Advanced Oxidation Processes for Wastewater Treatment

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Introduction

- **Oxidation-Reduction-Reaction**
  - Transfer of electrons (loss, gain)

- **Chemical Oxidation**
  - Main aim: Mineralization of organic compounds into \( \text{CO}_2 \), \( \text{H}_2\text{O} \) and harmless inorganic products

- **Oxidizing Agent**
  - Effects the oxidation of a substance
  - Gets reduced
# Oxidizing Agents

## Tabelle 1: Redoxpotentiale der in der Trinkwasseraufbereitung zugelassenen Oxidationsmittel [2]

<table>
<thead>
<tr>
<th>Reaktionen</th>
<th>Potentiale $E_0$ (Volt) 25 °C</th>
<th>Oxidant</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{OH}^* + H^+ + e^- \rightarrow H_2O$</td>
<td>2,33</td>
<td>OH-radicale</td>
</tr>
<tr>
<td>$\text{O}_3 + 2H^+ + 2e^- \rightarrow O_2 + H_2O$</td>
<td>2,07</td>
<td>Ozon</td>
</tr>
<tr>
<td>$\text{H}_2\text{O}_2 + 2H^+ + 2e^- \rightarrow 2H_2O$</td>
<td>1,76</td>
<td>Hydrogen Peroxid</td>
</tr>
<tr>
<td>$\text{MnO}_4^- + 4H^+ + 3e^- \rightarrow \text{MnO}_2 + 2H_2O$</td>
<td>1,68</td>
<td>Permanganat</td>
</tr>
<tr>
<td>$\text{O}_2 + 2H_2O + 4e^- \rightarrow 4\text{OH}^-$</td>
<td>0,40</td>
<td>Oxygen</td>
</tr>
</tbody>
</table>

The higher the Redox-Potential, the higher the Oxidation-Power

Quelle: DVGW Lehr-und Handbuch der Wasserversorgung Bd. 6 (2004) S.316
Advanced Oxidation Processes (AOP) - Characteristics

- same chemical feature: \(\rightarrow\) Production of OH-Radicals
  - Very reactive species
  - Attack the most part of organic molecules
  - Little selectivity of attack \(\rightarrow\) useful for an oxidant used in wastewater treatment

- Work under ambient Conditions

- AOP´s different reacting Systems e.g. :
  - Fenton-/Fenton-like Reactions,
  - Ozone-Water-UV Systems,
  - electrochemical Oxidation
  - Different combinations
Fenton Reaction

Producing OH radicals by means of addition of $\text{H}_2\text{O}_2$ to $\text{Fe}^{2+}$ salts

$$\text{Fe}^{2+} + \text{H}_2\text{O}_2 \rightarrow \text{Fe}^{3+} + \text{OH}^- + \text{OH}^*$$

Easy way to produce OH-Radical
Fe non toxic, abundant
No special instruments
pH dependent (2,7-2,8)
Neutralization - Flocks,
Sludge (disposal problems)
Ozone-Water-System $O_3/H_2O_2$  $H_2O_2/UV$  $O_3/UV$

$O_3$ higher absorption yield than $H_2O_2$
$H_2O_2$ is effective at wave lengths < 254nm
Special instruments
Ozone generation is expensive

\[ O_3 \xrightarrow{h\nu} O^1(D) + O_2 \]
\[ k_{O_3} \]
\[ O^1(D) + H_2O \rightarrow H_2O_2 \]
\[ H_2O_2 \xrightarrow{h\nu} HO^* + OH \]
Comparision of some AOP - Example

pH 3 u. 10 UV/O₃

pH ?? UV/ H₂O₂ / Fe²⁺

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Fig. 4 Degradation of a dyehouse waste (c₀(TOC) = 275 mg/l) with ozone and combinations

Fig. 5 Degradation of a dyehouse waste (c₀(TOC) = 275 mg/l) with H₂O₂, TiO₂ and Photo-Fenton
Points to consider for \( \text{O}_3/\text{H}_2\text{O}_2 - \text{H}_2\text{O}_2/\text{UV} - \text{O}_3/\text{UV} \)

- Influence of pH
- OH-Radical Scavenger
- Light wasting
- Mass transfer limitation
- Additional equipments
- Cost evaluation
  - Capital costs, operating costs, maintenance
  - Depends on the nature and concentration of the pollutants, flow rate, reactor configuration
Boron Doped Diamond – Elektrode (EAOP)

- Covered with thin layer Diamond
- Doped with Boron – make conductive
- Bears a high over voltage (Material)
- Generation of OH-Radicals directly from water

http://www.aktuelle-wochenschau.de/2006/images/woche8b/abb1.jpg
- Material does not expend
- No chemicals
- Water needs just a conductivity
- Degradation depends on current density
- Optimal current density – depends on COD
- Easy to handle
- Expensive to produce
Conclusions

- AOP’s high application
  - Drinking water
  - Waste water
  - Industrial wastewater
  - Soil

- Pretreatment for biological treatment

- High potential (research)

- Efficiency depends on character and concentration of pollutions
References


- Ruppert UV/O3, UV/H2O2, UV/TiO2 and the Photo-Fenton Reaction Comparison of Advanced Oxidation Processes for Wastewater Treatment, Cosmosphere 28 (1994) 1147-1454


- http://cover.deutschesfachbuch.de/books/3527299580/bx.jpg