Sustainable remediation of soil, water, wastes and sediments

Presented by Catherine N. Mulligan, Director of Concordia Institute of Water, Energy and Sustainable Systems (CIWESS)

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Mission and objectives

- CIWESS is an interdisciplinary team employing an integrated research and training program on water-energy systems such as for remote communities and activities in mining, resource management

- To enable optimal management of the water-energy nexus in regard to SDG and climate change

Concordia Institute for Water, Energy and Sustainable Systems (CIWESS)

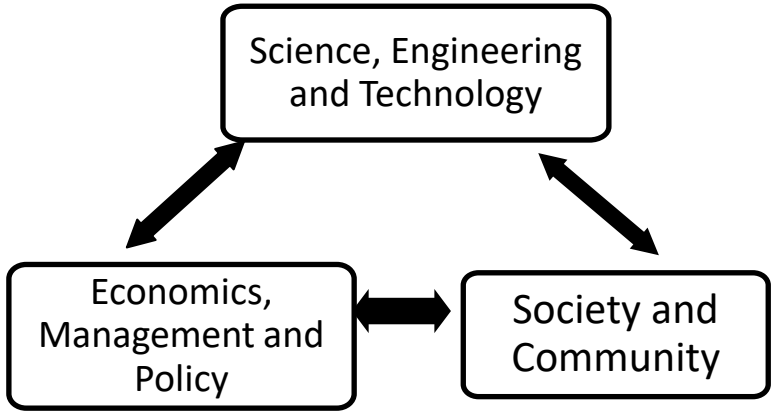
Multi-faculty approach:

- Engineering & Computer Science
- Arts & Science
- John Molson School of Business

Inter-university initiative:

- Concordia University
- McGill University
- Ecole de Technologie Supérieure
- UQAT
- York
- Dalhousie

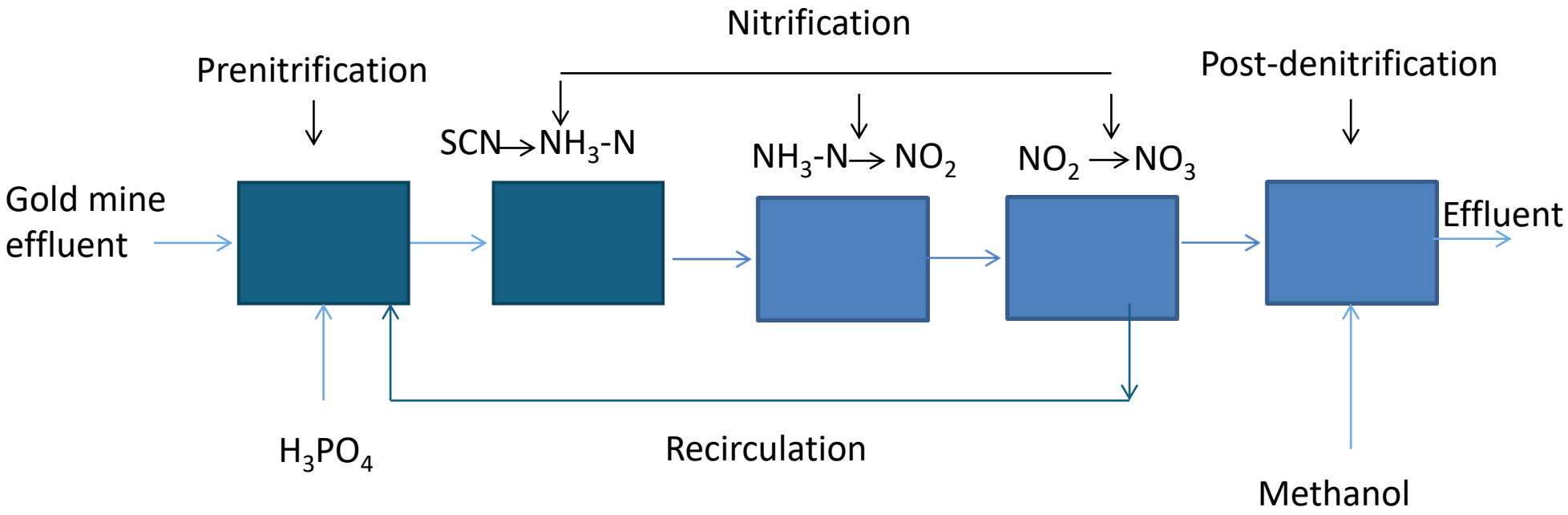
- International collaborators



Introduction

- The nexus of water-energy use is the linchpin of our contemporary economy.
- Energy production and generation is enormously water-intensive (accounting for 10% of global water withdrawals),
- Various elements in the water sector (e.g., treatment, production, and distribution) exert a heavy energy footprint (4% of global electricity consumption)
- Water availability is affected by water quality, including toxins, eutrophication, micropollutants, chemicals of emerging concern, and acidification.

Traditional nitrogen water treatment



Annamox Process

- Nitrite and ammonium ions are converted to nitrogen gas and water via the reaction:
- $NH_4^+ + NO_2^- \rightarrow N_2 + 2H_2O$
- Slow growing bacteria used in sequencing batch reactors, moving bed reactors and gas-lift loop reactors
- First full scale in the Netherlands in 2002.
- Applications for municipal, industrial effluents such as tannery and potato processing plants

