Extension of conventional wastewater treatment processes

Brief description

Despite significant efforts made over the past decades, the industrial sector remains a major water consumer, accounting for 20% of global water usage. Although the implementation of Best Available Techniques (BAT) has reduced the impact of industrial effluents, the development of new methodologies for water reuse and recycling remains a critical need. Process waters come into contact with a wide variety of chemicals, some of which are highly toxic and/or classified as priority or emerging contaminants. These compounds are often recalcitrant to conventional treatment processes, hindering water loop closure and potentially causing significant environmental impact even at low concentrations.

The **Research Group on Pulp, Paper, and Advanced Water Treatments** at the Complutense University of Madrid develops and applies new knowledge to address specific challenges related to the treatment of process waters, concentrates, and effluents, as well as the regeneration of wastewater for reuse in various applications.

Figure 1. *Photocatalysis system.*

The investigated treatments include **Advanced Oxidation Processes** (AOPs) such as **Fenton processes, photocatalysis**, **electrooxidation**, and **ozonation**, in conjunction with biological technologies for example **aerobic membrane bioreactors**. These solutions enable a higher removal of emerging contaminants, micro-pollutants, and recalcitrant organic matter.

How does it work?

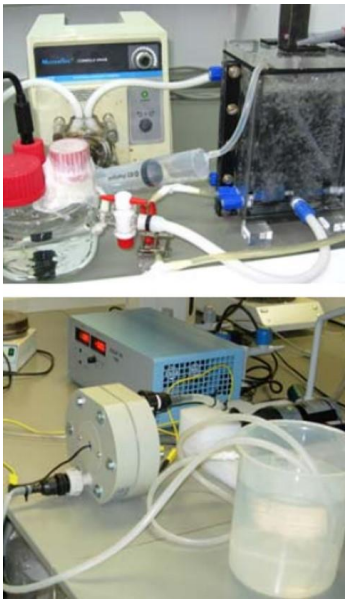

Figure 2. *Electrooxidation system.*

The technology integrates multiple treatment processes, selected based on the type of water and the specific contaminants present:

- **Aerobic Membrane Bioreactors (MBR):** They combine biological treatment with membrane filtration, achieving efficient purification and producing a high-quality effluent free of suspended solids.
- **Photocatalysis:** It uses UV light and catalysts such as TiO_2 to generate reactive radicals that oxidize persistent organic compounds.
- **Electrooxidation:** It applies electric current to generate oxidizing agents in situ, enabling the degradation of complex pollutants.
- **Ozonation:** It involves the injection of ozone, a powerful oxidant that removes color, odors, pathogens, and recalcitrant contaminants.
- **Conventional Biological Treatments:** They use microorganisms under aerobic or anaerobic conditions to remove biodegradable organic load.
- **Biodegradability Tests:** They include assays using *Pseudomonas putida*, respirometry, BOD (Biochemical Oxygen Demand), and Zahn-Wellens tests.
- **Toxicity Tests:** Employ bioassays with luminescent bacteria (*Vibrio fischeri*), measuring inhibition based on luminescence reduction. This is important to determine the toxicity of AOPs effluents when contaminants are not totally mineralized.

What problem does it solve?

The investigated treatments **overcome the limitations of conventional processes** by removing recalcitrant contaminants, reducing effluent toxicity, and improving water quality for discharge or reuse. They also enhance operational efficiency and minimize the generation of by-products.

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What future products will it develop?

Research conducted on the extension of conventional wastewater treatment processes has enabled the development of various systems and tools, including:

- Modular tertiary/quaternary treatment systems.
- Advanced portable reactors for use in hospitals, laboratories, or industrial facilities.
- Hybrid systems powered by renewable energy for autonomous treatment.
- Real-time monitoring and control of critical parameters.
- Compact and modular reactors suitable for small and medium-sized installations.
- Digital tools for real-time control and optimization.

The results obtained allow for **application** across various sectors, such as:

- Urban wastewater treatment plants (WWTPs) as tertiary or quaternary treatment.
- Pharmaceutical, cosmetic, textile, and food industries.
- Hospitals and laboratories, enabling point-of-origin treatment.
- Water regeneration for irrigation or non-potable urban uses.
- Emergency situations or remote areas with limited infrastructure.

Competitive advantages compared to other research.

- Integration of treatment processes for water loop closure and effluent reuse.
- High efficiency in the removal of micropollutants.
- Modularity, scalability, and easy integration with existing systems.
- Reduced consumption of chemicals and lower generation of waste and by-products.
- Automated operation adaptable to varying water qualities.
- Potential for water reuse in compliance with regulatory standards.

Where has it been developed?

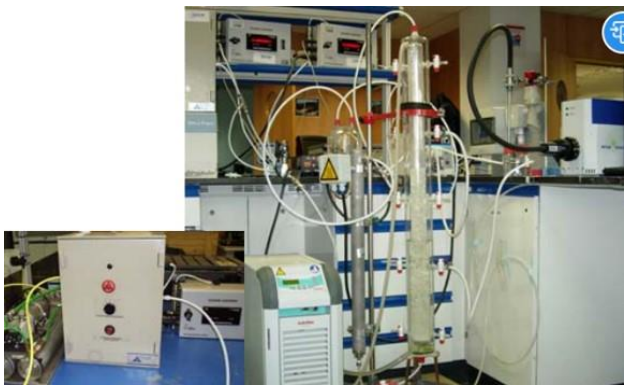

Figure 3. *Ozone generator and ozonation column.*

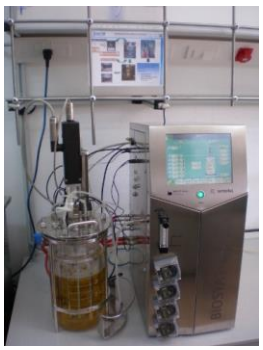

Figure 4. *Laboratory-scale MBR (Membrane Bioreactor)*

The **Pulp, Paper, and Advanced Water Treatment Research Group** at the Complutense University of Madrid (UCM) has the capacity to integrate these technologies to enable comprehensive contaminant removal through multiple pathways. The research group has extensive experience and has led several national and international projects related to Advanced Oxidation Processes (AOPs) and water reuse. The group is equipped with the necessary infrastructure and instrumentation to conduct laboratory- and pilot-scale studies in **photocatalysis** (Figure 1), **electrooxidation** (Figure 2), and **ozonation** (Figure 3), as well as biological technologies such as **membrane bioreactors** (Figure 4).

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And moreover…

The solutions developed address key **challenges related to water quality, environmental regulations, and the circular economy**. Their modular and adaptable design allows for implementation in both large-scale infrastructure and decentralized or hard-to-reach settings.

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