INTERNSHIP REPORT

Development of Nanofiltration Membranes Using Biopolymers (PHA)

Global Responsibility & Leadership (GRL)

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PREFACE

When I started my Bachelor in Global Responsibility and Leadership, I did not yet know which direction I wanted to take afterwards. At times this uncertainty worried me, questioning myself if I was moving in the right direction. Over time, several opportunities showed me a clearer path. Writing an op-ed on water adaptation for the Global Center on Adaptation, which led to the chance to attend COP29, together with speaking at the European Parliament about water adaptation in Fryslân, all became important stepping stones that pointed me toward water as the theme where I can make a real difference. These experiences reassured me that I am moving in the right direction, one that connects my passion for sustainability with concrete opportunities to contribute.

It was through this journey that I first met Johannes Boonstra, co-founder of Wetsus together with Cees Buisman. After keeping in contact, I eventually dared to ask Johannes whether Wetsus might have an internship opportunity for me. His encouragement and openness led to this internship, which not only became a valuable part of my Bachelor programme but may also be the start of future collaboration.

This report describes my experience as an intern at Wetsus from June to August 2025, where I supported a PhD student in her research on nanofiltration membranes made from biopolymers. It explains the organization, my tasks, and my learning journey. It also reflects on how this internship contributed to my development within the GRL programme and how it connects to my future ambitions in sustainability.

I would like to express my gratitude to my supervisor at Wetsus, Dr. Liang-Shin Wang, for her patient guidance and expertise, to my academic supervisor, Dr. Carol Garzon Lopez, for her support and enthousiasm, and to Johannes Boonstra for giving me this opportunity. Finally, I thank my colleagues at Wetsus for creating such a welcoming and stimulating research environment.

Marij Tolsma
Leeuwarden, August 2025

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INTRODUCTION

This report reflects on my internship at Wetsus, located in Leeuwarden, the Netherlands, where I worked from June 1st to August 31st, 2025. The focus of my internship was the project “Development of Nanofiltration Membranes Using Biopolymers (PHAs),” a research initiative led by a PhD student in the Membrane group at Wetsus.

For me, this internship represented more than just a research placement. It was a unique chance to step into the world of laboratory science and experience research from the inside. Coming from the Global Responsibility and Leadership programme, where I was trained primarily to analyze sustainability challenges from an interdisciplinary and societal perspective, I was now entering a more technical environment. This contrast allowed me to see research from a completely new angle, from conducting experiments in the lab and analyzing data in Python and Excel, to diving into academic literature in chemistry and material sciences, which often uses terminology quite different from what I was used to.

The project itself aimed to explore the potential of polyhydroxyalkanoates (PHAs), a biodegradable biopolymer, in the fabrication of sustainable nanofiltration membranes. PHAs such as PHBV are increasingly being explored for membrane fabrication due to their biodegradability and potential role in sustainable water treatment (Wang et al., 2023). Using biopolymers in membrane development could help reduce reliance on fossil-based plastics and make water technology more environmentally friendly. If successful, PHA membranes could contribute to water purification, pollutant removal, and resource recovery, all of which connect to global sustainability goals and the mission of Wetsus.

Through this internship, I set myself the goal of achieving several learning outcomes:

- **Gaining hands-on experience in general lab skills and specialized techniques for membrane development.**
- **Developing a deeper understanding of the properties and applications of biopolymers in water technology**
- **Strengthening my skills in data analysis, academic reporting, and interdisciplinary teamwork in both research and applied contexts**

In line with the Global Responsibility and Leadership programme, this internship allowed me to bridge theory with practice. It gave me the opportunity to combine my interdisciplinary background in sustainability and leadership with technical, chemistry-focused research. By doing so, I began to see how these two sides, understanding the societal and policy relevance of innovation on the one hand, and having the technical knowledge to actually carry out and evaluate research on the other, can complement one another. This insight has not only shaped the way I view my studies but has also helped me envision a possible future where I combine GRL with a technical Master’s in water technology, giving me a broad skill set to contribute to sustainable solutions.

