جامعة قطر
QATAR UNIVERSITY

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Towards a Novel Wastewater Treatment Process: A Submerged Membrane Elector-Bioreactor (SMEBR)-Simultaneous Biodegradation, Electrocoagulation and Membrane Filtration

Khalid Bani-Melhem
Research Associate Professor
Email: kmelhem@qu.edu.qa

Presentation outline:

- Introduction:
  - Recent wastewater treatment facilities
  - Motivation of the proposed research methodology
- Research methodology
- Applications of the SMEBR
- Limitations of the SMEBR
- Recommendation for future research

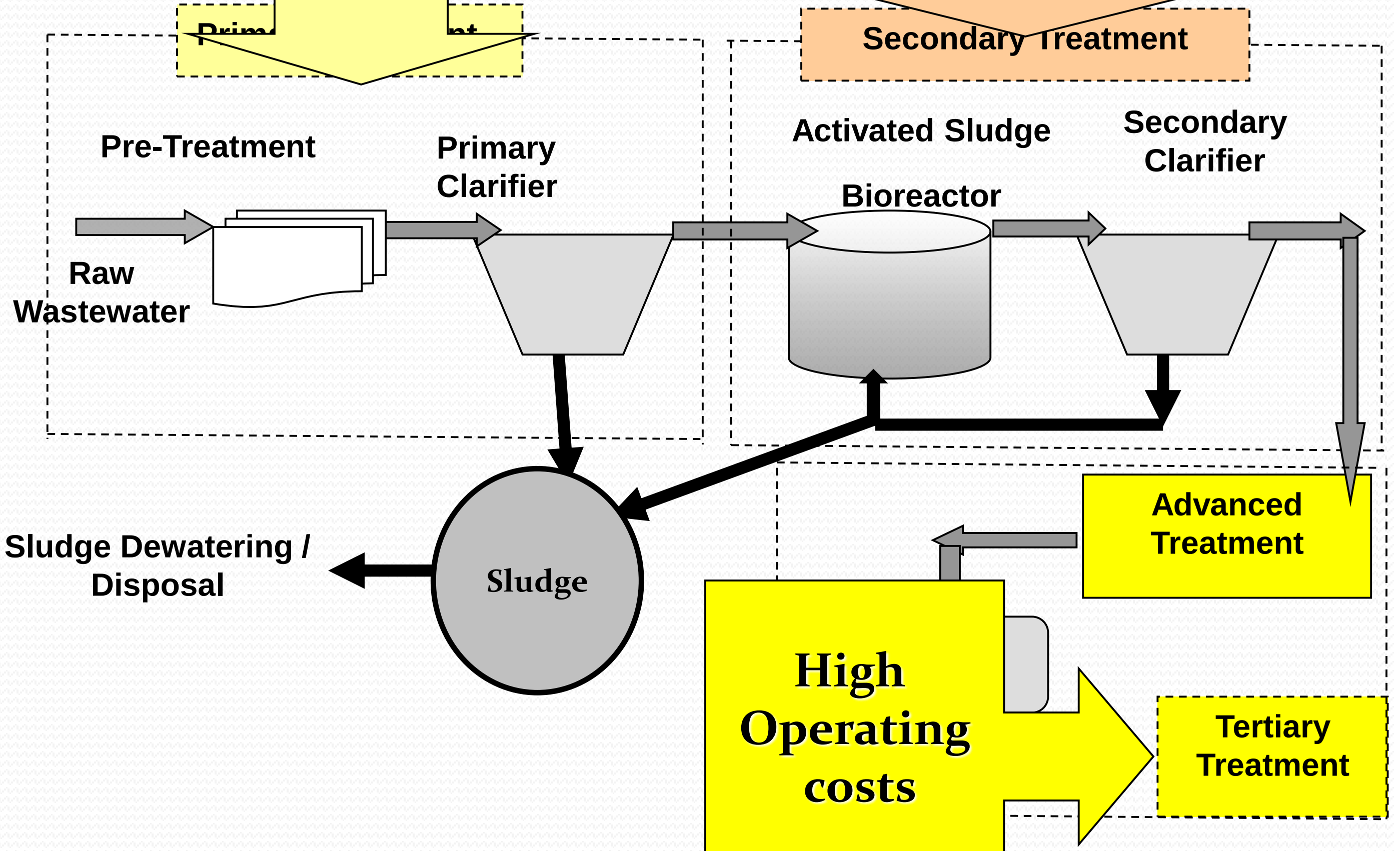
Introduction

Mo

- High amount in sludge production.
- Needs more space
- Does not reach acceptable standards regarding nutrients removal.

