Enzyme supplemented membrane bioreactor (EnMBR) for degradation of recalcitrant compounds in industrial wastewater (DST/TMC/2K11/342)

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Participating Institutes

The Energy and Resources Institute (TERI), New Delhi, India
(Indian Project Coordinator)

KULeuven (KUL), Leuven, Belgium
(EU Project Coordinator)

Centre Tecnologic de la Quimica de Catalunya (CTQC), Tarragona, Spain

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Background

- Recalcitrant compounds in industrial wastewater
  - — difficult to degrade in conventional biological treatment
  - — additional enzymatic / chemical treatment required
- Membrane applications in wastewater treatment
  - — membrane fouling unavoidable
  - — suitable cleaning strategies required
- Enzymatic treatment
  - — applicable to recalcitrants degradation and membrane cleaning
  - — versatile and environment-friendly
  - — enzyme stability and appropriate reactor configuration required

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Enzyme immobilization

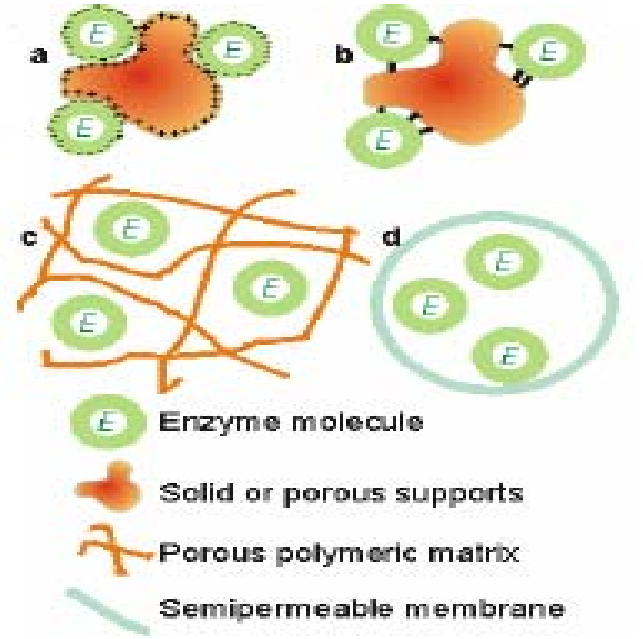
Advantages of immobilized enzyme

- Enzyme can be reused
- Enhances operational stability

Characteristics	Adsorption	Covalent binding	Entrapment	Membrane confinement
Preparation	Simple	Difficult	Difficult	Simple
Cost	Low	High	Moderate	High
Binding force	Variable	Strong	Weak	Strong
Leakage	Yes	No	Yes	No
Applicability	Wide	Selective	Wide	Very wide
Running problems	High	Low	High	High
Microbial protection	No	No	Yes	Yes

http://www.lsbu.ac.uk/water/enztech/immethod.html

Immobilization methods



a. **Adsorption**
b. **Covalent linkage**
c. **Enzyme entrapment**
d. **Enzyme encapsulation**

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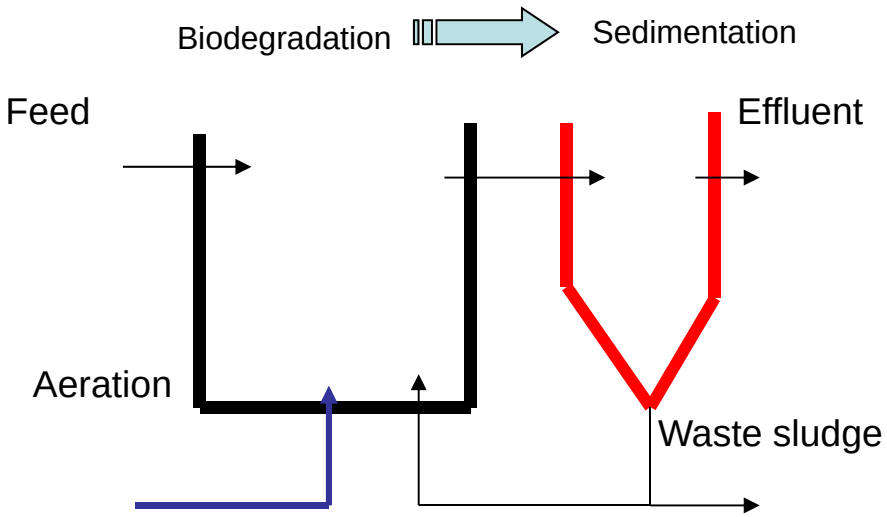
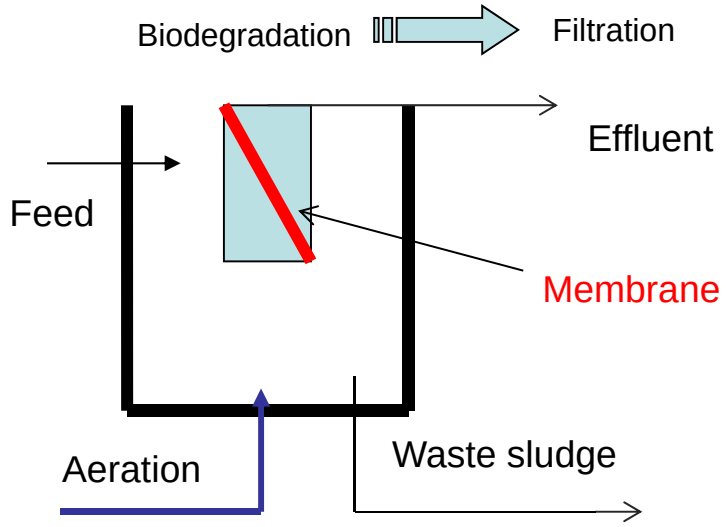
Aerobic biological wastewater treatment