DESCRIPTION OF THE INTERNSHIP ORGANIZATION

Wetsus is a European centre of excellence for sustainable water technology, located in Leeuwarden, the Netherlands. It brings together universities, research institutes, and companies in a unique multidisciplinary setting, where scientific research and applied innovation intersect. Its mission is to contribute to sustainable water management worldwide by fostering breakthrough technologies that address pressing global challenges such as water scarcity, energy use, and resource recovery.

The research at Wetsus is organized in thematic groups (e.g., membranes, resource recovery, biofilms), which combine the expertise of PhD students, postdocs, professors and industrial partners. The international and interdisciplinary character of Wetsus creates an environment where young researchers can interact daily with leading scientists and industry stakeholders. This collaborative approach strongly aligns with the Global Responsibility and Leadership programme, which emphasizes interdisciplinary problem-solving for global challenges.

DISCRIPTION OF THE INTERNSHIP ITSELF

During my internship, I carried out a series of experiments designed to better understand the transport behavior of PHA-based membranes. The main focus was on three aspects of performance: size selectivity, mechanical stability, and ion rejection. These parameters are crucial when evaluating the potential of new membrane materials, as they determine whether a membrane can effectively remove contaminants from water while remaining resilient throughout operation.

Determining pore size by molecular weight cut-off tests (MWCO)

The first set of experiments concerned the molecular weight cut-off (MWCO), which is a method used to estimate the approximate pore size of a membrane. MWCO tests aim to identify the molecular size at which the membrane rejects about 90% of the solute, indicating which substances the membrane can or cannot retain. To measure this, I used a mixture of polyethylene glycol (PEG) molecules of various sizes, ranging from 600 to 10,000 Daltons, and filtered them through six membranes that were specially developed for this project with varying polymer compositions.

The expectation was that the membranes would reject most of the larger PEG molecules, thereby showing a clear “cut-off” point. However, the results were surprising. None of the membranes achieved the expected 90% rejection, and in several cases, especially with the larger PEG molecules (8,000–10,000 Da), I even observed negative rejection (figure 1). This meant that the concentration of PEG in the permeate was higher than in the feed, a counterintuitive result suggesting that the membranes were actually fasilitating the pass through of PEG, something that should not have happened according to the literature.

To understand why this happened, I conducted a literature review. Studies suggested that PEG’s flexible, chain-like shapeallows it to deform and squeeze through pores that would normally block rigid molecules of similar size (He et al., 2022). In addition, PEG may interact with the membrane material itself, temporarily swelling the pores and lowering rejection rates (Pierucci et al., 2017). Based on these findings, the group decided to explore the use of dextran, a more rigid polymer, as an alternative for MWCO testing (Bowen & Mukhtar, 1996). Experiments with dextran were initiated near the end of my internship.

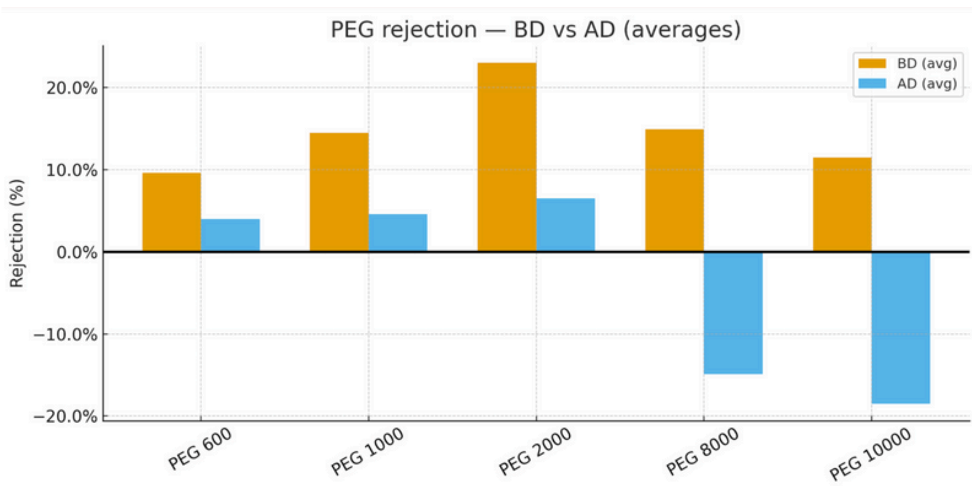


Figure 1. Average rejection rates of PEG molecules with different molecular weights (600–10,000 Da) for BD and AD type membranes