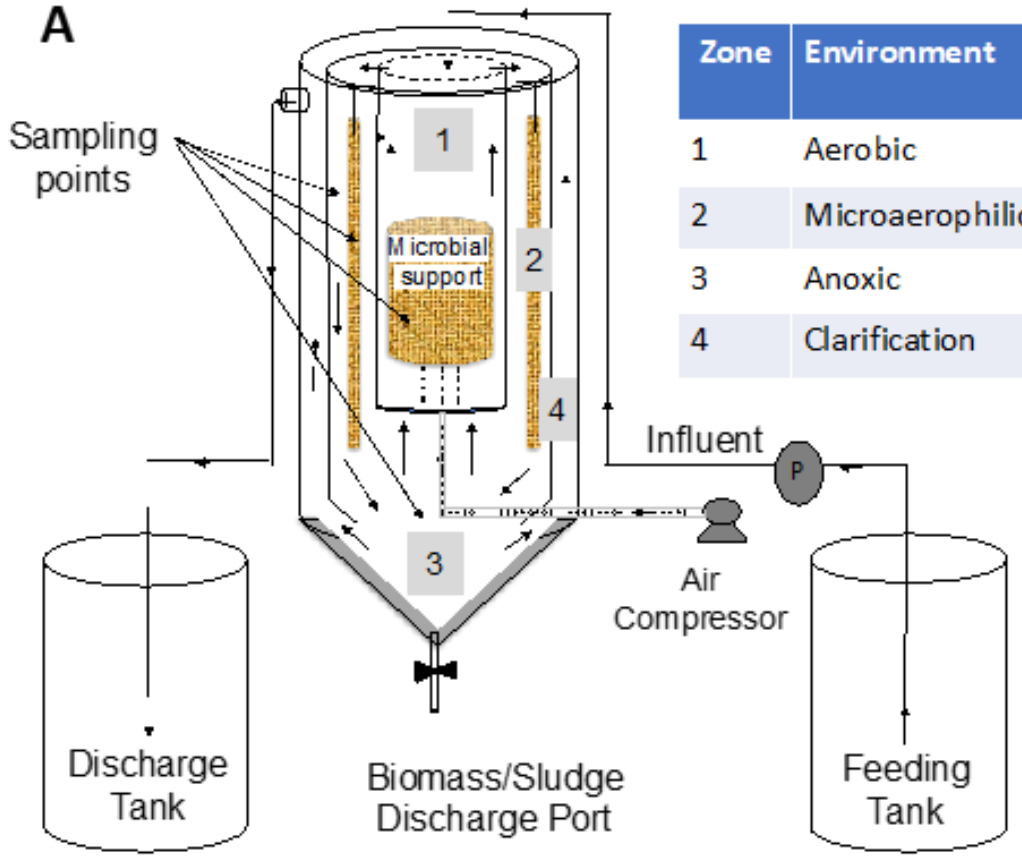
Annamox

- Compared to conventional nitrogen removal
- Less aeration due to partial oxidation instead of full oxidation
- Methanol addition not required
- Less sludge production
- Reduction of CO_2 emissions and costs by up to 60%
- Slow startup major disadvantage

Reactor development

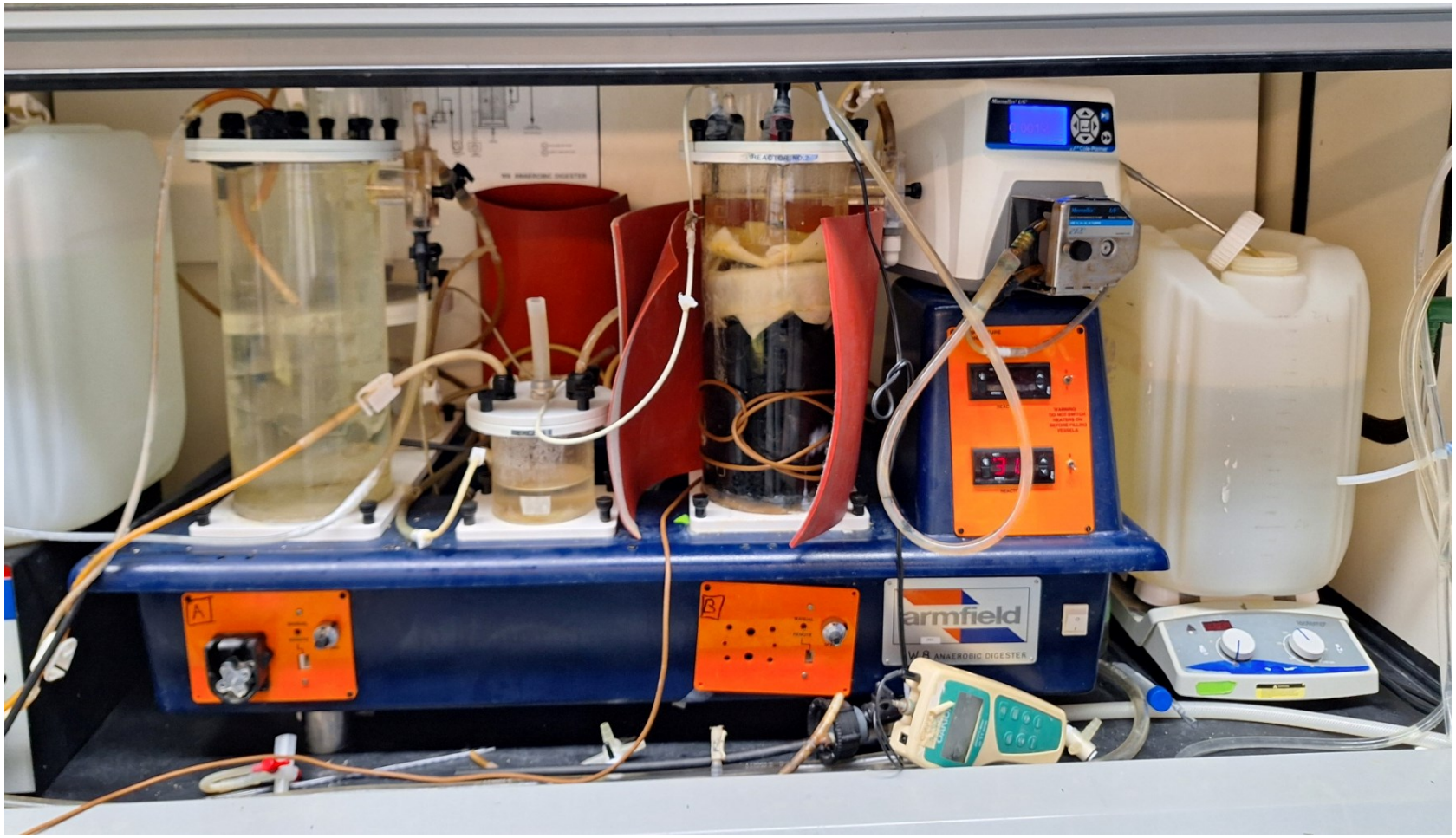
- Use of single reactor instead of multiple reactors
- Reduces cost and energy requirements
- Control of dissolved oxygen key
- BIOCAST reactor is multizone reactor being evaluated for reactor for removal of organics, nitrogen and phosphorus
- Synthetic wastewater and now mining effluent being evaluated