Activated Sludge Process (ASP)

- Variable effluent quality
- Sludge settling problems
- Large footprint

Membrane Bioreactor (MBR)

- Consistently high effluent quality
- HRT-SRT decoupled
- Smaller footprint
- Lower excess sludge production

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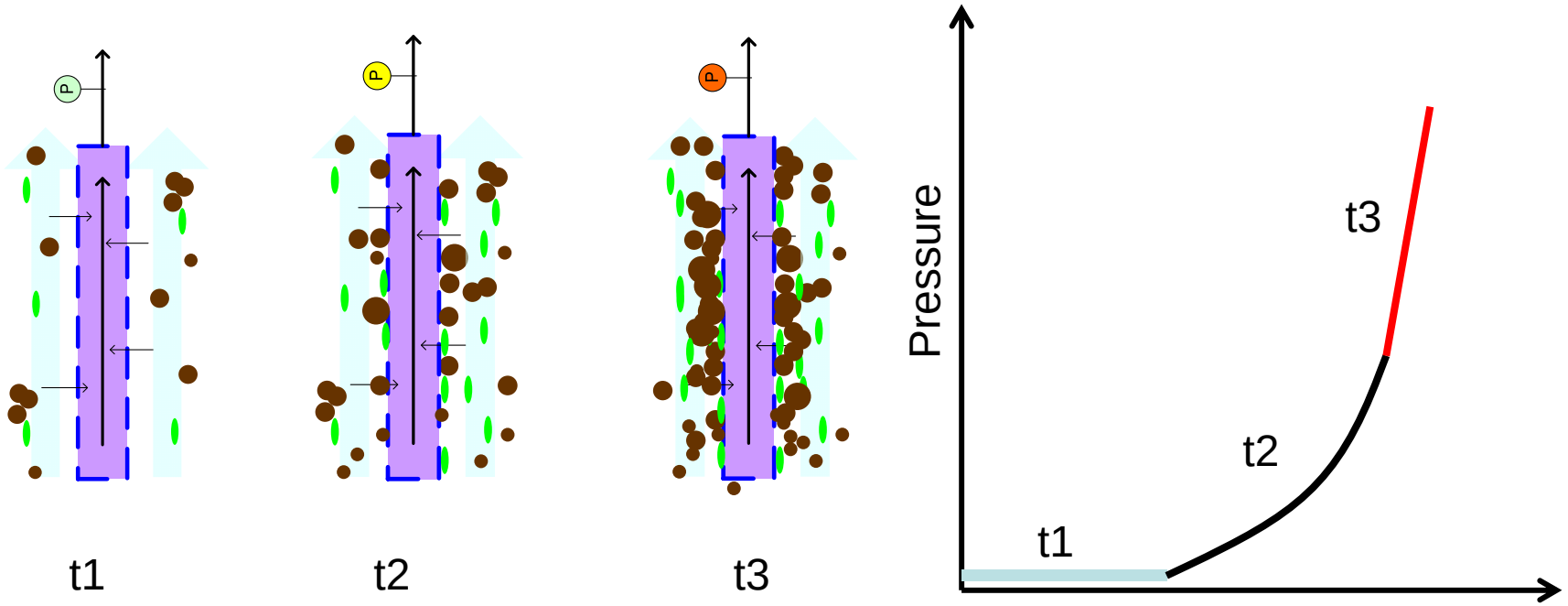
Membrane fouling



Fouling:
- Bio
- Organic
- Inorganic

Fouling:
- Internal
- Pore blocking
- Cake layer

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Objective

Incorporate enzymatic degradation in MBR

(i) Enzyme immobilization on suitable media

(ii) Testing of immobilized enzyme in MBRs

(iii) Long-term performance evaluation

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Enzyme-substrate combinations