Does not reach an standards

ewate nt Facilities



High Operating costs

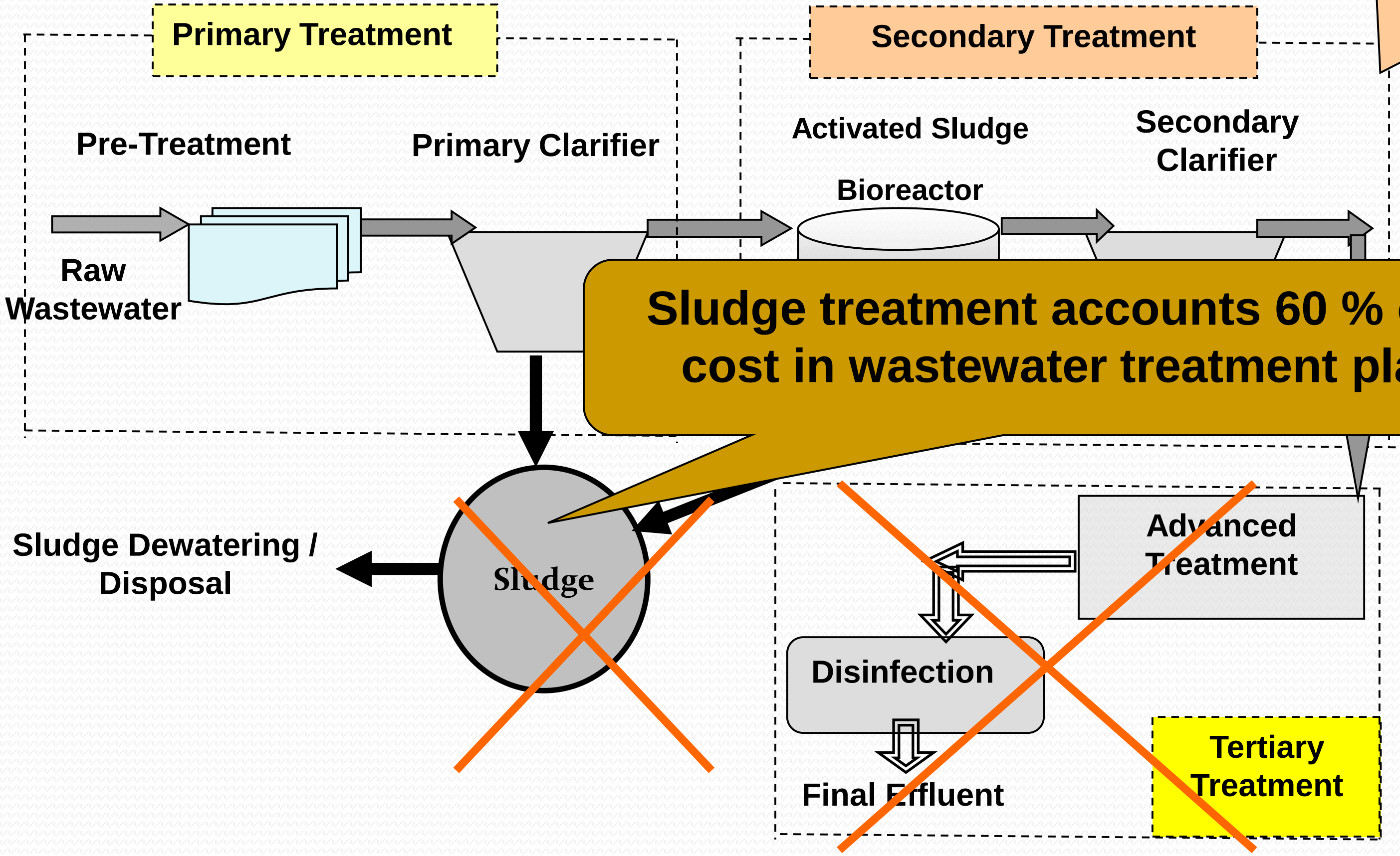
Simplified schematic diag ntional sewage treatment plant