Biocast Reactor (Saborimanesh et al. 2020)



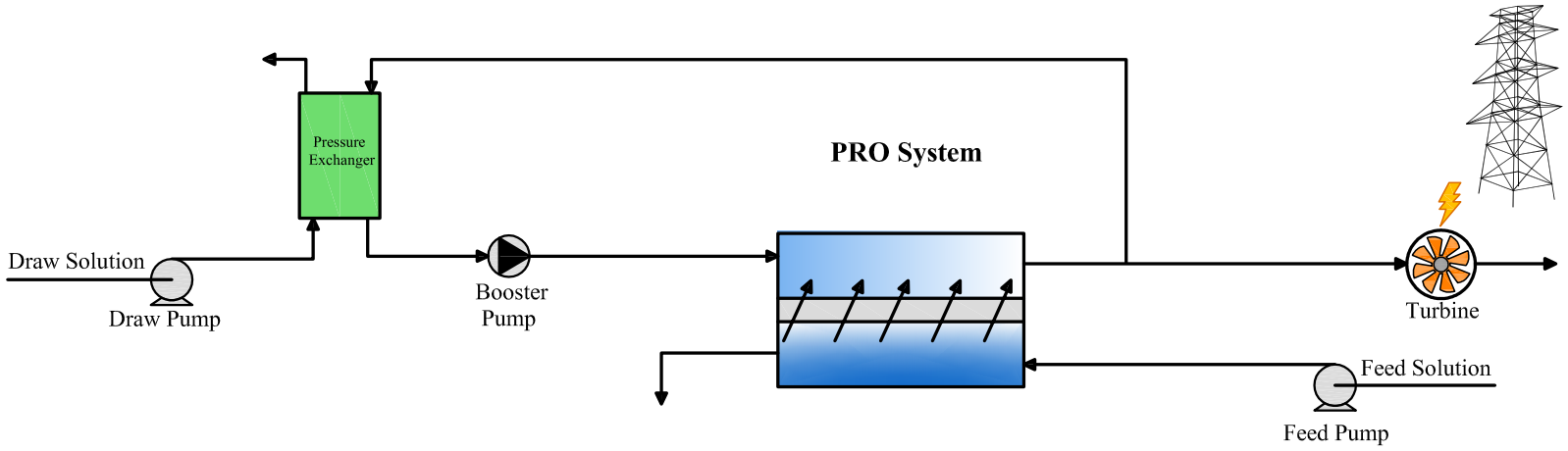
Zone	Environment	Height (cm)	Diameter (cm)	Volume (L)
1	Aerobic	-	16.7	17
2	Microaerophilic	91	35.7	61
3	Anoxic	100	-	22
4	Clarification	-	49.5	65