Pure Water Permeability (PWP) and Compaction Tests

A second part of my work involved testing the pure water permeability (PWP) of the membranes, which measures how easily water can pass through them. This parameter is important because membranes are subject to compaction under pressure: when water is pushed through at high pressure, the membrane structure may compress, reducing the number of open pathways for water to flow. Over time, this can decrease performance in real applications (Ding et al., 2024).

To investigate this, I carried out a structured sequence of pressure tests. First, I measured water flux while lowering the pressure from 10 to 2 bar on reference membranes, to establish a baseline. Second, I gradually increased the pressure from 2 to 10 bar on two membranes, to see whether any irreversible compression would occur. Finally, I applied a full loop (2 → 10 → 2 bar) to another set of membranes, to determine whether the response was elastic (fully reversible) or plastic (leading to permanent changes).

The results showed clear evidence of compaction. When pressure was reduced back to 2 bar after being raised to 10 bar, the water flux was lower than it had been during the initial 2 bar stage (figure 2). This demonstrated that the membranes had undergone structural compression and did not fully recover to their initial state. Similar compaction effects have also been described in other nanofiltration studies, where pressure cycling reduced permeability over time (Mänttäri et al., 2004). This finding is important for understanding the mechanical stability of PHA membranes.

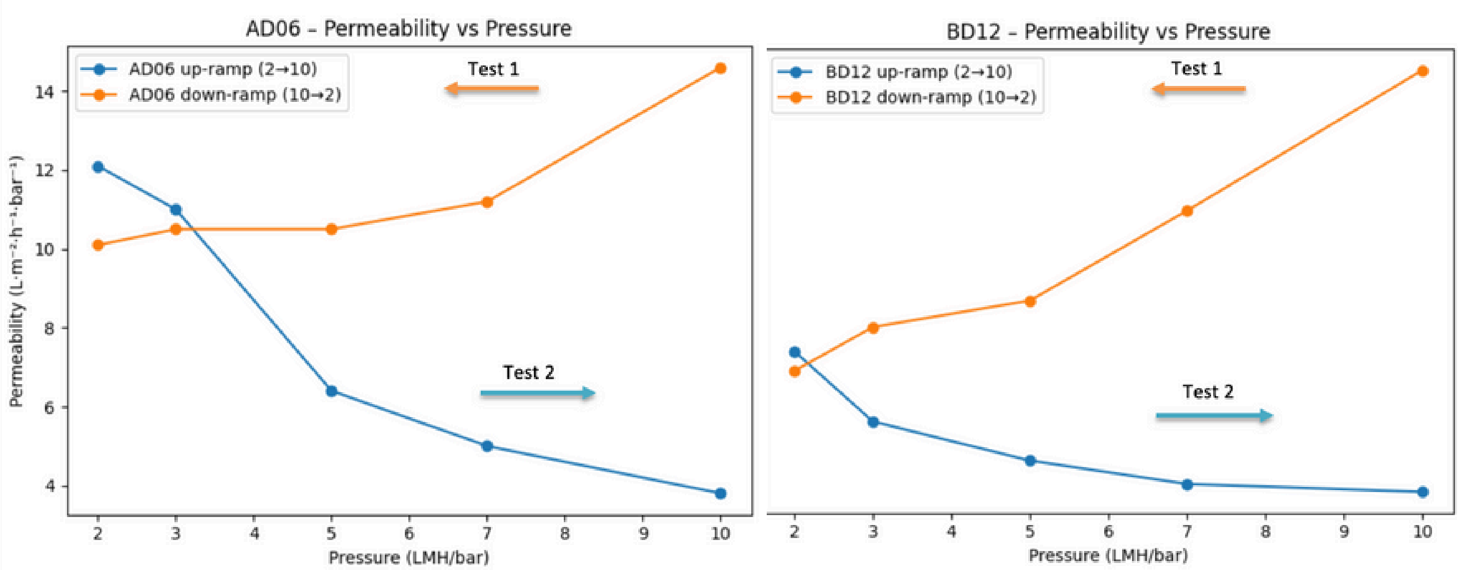


Figure 2. Permeability of AD06 (left) and BD12 (right) membranes as a function of applied pressure during up-ramp (2 → 10 bar) and down-ramp (10 → 2 bar) tests.

Salt Rejection Experiments

The third and perhaps most intriguing part of my internship focused on salt rejection experiments, tests that assess how well membranes discriminate between ions based on their size and charge. Generally, nanofiltration membranes are expected to reject divalent ions (such as Mg^{2+} and Ca^{2+}) more strongly than monovalent ions (like Na^{+}). A typical expected rejection sequence is: $MgSO_4$ > NaCl > $CaCl_2$/$MgCl_2$

However, my results told a different story. Surprisingly, NaCl was rejected more strongly than the $MgSO_4$ (figure 3). Even more striking, magnesium salts caused unexpected and sometimes problematic behavior. In certain tests with $MgCl_2$, the water flux and rejection suddenly dropped and did not recover, indicating that the membrane had undergone a permanent change (figure 4). Across several membranes, we observed lower flux and lower-than-expected rejection whenever magnesium was present.

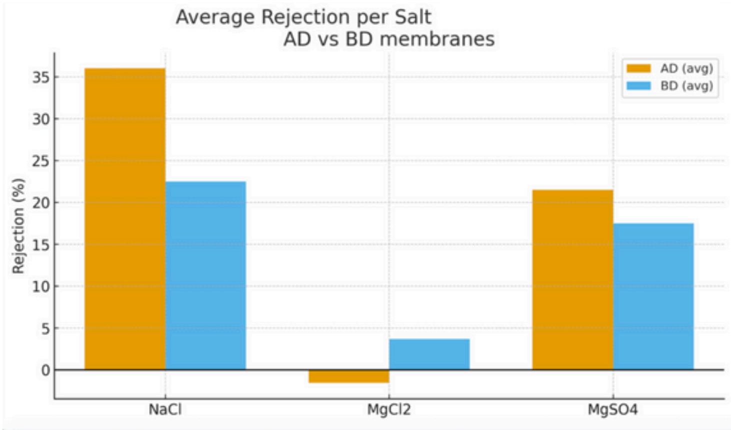


Figure 3. Average salt rejection of AD and BD membranes for NaCl, $MgCl_2$, and $MgSO_4$

