Development of a 3D-electrode on the basis of magnetic particles

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Research topic

The project targets the closure of process cycles in the chemical industry by treating salt and organics containing waste water by means of an electrochemical magnetically stirred reactor to provide a sustainable economy. The innovation consists of the first time combination of a magnetically stirred reactor with electrochemical polarization. Thereby it should be demonstrated that this reactor allows the elimination of low concentrated organics from salt containing waste water accompanied by the electrochemical regeneration of the deployed magnetic particles.

Background

Starting point

In the vast majority of all processes in the chemical industry salt and organics containing waste waters accumulates. Up to now the purification respectively the disposal is inefficient and associated with high effort/costs. Electrochemical techniques have all the attributes to accomplish these sophisticated technical, economical as well as ecological challenges.

Theory

Electrochemical processes are known to be running solely at the interface between the electrode and the surrounding liquid. To reach high yields, the ratio between the electrode surface and the volume of the liquid should be maximized.

In this project we use magnetic carbon micro particles in combination with an magnetically stirred reactor (MSR).

The magnetic particles interact with external alternating magnetic fields.

- Intensive movement of the particles
- Torsional moment is induced (Fig. 1).

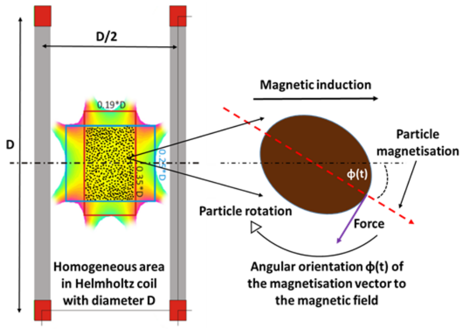

Fig. 1: Homogeneous field within two Helmholtz coils and the impact of the magnetic particles [1]

Improvements

Magnetically stirred reactor in comparison to conventional fluid beds

- enhanced mixing and thereof resulting a more effective mass transfer
- more homogeneous distribution of the particles
- broad range of feasible liquid flows

Tasks

1. Design of a laboratory reactor cell with 3-electrode assembly (Fig. 2)
2. Construction of a measurement setup with potentiostat, reactor cell mounting, thermostatic control, diaphragm pump, etc., which enables a continuous operation of the reactor

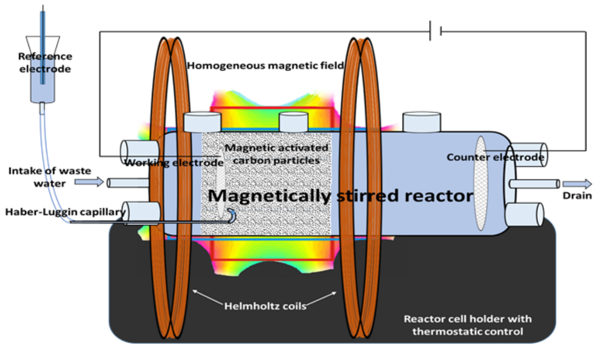

Fig. 2: Schematic depiction of the electrochemical magnetically stirred reactor

3. Experiments to investigate the desalination first of artificial later on of real industrial waste water, by varying the operation parameters such as liquid flow, temperature, electrode potential, current density, etc.. Out of this fundamental insights of the adsorption of ions onto activated carbon should be gathered. In this context the carbon material is modified in consultation with the project partners. Additionally the suitability of the new electrochemical magnetically stirred reactor to other promising applications should be revealed.
4. Establishment of the summary (TOC) as well as the substance specific analytics (HPLC, ion chromatography) to quantify organic pollutants. A potential challenge thereby is the high salt content of the sample matrix.
5. Investigations of potential driven adsorption of organics onto the magnetic carbon particles (Fig. 3) by varying the operation parameters. Out of the gained data conclusions of the interaction of organic molecules with polarized carbon surfaces should be drawn. The electrochemical characteristics of single particles should be analyzed by cyclovoltametry. Furthermore the features of the magnetically stirred reactor should be determined (current limit, mass transfer coefficients).

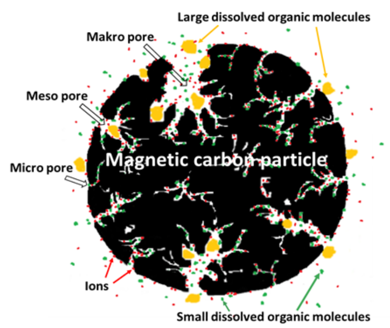

Fig. 3: Schematic depiction of a magnetic carbon particle with absorbed ions and organics [2]

6. Regeneration of the particles via potential dependent desorption of the organic compounds from the particle surface. As well as in task 3 the material characteristics of the carbon should be adjusted and optimized to the requirements.
7. Endurance tests to study the stability of the particles and elucidation of deterioration mechanism. In this process it has to be checked if particle properties, for example adsorption characteristics, electrochemical activity, shape and size (determination by means of microscopic analysis) alter during continuous operation (up to 3 weeks). Basic tests should clarify which operation parameters like potential, current density, magnetic induction, liquid flow, temperature, etc., affect the electrochemical adsorption and desorption of organic compounds in the longer term.
8. Participation in the conception of the demonstrators (design, dimensions, connection to plants at the location of the industrial partners, occupational safety, risk assessment) based on the laboratory data. Additionally the operation parameters have to be define.

Aims

- The electrochemical magnetically stirred system represent a new reactor concept by which for the first time it should be possible to purify industrial waste water containing organic residues sustainably, thus the regained feedstocks can be returned in the economic cycle. Another important factor is the minimization of the environmental impacts of the essential resource water.
- Furthermore the electrochemical magnetically stirred reactors offer a high innovation potential in other scopes for example microbiological electrosynthesis, water softening, treatment of particle and/or fiber-containing medias, electro organic synthesis, processing brackish water, elimination of trace substances in sewage plants or the recovery of valuable materials like heavy metal ions out of process waste water.

Literature

[1] Scheme adapted from KIT & M-Pulse Magnetisiertechnologie
[2] Scheme adapted from Begg Cousland S.R.L.

Project partners:

covestro · DWI Leibniz-Institut für Interaktive Materialien · EVONIK INDUSTRIES · Fraunhofer ISC Projektgruppe IWKS · fumatech functional membranes for fuel cells BWT GROUP · KIT Karlsruher Institut für Technologie