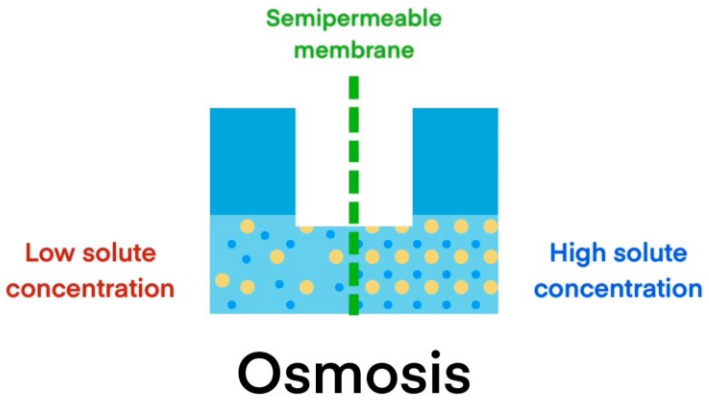
Annamox Reactors



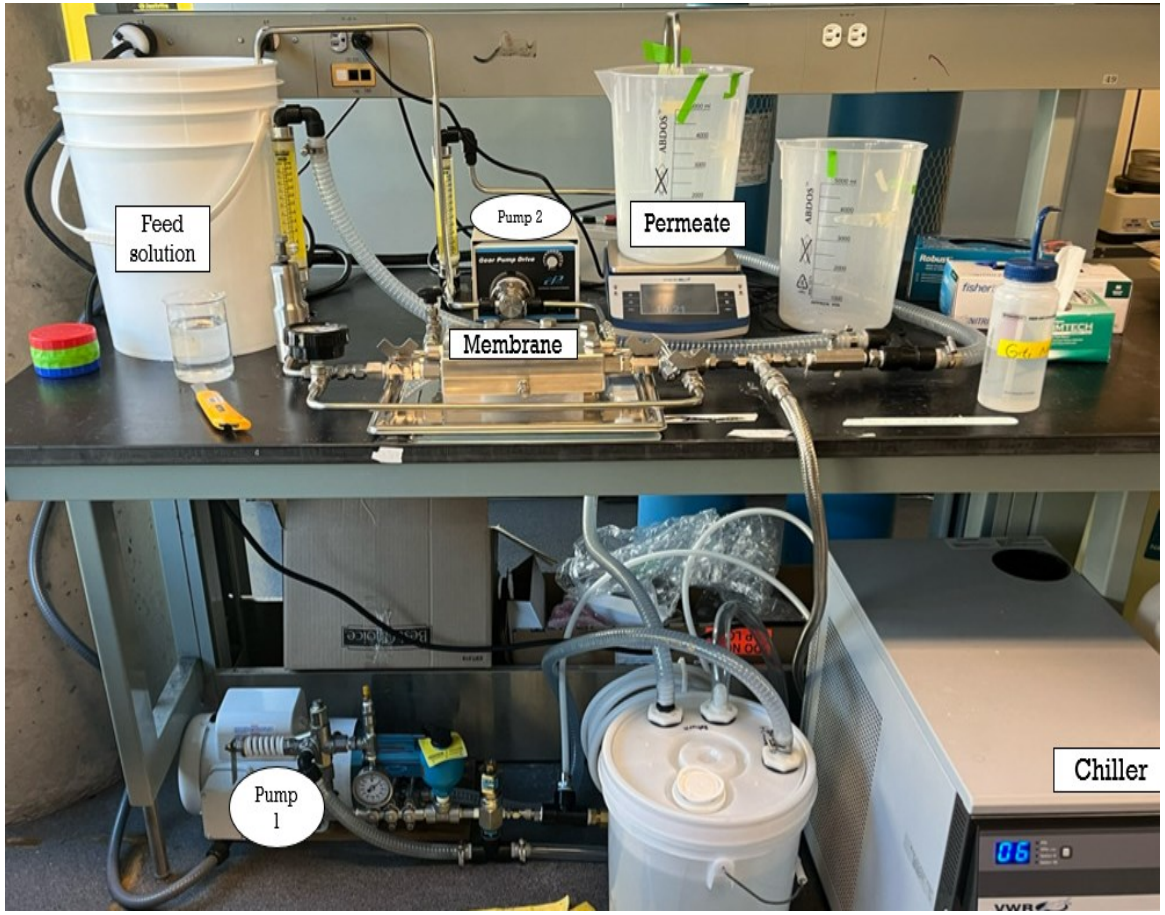
Pressure retarded osmosis (PRO)

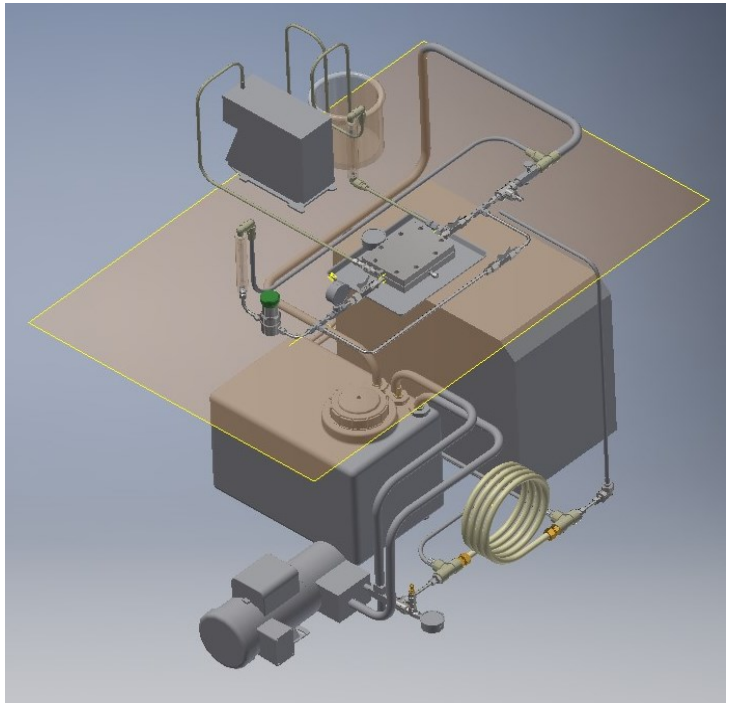
- Harnessing osmotic energy through a semi-permeable membrane
- Water movement from low salinity to high salinity against hydraulic pressure





UF, NF & PRO Setup





Generated Power Density by PRO

A profitable PRO plant typically requires a power density within the range of 4-6 W/m^2 (Source: Gerstandt et al. (2008)).

- ✓Commercial membrane (CTA) and prepared TFN membrane have more than 6 W/m^2.
- ✓Better performance of modified membrane compared with commercial membrane was obtained.