Application	Substrate	Enzyme
Wastewater treatment (pulping)	Lignin	Laccase, Mn-peroxidase (from white rot fungi)
Wastewater treatment (molasses distilleries)	Melanoidins	Laccase, Mn-peroxidase (from white rot fungi)
Membrane cleaning (various applications)	Fats, proteins	Lipase, Protease
Industrial wastewater	Chlorophenols	Chloroperoxidase

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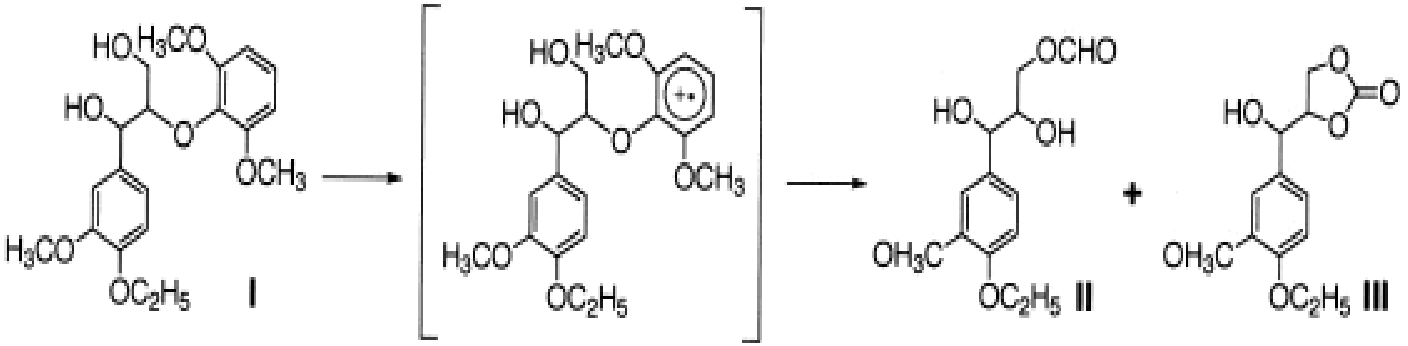
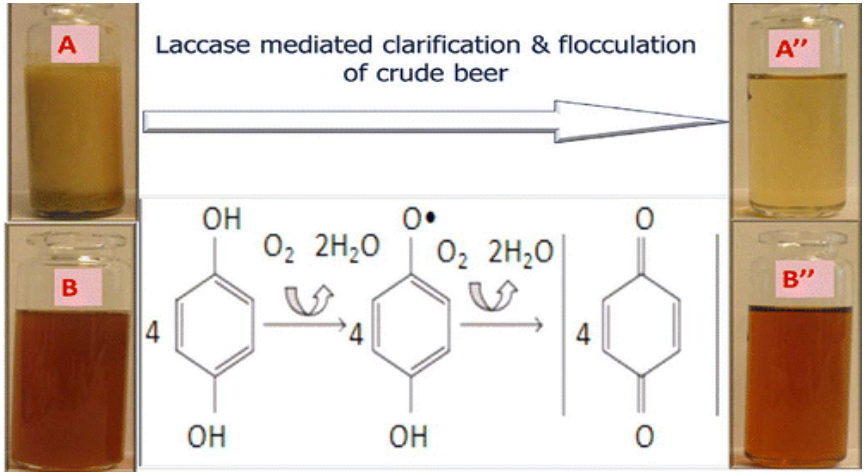
Enzymatic degradation