Introduction

Motivation of the proposed research methodology

Impact of the Recent Wastewater Treatment Facilitie

Needs modification



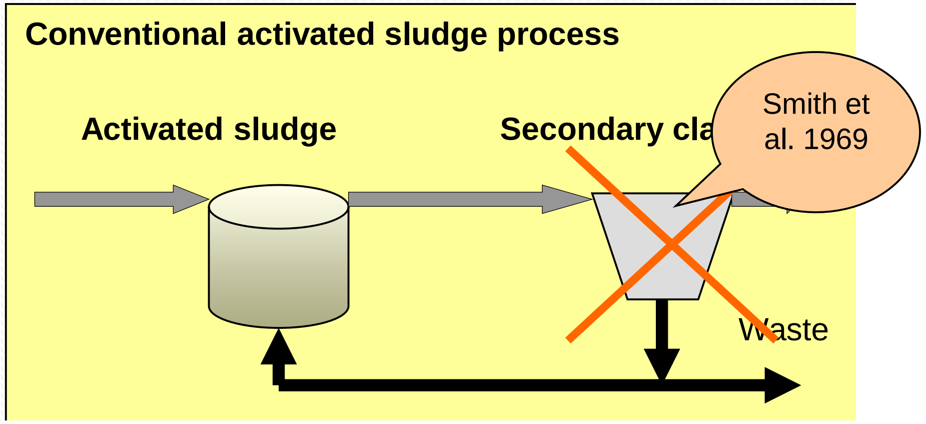
Sludge treatment accounts 60 % of the cost in wastewater treatment plants

Simplified schematic diagram of conventional sewage treatment plant

Introduction

Example of Development the Current Wastewater Treatment Methods:

Membrane Bioreactor Technology (MBR)



Conventional activated sludge process

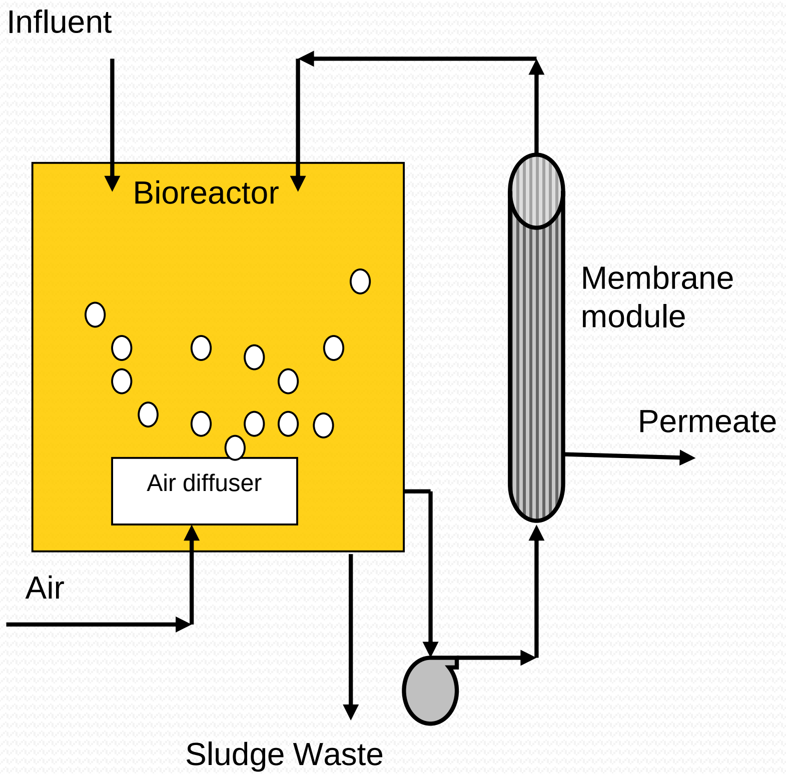
Activated sludge

Secondary cla

Smith et al. 1969

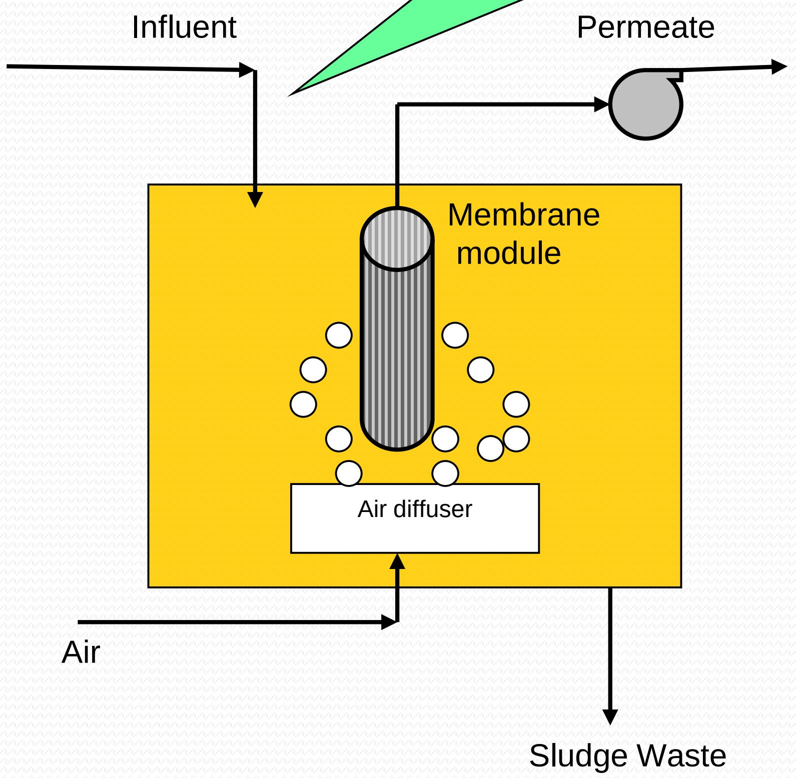
Waste

MBR Configurations



External membrane bioreactor system (Smith et al., 1969)

