Application of Submerged Plasma Irradiation Process for the Treatment of Industrial Wastewater

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1. Introduction

Treatment of wastewater by using plasma process has attracted attention of many researchers due to its higher efficiency in short period of time. Plasma process is one of the advanced oxidation processes based on the production of hydroxyl radicals. O, HO₂, ozone, hydrogen peroxide [Sun et al, 1998] are also produced during plasma processes. All these active species are good oxidizing agents. These oxidizing agents can react with organic pollutants and oxidize them into carbon dioxide. Studies have shown that almost all kinds of organic pollutants can be degraded by plasma process [Malik et al, 2001]. Plasma process is able to remove types of organic compounds (benzene, phenol, dyes) from wastewater. Discharge of industrial wastewater directly into water sources can result in increment of COD value. High value of COD increases bacterial growth. It consumes and diminishes oxygen level that can be fatal to aquatic animals. Most of the studies are done in artificial raw water with certain kind of pollutants in it. Actual wastewater is the mixture of different kinds of compounds and some compounds such as alcohol and carbonates decrease efficiency of plasma processes. This study was conducted in an attempt to monitor the removal of COD from industrial wastewater with and without using additives.

2. Materials and methods

This study was conducted in wastewater from D Steel. Different conditions used for the experiment are shown in table 1. The experimental apparatus consists of a feed tank, reactor, high voltage power supply and a pump as shown in fig 1. The reactor has a volume of 50mL and encloses a needle electrode (d=2mm) made of tungsten. Tungsten electrode is enclosed in a ceramic case and the distance between needle electrode and ground electrode is 12cm. Five liters raw water was kept in inlet tank and circulated for 30 minutes in different flow rates.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Conditions</th>
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<tbody>
<tr>
<td>Voltage (V)</td>
<td>450, 600, 900, 1200, 1500</td>
</tr>
<tr>
<td>Flow rate (L/min)</td>
<td>2, 3, 4</td>
</tr>
<tr>
<td>Initial Conductivity (mS)</td>
<td>3.09</td>
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<tr>
<td>Concentration of H₂O₂ and FeSO₄ (mg/L)</td>
<td>80</td>
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</tbody>
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3. Results and discussion

Increase in magnitude of voltage increases the intensity of plasma. Plasma discharge becomes stronger with the increase on voltage. In 30 minutes operation time and 1500V applied voltage, COD_{Cr} removal was found to be 12% higher than in 450V in same operation time. COD_{Cr} removal was found highest at 1500V but the device may not run continuously at a higher voltage due to increase in water temperature so 1200V was taken as the optimum voltage during the study. Increase in voltage increases the intensity of plasma and the concentration of hydroxyl radical in water. Moreover, increase in voltage can also increase formation of ions and their kinetic energy. This increases radicals in bulk solution. Higher voltage provides energy sufficient for the production of active species which react with organic compounds and degrade them. Similarly, flow rate of 3L/min was taken as the optimum flow rate with COD_{Cr} removal of 17.6% in 30 minutes of operation time. Studies have shown that addition of chemicals like hydrogen peroxide and ferrous sulphate increases the efficiency of plasma treatment. But in this study, addition of hydrogen peroxide and hydrogen peroxide along with ferrous sulphate did not show any significant effect on COD_{Cr} removal but COD_{Cr} removal with the addition of ferrous sulphate was 8% greater at the end of same treatment time compared to the discharge without ferrous sulphate. Addition of ferrous sulphate initiates Fenton reaction in solution resulting in the production of higher concentration of hydroxyl radicals. Hydroxyl radical is considered as the most important agent in the oxidation of organic pollutants as its oxidizing potential is higher than other active species. Similarly, addition of hydroxyl radical is supposed to increase efficiency of plasma treatment but this trend is not seen in this study. Presence of hydrogen peroxide interferes measurement of COD as it can consume the oxidizing agent used during the measurement of COD. This ultimately shows high COD values.

![Fig. 1 Effect of operation time and FeSO4](image)

4. Conclusions

1) Higher voltage was found to be beneficial for COD_{Cr} removal from waste water and the flow rate of 3L/min was found to be the optimum flow rate.

2) Addition of ferrous sulphate showed an increase in efficiency of plasma treatment. This can be due to the increased production of hydroxyl radicals by Fenton reaction.

References