Aromatic ring cleavage of lignin and its intermediates by Laccase

Kawai et al., 1999, FEBS Letters



Dhillon et al., 2012, J Agr Food Chem

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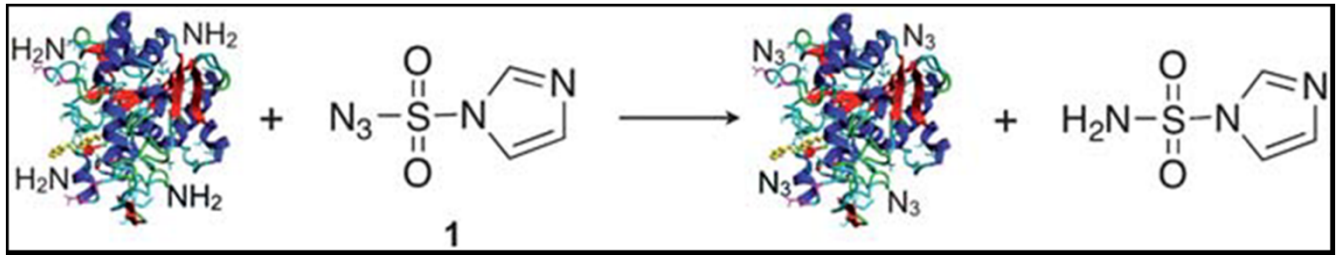
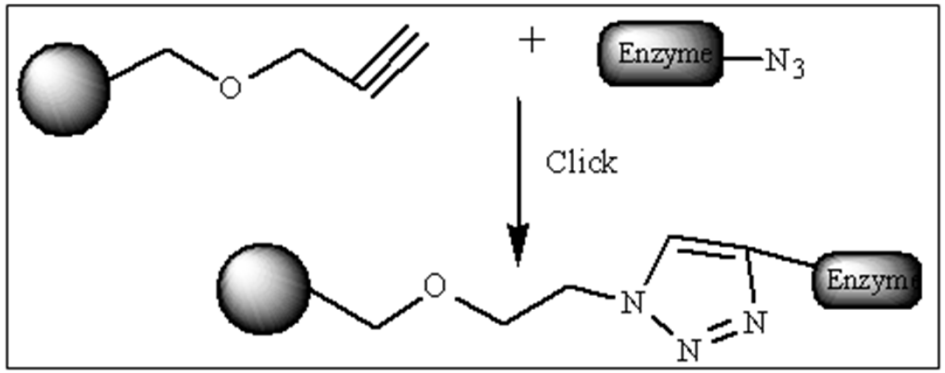
Enzyme immobilization

Synthesis of azide functionalised lipase



Synthesis of polymer supported lipase



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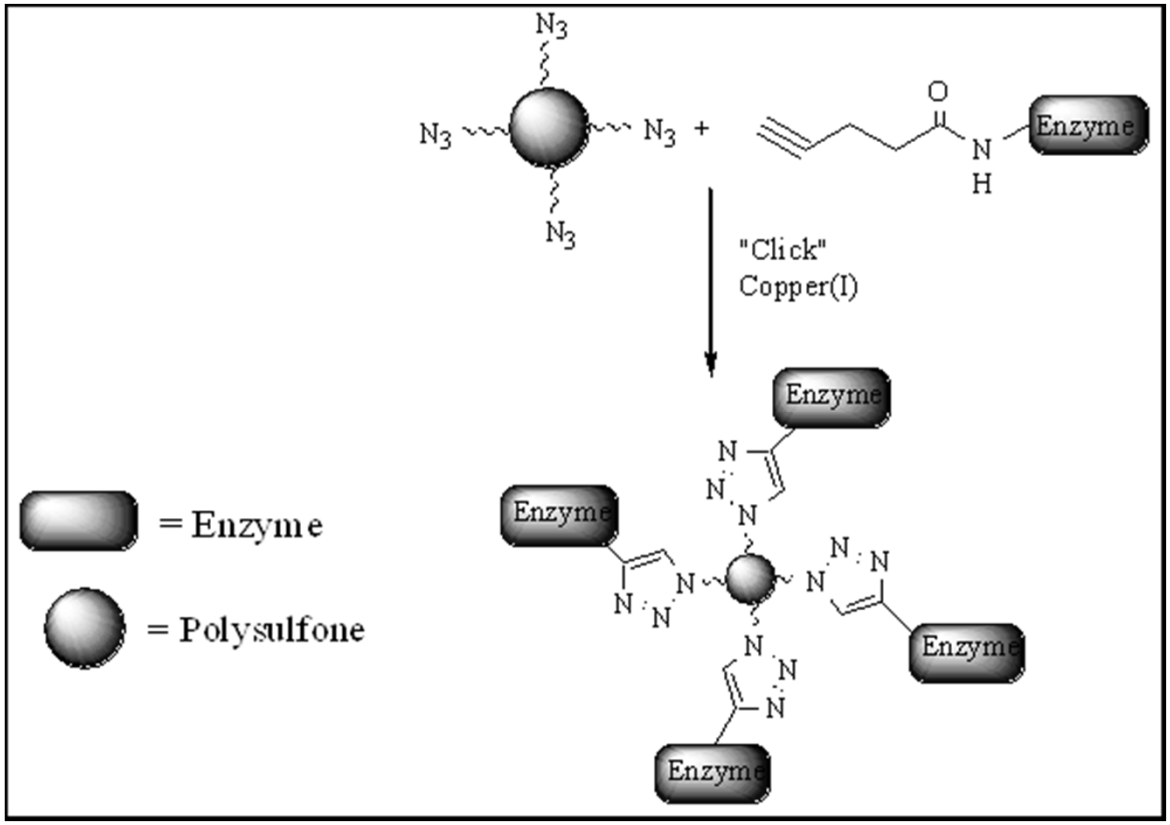
Enzyme immobilization