Land requirements can be decreased up to 50 %



Submerged membrane bioreactor system (Yamamoto et al., 1989)

Introduction

Comparison between MBR configurations

Item	External MBR	Submerged MBR
Shape	External the bioreactor	Inside the bioreactor
Cost	High	Low
Energy consumption	The energy demand is high	The energy demand is low (can be up to two order of magnitude than external MBR
Space	Need more space	Need less space
Flux	Operate at high flux	Operate at low flux (need more membrane area)

Conceptual framework of submerged membrane bioreactor (SMBR) system

Conclusion:

Membrane Fouling = Decreasing in permeate flux.

= Decreasing in efficiency.

= Increasing in maintenance.

= Increasing in operating cost.

Introduction

Current Anti-Fouling Strategies

- **Washing the membrane module (physically and chemically).**
- **Supplying air near the membrane surface.**
- **Optimizing the operating conditions.**
- **Improving the wastewater characteristics.**

(adding chemicals coagulants and adsorptive materials).

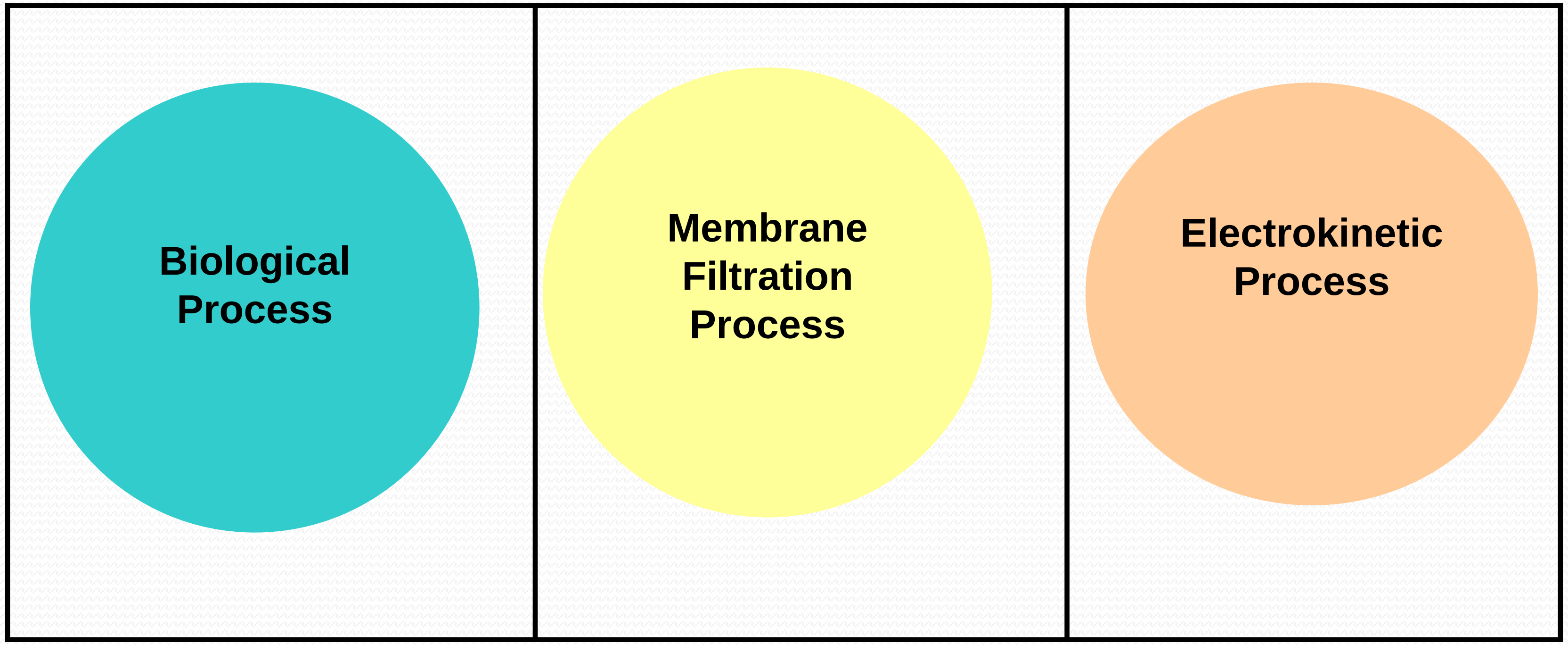
Impacts of these strategies:

- **Increasing in operating cost.**
- **Producing high amount of sludge.**

Conclusion:

Another strategy is required

Solution: Development a new method for wastewater treatment



Initial idea for developing a new wastewater treatment method

Research Objectives

- **Designing a new hybrid wastewater treatment method combining:**
  - **Biological process**
  - **Electrokinetics**
  - **Membrane filtration**

- **Investigating:**
  - **best operation parameters**
  - **performance of the new system:**
    - **excellent quality effluent (COD, nutrients)**
    - **reducing membrane fouling**
    - **reducing sludge generation**

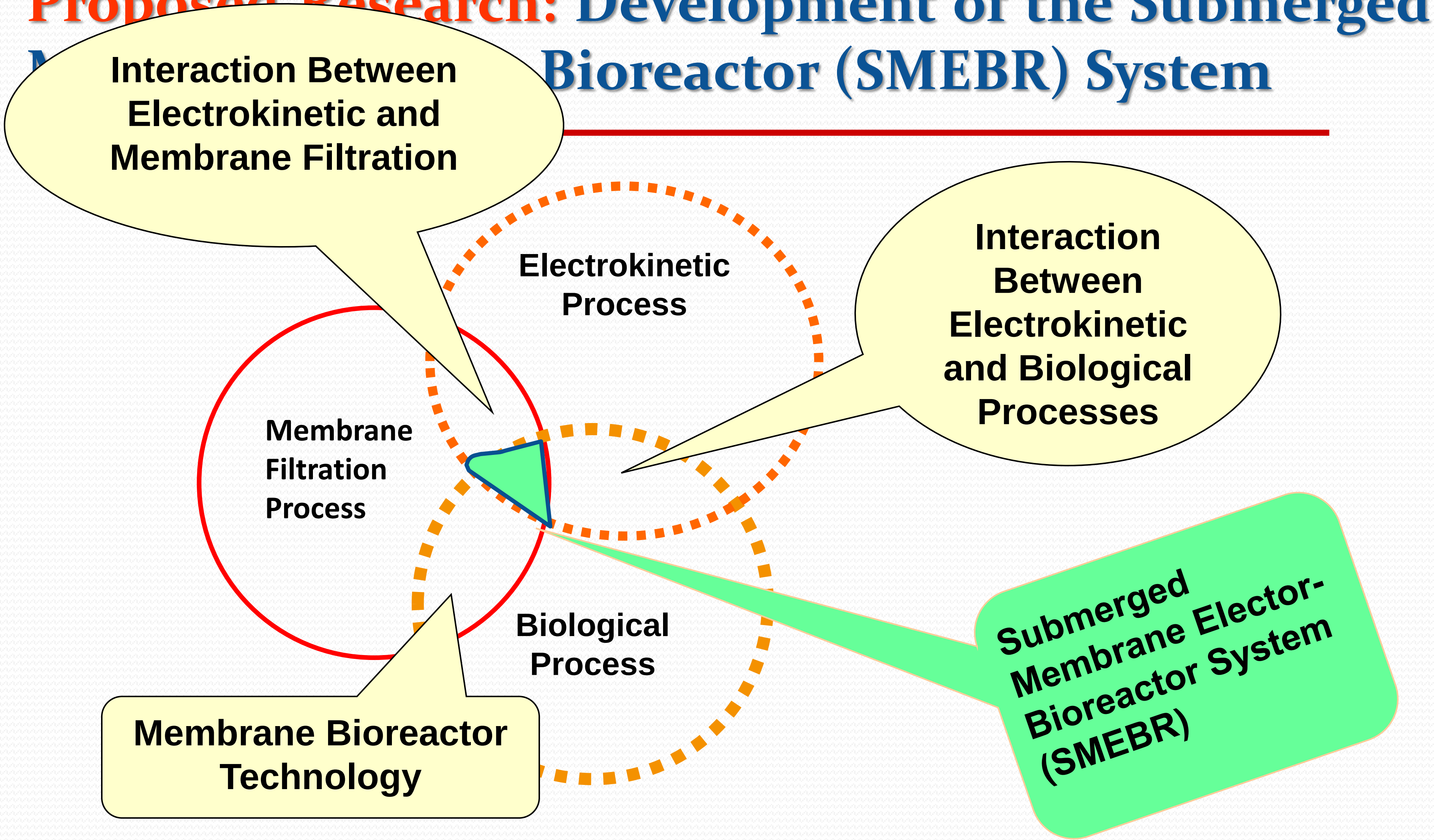
(Proposed Research)

