) (56) used \( \text{H}_2\text{O}_2/\text{UV} \) treatment method to degrade dimethyl sulfoxide (DMSO). The DMSO concentration was 1,000 mg/L, and the \( \text{H}_2\text{O}_2 \) concentration was the same as that of the DMSO with a UV radiation intensity of 5.5 mW/cm\(^2\). In this case, the degradation of the compound was almost 100% after 180 min of reaction at pH 3 and a temperature of 25°C. In contrast, with a pH of 10, at the same temperature and the same time period, the decomposition was 83%. Therefore, these results seem to indicate that the degradation of this toxin is more effective when carried out in an acid medium as compared to an alkaline medium.

Stasinakis et al., (2008) (57) reviewed the application of various advanced oxidation processes for wastewater treatment. They presented 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.
**Fares Al Momani et al., (2008)** (58) investigated the degradation of aqueous solutions of cyanobacteria using advanced oxidation processes. They assessed the process parameters like - the effect of concentration of reactant, temperature, and pH on toxins degradation along with the reaction kinetics. They observed that ozone combined with Fe (II) to be more efficient in toxin elimination.

**Mohajerani et al., (2009)** (59) have reviewed the integration of advanced oxidation technologies and other traditional wastewater treatment processes. They observed that the integration of physical, chemical, and biological treatment processes are useful to take advantages of the methods and to minimize the drawback of each method.

**Poyatos et al., (2009)** (60) reviewed different types of advanced oxidation processes and their application to the treatment of polluted wastewater. The various treatment systems described are shown to effectively degrade and remove specific pollutants, which otherwise would have been extremely difficult to eliminate with conventional processes since many of these compounds are not biodegradable.

The use of Fenton’s reagents in destruction of waste material present in Tambla Tributory (Durgapur, India) industrial wastewater is investigated by **Tamal Mandal et al., (2010)** (61). Various process parameters like pH, temperature, H₂O₂ and FeSO₄ are optimized for the removal of COD. They observed 95% COD removal at an optimum concentration of FeSO₄ (6 gm/l) and H₂O₂ (220gm/l).

**Emad S. Elmolla & Malay Chaudhuri (2010)** (62) studied different advanced oxidation processes for treatment of antibiotic aqueous solution containing amoxicillin, ampicillin, and cloxacillin. They found all the studied
processes to efficiently degrade the antibiotics except for UV/ZnO. They observed Photofenton process exhibiting higher rate constant (0.029 min\(^{-1}\)) than the Fenton process (0.0144 min\(^{-1}\)).