Polysulfone supported chloroperoxidase



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Enzyme immobilization

Silica supported lacasse

Step 1

Ceramic/porous material functionalization with alkyl-amino groups and polymeric membranes by acid treatment

↓ Washing

Step 2

Activation by treatment with glutaraldehyde

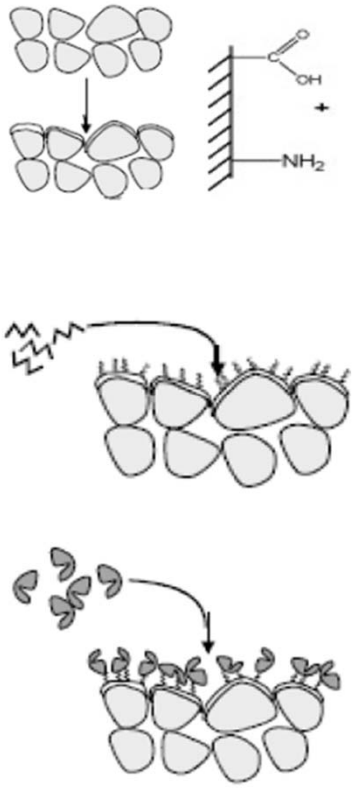
↓ Washing

Step 3

Enzyme attachment

↓

Enzymatic immobilized membrane/material



Adapted from Silva et al., Enzyme Microb Tech. 2007, and Rios et al., J Membrane Sci 2004

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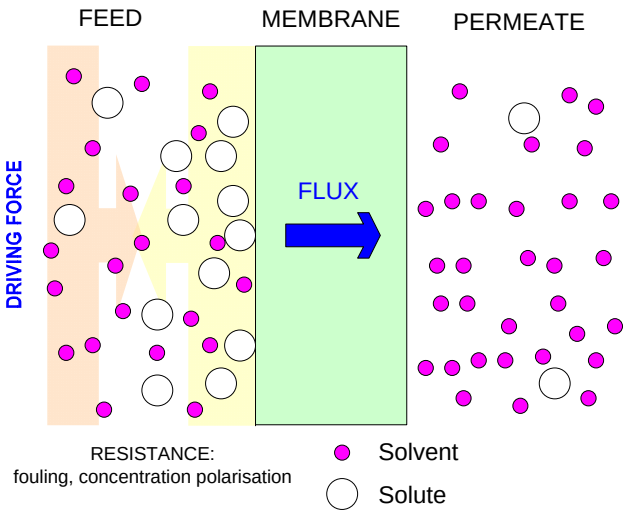
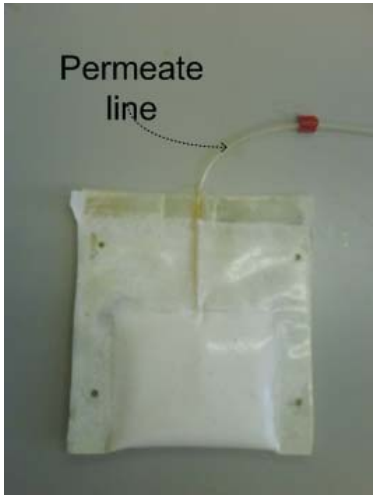
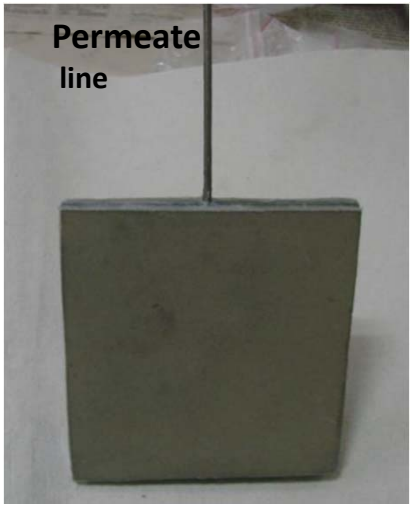
Membranes