Development of the *Submerged*

***Membrane Electro-Bioreactor (SMEBR)* :**

A new method for wastewater treatment
And fouling reduction

Proposed Research: Development of the Submerged M Bioreactor (SMEBR) System


Interaction Between Electrokinetic and Membrane Filtration

Electrokinetic Process

Interaction Between Electrokinetic and Biological Processes

Membrane Filtration Process

Biological Process

Membrane Bioreactor Technology

Submerged Membrane Elector-Bioreactor System (SMEBR)

Conceptual framework of the Submerged Membrane Electro-Bioreactor (SMEBR) system

Proposed Research: Development of the Submerged Membrane Electro-Bioreactor (SMEBR) System

Biological reactor (synthetic wastewater)

Membrane module (hollow fiber, ZW-1, Zenon)

Electrodes (metallic)

Conceptual components of the Submerged Membrane Electro-Bioreactor (SMEBR) system

Proposed Design: Considerations for the SMEBR Design

- Electrodes Configurations Constraints:

Suitable electrodes' materials for the application of SMEBR system

No decrease of the electrical current efficiency between the electrodes

Keeping DC field between electrodes identical in all directions in the bioreactor

The electrodes assembly would not interfere with the feed and flow toward membrane module

Keeping undisturbed circulation of air in bioreactor

Proposed Design: Considerations for the SMEBR Design

- Electrical Parameter Constraints:

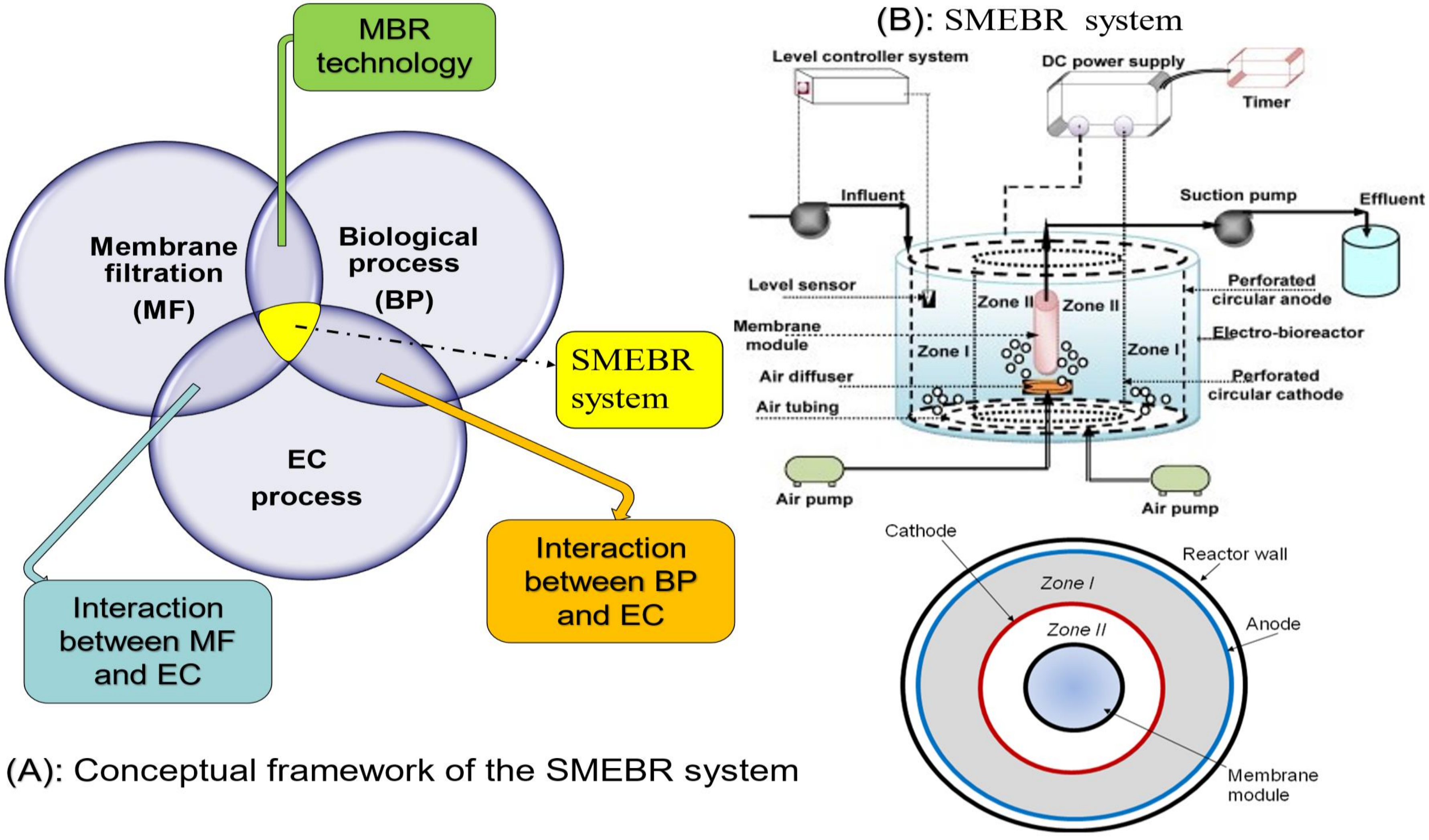
Electrokinetic processes cannot affect microbial activity