Study Area : Lake Caron

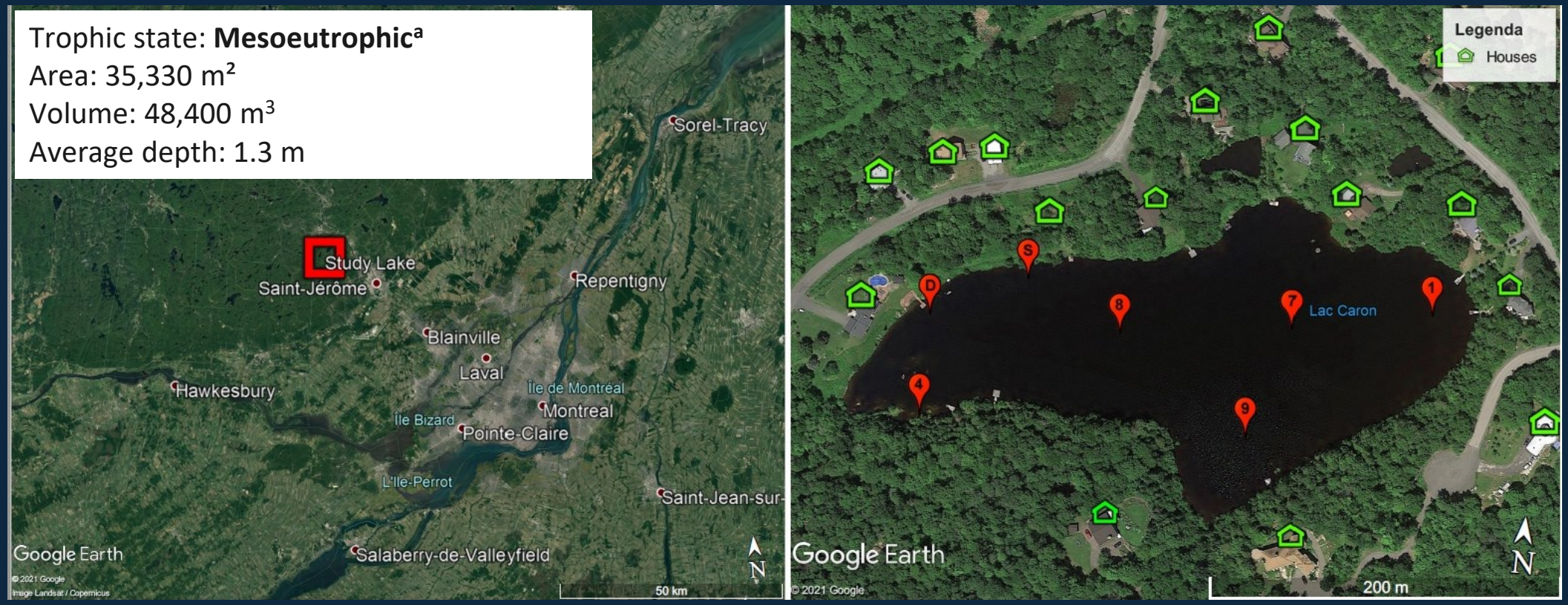
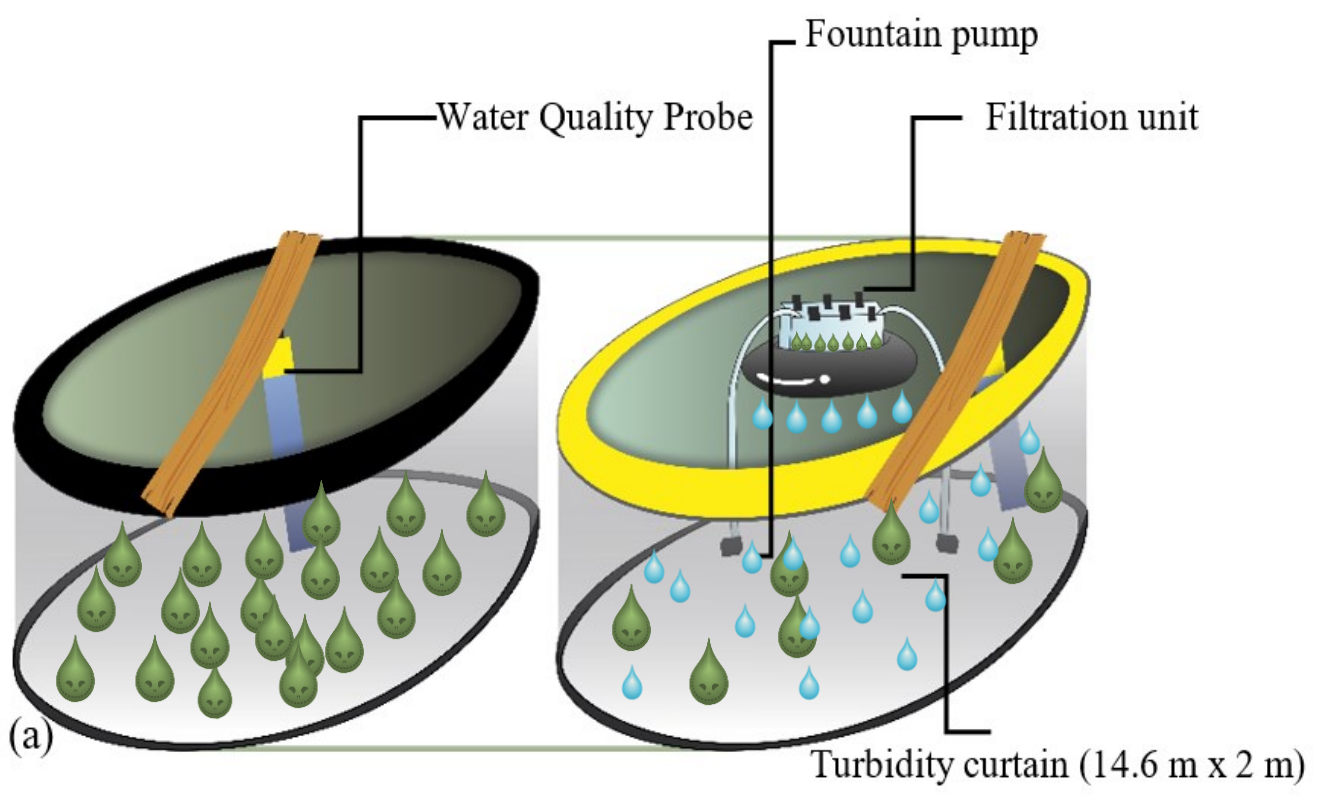