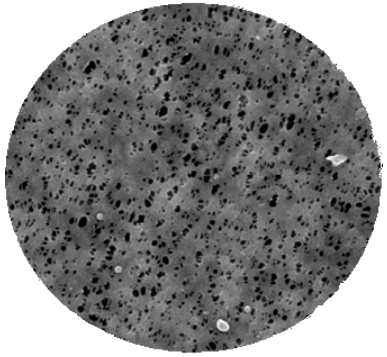
polymeric

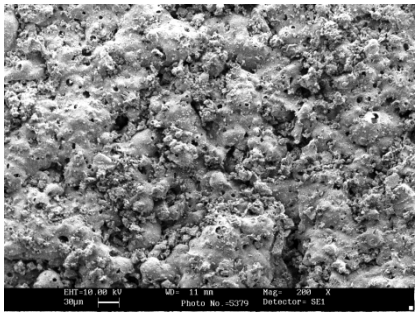


ceramic



Membrane module





SEM of membrane surface

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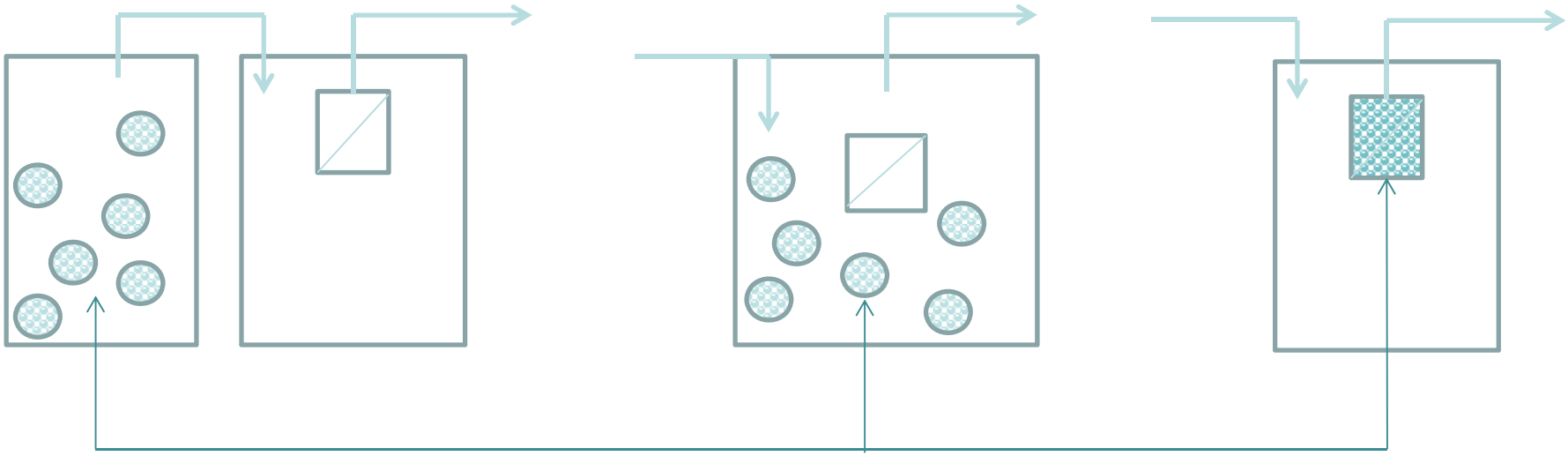
MBR configurations