An accurate value for applied direct current (DC) field

The best operating mode of the applied direct current (DC)

The electrical field which cannot affect the longevity of membrane material

Proposed Design: Submerged Membrane Electro-Bioreactor System



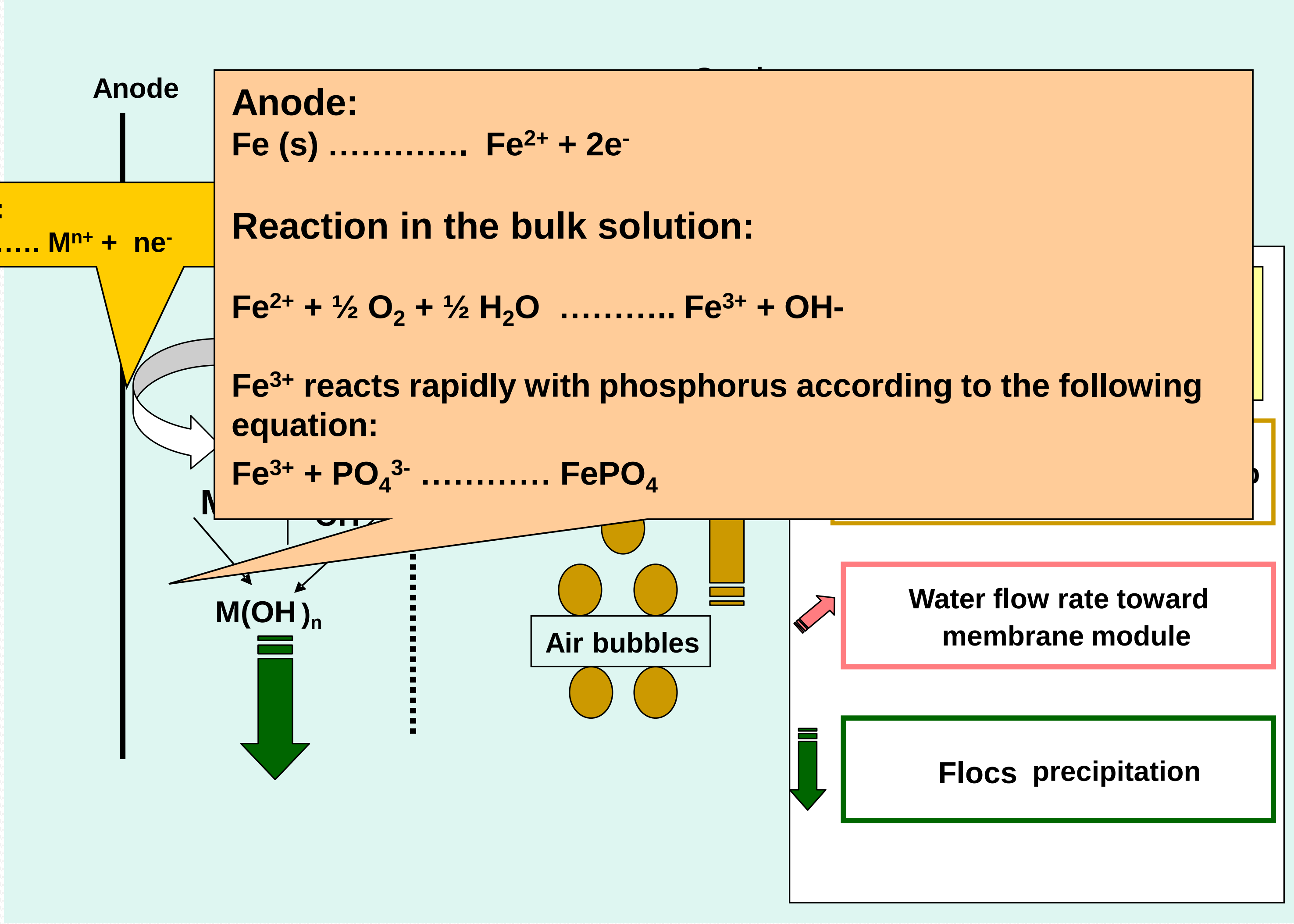
(A): Conceptual framework of the SMEBR system