Figure 24: Lake Caron location and details with sampling stations and households

Experiment Deployment



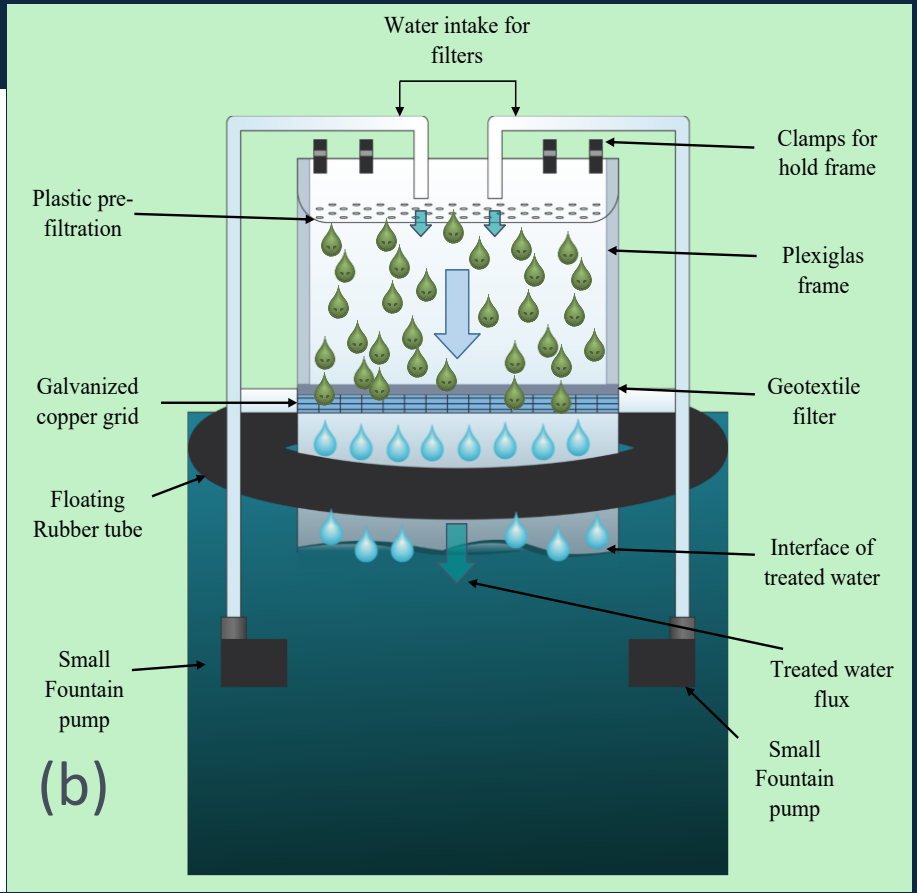
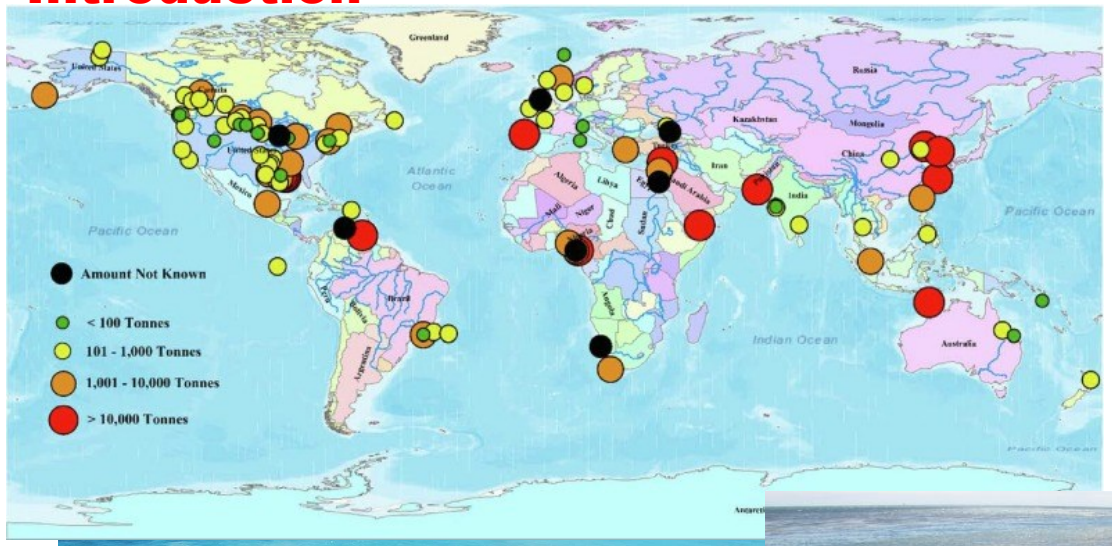


Figure 25: (a) : Schematic 3D-view of experiment deployment (b) : Schematic of the floating filtration unit

Introduction



- Since 2000, more than 100 oil spill incidents
- Spilled oil frequently reaches shorelines
- Highly weathered ➔ Difficult to remove
- Affects coastal biota and communities
- Shoreline cleanup ➔ Physical and chemical treatment, and bioremediation

Dead sea turtle after explosion of oil drilling rig (June 2010, Gulf of Mexico)

Oil spill after a bulk carrier ran aground (July 2020, Mauritius)

Stranded oil on beach after pipeline release (May 2015, California)

https://doi.org/10.1016/j.jenvman.2020.111232
https://www.greenpeace.org/international/story/49085/mauritius-worst-environmental-disaster-one-year-on/
https://response.restoration.noaa.gov/about/media/natural-seeps-historic-legacy-what-sets-apart-latest-santa-barbara-oil-spill.html
https://www.msnbc.com/all/animals-dying-record-numbers-bp-spill-gulf-of-mexico-msna304061