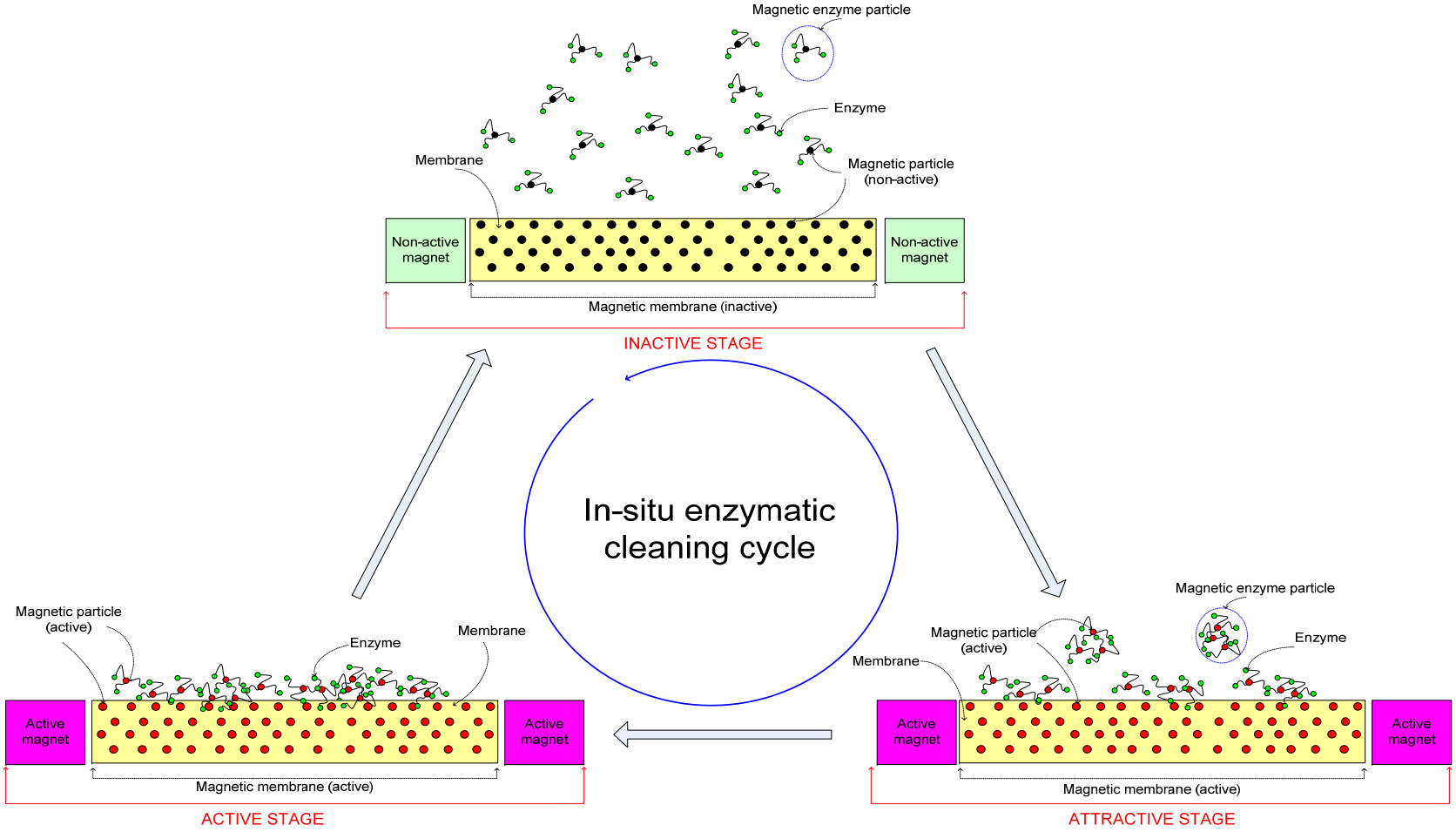


Supports with immobilized enzymes

Supports:

- Porous materials
- Supermagnetic ironoxide nanoparticles
- Polymeric and ceramic membranes

Insitu enzymatic cleaning: concept



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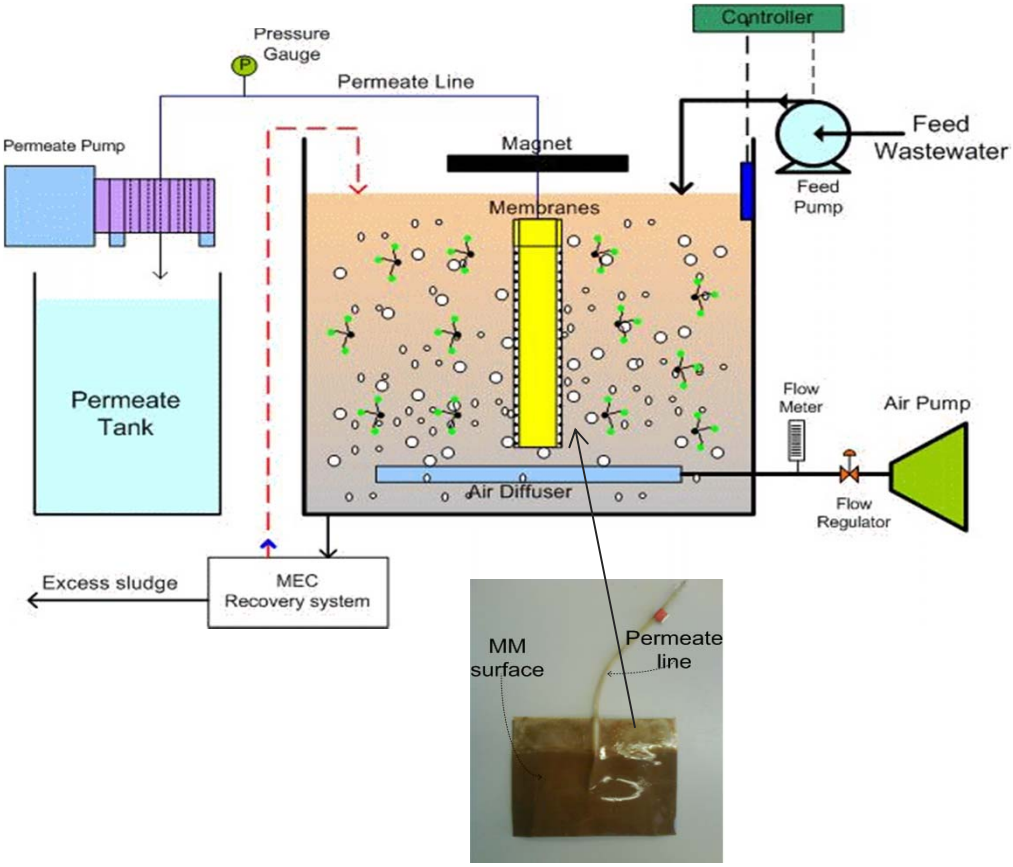
Example: Insitu enzyme immobilization



