MSc thesis project

Sustainable bio-based polymers from wastesludge for wastewater purification

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1- Overview

In an effort towards a green and circular economy, recent advances in wastewater processing in the Netherlands have resulted in a new technology for efficient wastewater treatment. This biological process (Nereda^{TM}) is using granular sludge instead of conventional flocculant activated sludge[1]. The produced granular sludge contains a high fraction of biopolymer (Kaumera Nereda^{TM} Gum) which can be extracted from the sludge granules that are in essence a waste by-product from wastewater purification (see Fig. 1). This biopolymer is fire-retardant and has versatile amphiphilic properties, able to adsorb or repel water. It is a water-soluble polymer that can hold up to 80% of nano-fillers. It has been investigated for utilisation as a bio-stimulant and a coating for fertilizers, textile and paper, and as a curing agent for concrete. Besides these relatively low-tech applications, broader use cases will emerge as understanding of these polymers grows. This will allow to gradually substitute the non-renewable polymers with green and circularly useable ones.

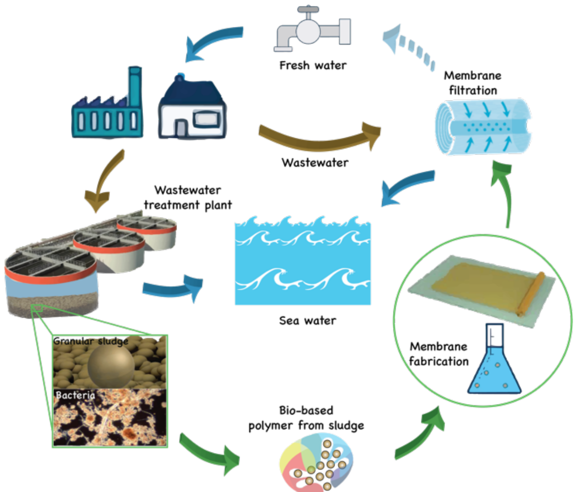

Fig. 1. Waste for wastewater purification

2- Problem statement

Global production of petroleum-based polymers increased from 2 million metric tons (Mt) in 1950 to 380 Mt in 2015. As of 2015, approximately 6300 Mt of plastic waste had been generated, around only 9% of which had been recycled[2]. To achieve carbon-neutral polymer industry, we urgently require renewable alternatives to meet our needs for a wide range of polymers. Bio-based polymers (BBP) are emerging materials that perfectly meet these needs. Manufacturing process (biological, chemical and physical processing) of these emerging materials utilises renewable biomass as raw materials; therefore, making the bio-based polymers green, renewable, and biodegradable[3]. Environmental protection and respective regulations will result in bio-based polymers incrementally phasing out the non-renewable ones in all applications, from food packaging to industrial machine parts and membrane separation industry[4]. Among the membranes materials, polymers account for 95% of the total industrial market. However, polymeric membrane market has low sustainability due to requirements of fossil-based polymers and hazardous solvents for membrane fabrication. Thus, promoting the green transformation of this expanding field is imperative[5].

3- Objectives

In an effort towards improving the sustainability of membrane technology, in this project a smart membrane for wastewater/water treatment from Kaumera wastewater-extracted bio-based polymer

[1] https://kaumera.com/english/kaumera/
[2] Geyer et.al., Production, use, and fate of all plastics ever made, *Science Advances*, 3 (**2017**), e1700782.
[3] S. Gao et. al., Stimuli-responsive bio-based polymeric systems and their applications, *J. Mater. Chem. B*, 7 (**2019**), 709.
[4] P. Tomietto et. al., Biobased polyhydroxyalkanoate (PHA) membranes: Structure/performances relationship, *Separation and Purification Technology*, 252 (**2020**), 117419.
[5] W. Xie et. al., Toward the Next Generation of Sustainable Membranes from Green Chemistry Principles, ACS Sustainable Chem. Eng., 9 (**2021**), 50-75.

will be developed and investigated. It aims to achieve a functional purification membrane, validate its functionality and investigate controlling its operation via electrostriction effects. If successful, this project will create the required evidence of feasibility of our sustainable wastewater treatment concept and/or pinpoint the scientific-technical challenges for the follow-up research.

4- Research plan

This project will join the expertise in bio-based/microbial polymers (prof. Loosdrecht at BT/TNW), separation membranes (dr. Bazyar at P&E/3mE) and smart material sensors/actuators (dr. Hunt at MNE/3mE) in order to create the next generation wastewater purification technology that is circular and sustainable. This requires executing the following tasks:

T1: Literature study. This task will establish the fundamentals required to understand and meaningfully execute this project. This concerns studying (1) unique properties and processing methods of the bio-based polymers; (2) working principles, manufacturing process and separation membranes; and (3) fundamental driving processes in electroactive polymer actuation. Items of this task are aligned with the expertise of each of the three supervisors.

T2: Bio-based polymer membrane. This task will develop a recipe and process for making filtration membranes with desired properties for water treatment (micro- or ultrafiltration). The challenges lie in (1) creating mechanically stable porous membranes from pure Kaumera BBP and its blends with water-soluble polymers (e.g., NaAlg and PVA); and (2) tuning the mechanical and filtration properties of these membranes via the manufacturing process. This task relies on the membranes manufacturing facilities, expertise (manufacturing, functioning, characterisation) and supervision of dr. Bazyar.

T3: Water purification cell. Investigating the membrane functionality requires a test platform. This task will (1) design and build a water purification cell prototype that encases the membrane of T2 and connects it to the auxiliary equipment (water supply and purity measurement equipment); and (2) experimentally characterise the filtration properties of the manufactured membrane. This task will rely on the membrane characterisation experience and equipment of dr. Bazyar.

T4: Electroactive properties. This task will study electroactive response of the membrane to achieve tuneable permeability via electrical activation. The challenges lie in (1) application of electrodes on the membrane (made in T2) via printing, pressing or electroless plating techniques; and (2) investigating electromechanically induced changes on the membrane permeability in the purification cell design of T3. This task relies on the expertise and supervision of dr. Hunt.

Table 1. Time plan of the master project

# Task	**Month**								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
T1: Literature study									
T2: BBP membrane									
T3: Water purification cell									
T4: Electroactive properties									
Writing thesis									

5- Student profile

Suitable candidate is passionate about sustainable and circular industry of the future and wants to contribute to it via interdisciplinary research. She/he follows curriculum in TNW or 3mE that links to materials science, chemistry, engineering or similar (e.g., bioengineering, chemical engineering). It is beneficial to have prior experience with polymers, membranes fabrication, characterisation and testing. This project will be conducted at P&E lab/3mE.