Physical treatment


Vacuum systems for oil removal


Flooding using hoses without nozzles


High pressure washing

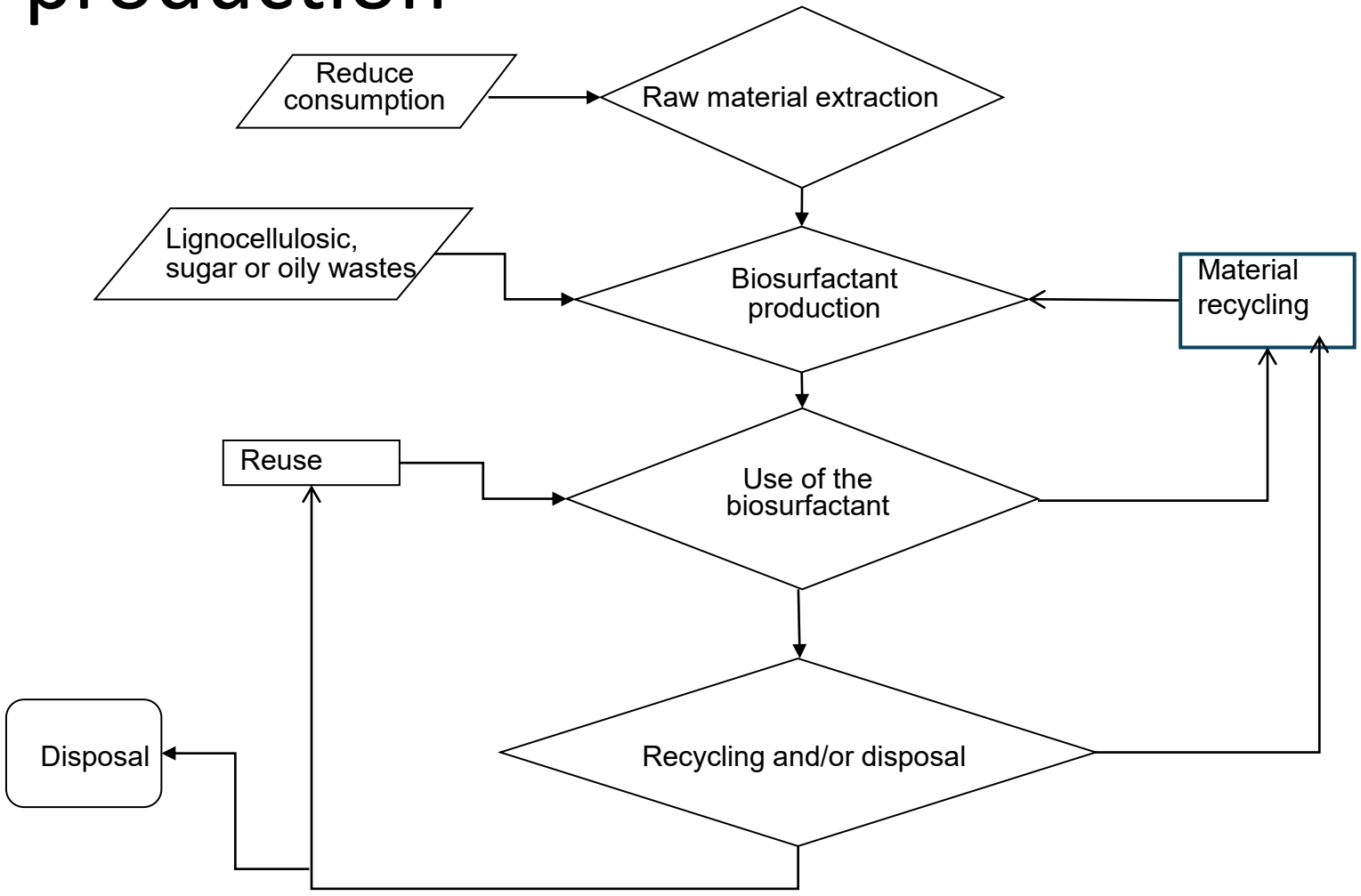

Manual removal of oil with shovels, bags, and buckets

Sources:
ECCC, 2016. A Field Guide to Oil Spill Response on Marine Shorelines. Environment and Climate Change Canada, Ottawa, ON.

Biosurfactants

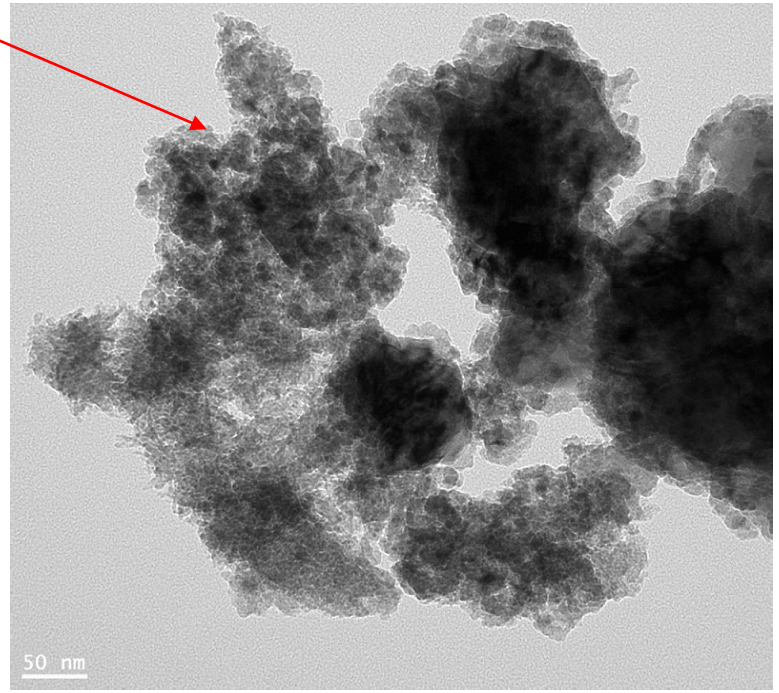
- Produced either on the surfaces of microbial cell or excreted extracellularly by bacteria or yeasts
- Advantages
  - Higher biodegradability and lower toxicity
  - Potentially more economic than the other surfactants
  - Potential to decrease the environmental impacts of soil, sediment, mining residues and wastewater contaminants