(B): SMEBR system

(C): Top view of the SMEBR system

Fig. (A)Basic idea of the SMEBR system, (B) main elements of SMEBR and (C) Top view. (Bani-Melhem and Elektorowicz 2011)

Proposed Research: Major Types of Fluid Motions in the SMEBR System



Anode:
M ………. M^{n+} + ne$^-$

Anode:
Fe (s) ………… Fe^{2+} + 2e$^-$

Reaction in the bulk solution:

Fe^{2+} + ½ O$_2$ + ½ H$_2$O ………. Fe^{3+} + OH-

Fe^{3+} reacts rapidly with phosphorus according to the following equation:

Fe^{3+} + PO$_4^{3-}$ ………… FePO$_4$

Advantages of the SMEBR

In comparisons with traditional wastewater treatment methods, the SMEBR system has many significant benefits such as:

(i) A smaller footprint;

(ii) No chemicals are required for coagulation;

(iii) Reducing the operating costs by reducing the requirements of aeration in conventional SMBR systems;

(iv) Improving sludge dewatering conditions.

(v) The designed SMEBR system may find a direct application for various types of wastewaters including sewage, without extensive pretreatment.

(vi) Such a solution is required by several small municipalities, mining areas, agriculture facilities, military bases, and different regions.

(vii) Finally, such a compact hybrid system can easily be adapted to a mobile unit, and it can be driven by solar energy.

Some limitations of the SMEBR

- The applied DC field, and DC exposure time play a significant role in a successful SMEBR design (A low DC field and low DC exposure time would not create sufficient conditions for better coagulation, but similarly, a high DC field and higher exposure time might produce a negative impact represented by a decrease in the growth of microorganisms.
- Energy consumption can be limited factor. However, the SMEBR can be driven by solar energy (<u>suitable for application in Gulf area</u>).

Some results from the literature about the performances of the SMEBR.

Applications	Type of electrodes	Operating conditions	Fouling reduction (%)	Pollutant removals/ Results achieved	References
Municipal Wastewater (Synthetic)	Ande: Fe Cathode: Fe	Dc= 1 V/cm Mode of DC: 15 min ON/45 min OFF)	16.3%	COD:> 96% PO4-P: > 98%	Bani-Melhem and Elektorowicz, (2011).
Municipal Wastewater (Synthetic)	Ande: Al Cathode: Fe	Dc= 1 V/cm Mode of DC: 15 min ON/45 min OFF)	52%	PO4-P: > 98%	Bani-Melhem et al., 2009
Municipal Wastewater (Synthetic)	Ande: Al Cathode: Fe	NA	Fouling decreased significantly	COD: 92%% PO4-P: 99% NH3-N: 99%	Elektorowicz et al., 2011.
Municipal Wastewater (Synthetic)	Ande: SS (mesh) Cathode: Cu (wire)	0.036 V/cm, 0.073 V/cm	20-25%	20 times reduction of filtration resistance, reduced sludge EPS	Liu et al., 2012
Landfill leachates	Ande: Al (sheet) Cathode: Al (sheet)	HRT= 48 h SRT= 90 days	Fouling decreased significantly	COD: 98.5%% PO_4^{3-}–P: 99% NH3-N: 99% UV254: 96% Heavy metals: 95% Humic acid: 96%	Farsani et al., 2022.
Municipal Wastewater (Synthetic), pharmaceuticals	Ande: AL (mesh) Cathode: SS (mesh)	DC= 0.3, 0.5 and 1.15 mA/cm²	24, 44 and 45%	COD: 100% DOC: 100%	Borea et al., 2019

Recommendation for future research

Although the SMEBR system proved effective efficiency in terms of pollutant removal and fouling reduction, there is still a wide range of investigation that needs to be explored.

1. **A pilot scale investigation** would be required to expose the system to a variable quality of wastewater influent.
2. **The impact of various operational and design parameters**, such as sludge retention time (SRT), hydraulic retention time (HRT), and transmembrane pressure (TMP) need further investigation based on pilot scale operation.
3. **Cost Analysis** : The feasibility of the newly designed system as a wastewater treatment method needs detailed analysis
4. **Electrical Parameters** such as: DC , air gap between electrodes
5. **Materials of electrodes**