Membranes with magnetized nano particle

- Nano particle – para magnetic
- Magnetized nano particle
- Enzyme immobilized

Mechanism

Magnet ON

1. Magnetic properties activated
2. Particle form aggregation
3. Particle aggregate is attracted to the membrane surface

Magnet OFF

1. Magnetic properties deactivated
2. Particle disperse to bulk solution
3. Particle in membrane surface disperse to bulk

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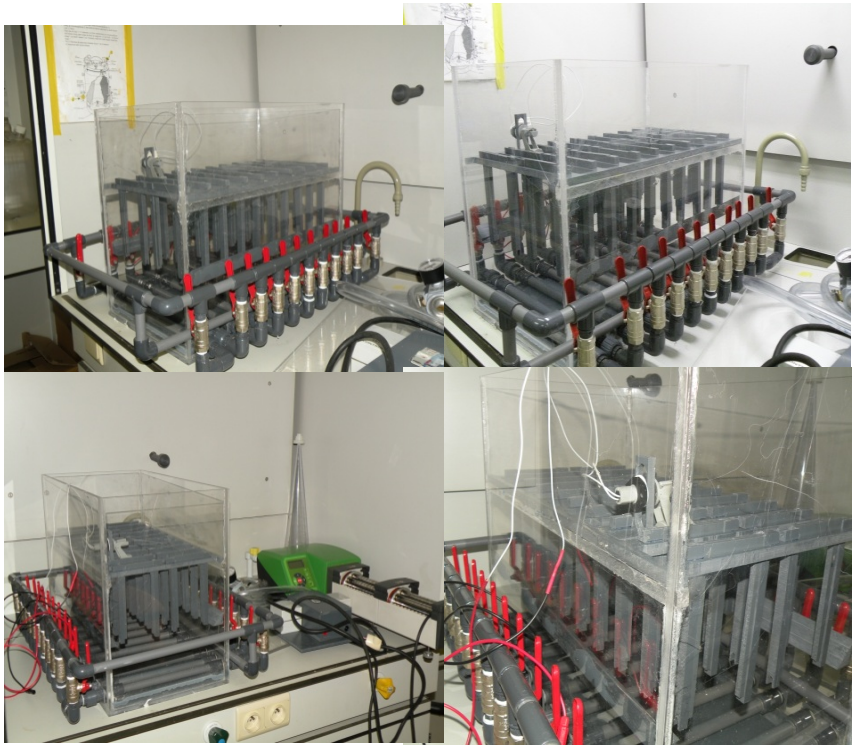
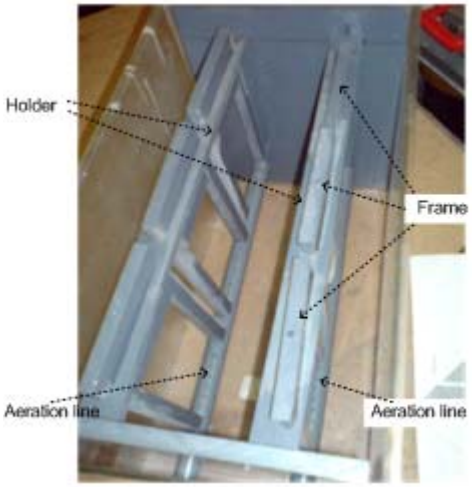
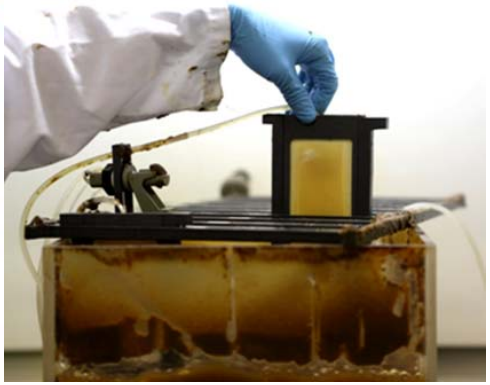
High throughput MBR (HT-MBR): Screening







HT-MBR

- 20 parallel modules
- Individual air flow regulator
- Minimize dead-zone
- Removable module holder
- Cast and test frame

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Outcome

- Process intensification using enzymatic degradation in conventional MBR operation
- Novel reactor configurations for rapid screening and fouling control
- Procedures for enzyme immobilization

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