Waste substrates for biosurfactant production

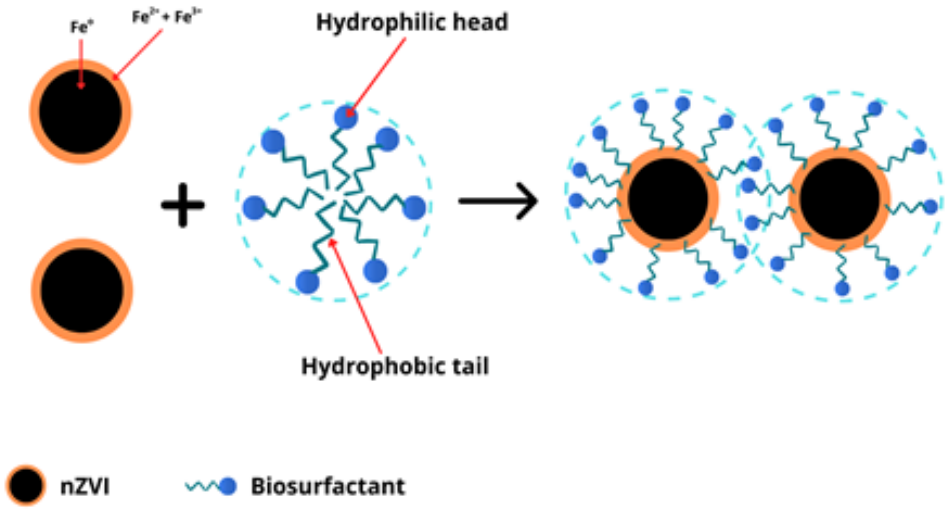


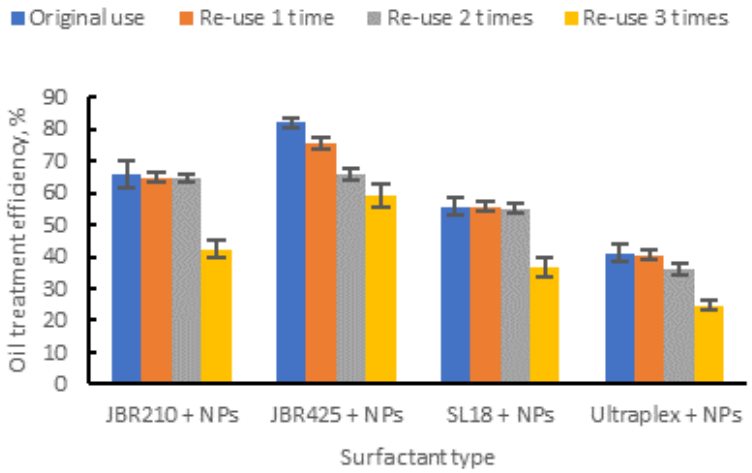
TEM of Fe/Cu Particles

Zero valent iron



NPs and biosurfactant applications

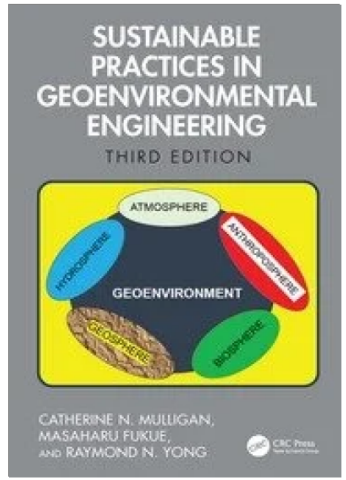




Vu, K.A., Mulligan, C.N. (2022c). Remediation of 1402 oil-contaminated soil using Fe/Cu nanoparticles 1403 and biosurfactants. Environ. Technol. 1-18. 1404 https://doi.org/10.1080/09593330.2022.2061381

Conclusions

- ✓ The feasibility of treating mining effluents for ammonia removal by annamox process and energy production by PRO
- ✓ Promising results by modified membranes with nanoparticles compared with commercial membranes for energy production
- ✓ Promising results for reduction of nutrients in lake waters by filtration.
- ✓ Promising results for metal and oil removal by biodegradable and nontoxic biosurfactants with nanoparticles and bioremediation



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Sustainable Practices in Geoenvironmental Engineering, Third Edition

Catherine N. Mulligan, Masaharu Fukue, Raymond N. Yong

This third edition focuses on the application of geoenvironmental engineering procedures and practices to mitigate and reduce the adverse impacts on the geoenvironment from anthropogenic sources including emerging contaminants such as micro and nanoplastics, pharmaceuticals, and fire retarding chemicals. Thoroughly updated with three new chapters and extensive use of case studies to showcase examples of sustainable practices, this new edition discusses many activities that are still generating geoenvironmental impacts that are adverse to the quality and health of the geoenvironment. It includes new tools and procedures that have been developed to evaluate and minimize adverse impacts.

New in this edition:

- Discusses the impacts of climate change and potential mitigation.
  Addresses emerging contaminants of concern.
- Introduces an entirely new chapter on sustainable nitrogen and carbon cycles.
- Includes new case studies like the Fukushima case study on sediments and microbial induced precipitation processes.
- Provides new practices and tools for sustainability to evaluate and to minimize adverse impacts
  Discusses the aspects of social sustainability and cultural aspects of the geoenvironment.

Dr. Catherine N. Mulligan is the founder and director of the Concordia Institute of Water, Energy and Sustainable Systems. She is a Fellow of the Canadian Society for Civil Engineering (CSCE) and its current Past President. She is also a Fellow of the Engineering Institute of Canada (EIC) and the Canadian Academy of Engineering (CAE) and a Fellow of the Royal Society of Canada.

Dr. Masaharu Fukue is a professor emeritus at Tokai University, Japan. He has recently established the Japanese Geotechnical Association for Housing Disaster Prevention to apply the theory and practice of one of his patented processes.

Dr. Raymond N. Yong is the William Scott Professor Emeritus at McGill University, Canada. He is a fellow of the Royal Society Canada and a Chevalier de l'Ordre National du Québec.

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