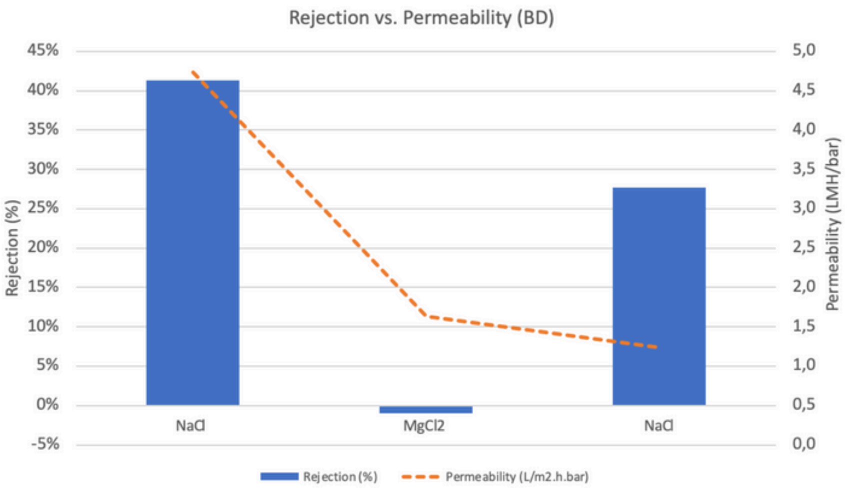


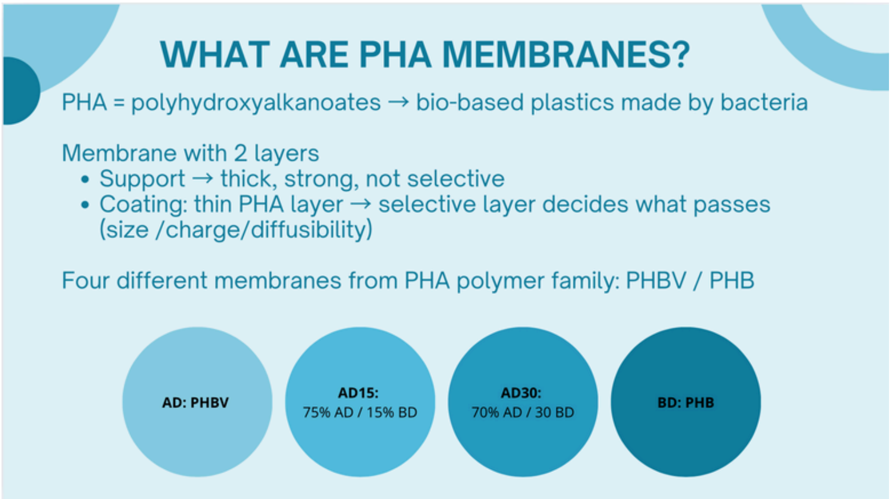
Figure 4. Rejection vs. permeability for BD membranes.

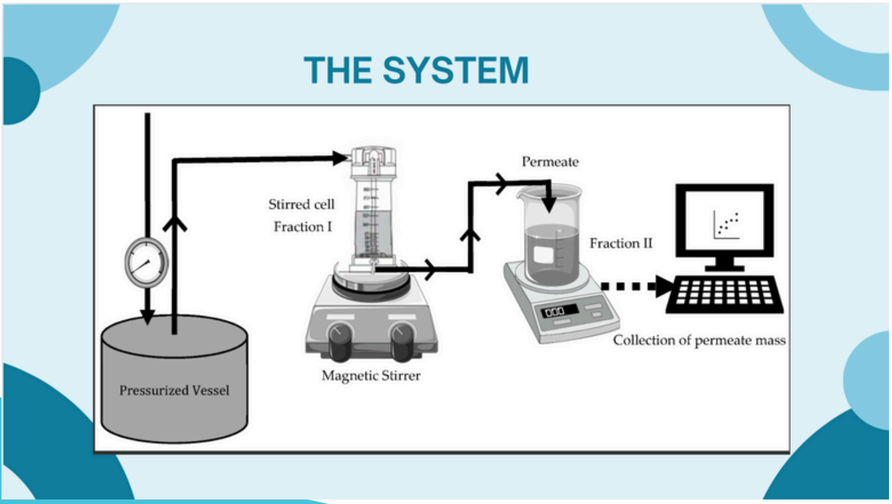
To explain this phenomenon, I reviewed literature and discussed the findings with colleagues at Wetsus. One possible explanation is that magnesium ions, which have a relatively large hydration shell and strong charge, interact strongly with the PHA membrane material. Divalent ions such as Mg^{2+} are known to promote charge neutralization and bridging effects on membrane surfaces, leading to the formation of dense surface layers that hinder water transport and decrease flux (Mallya et al., 2023). This could explain the sudden and sometimes permanent flux decline observed during the $MgCl_2$ tests. However, several experiments also showed lower rejection of magnesium salts. If a dense layer had indeed formed on the surface, we would normally expect the opposite, a tighter barrier and thus higher rejection. Therefore, the bridging effect can only partly explain the observed results, and it's something that needs to be further researched.

Final Presentation and Outputs

At the end of my internship, I presented my findings to the Wetsus Membrane Group in a presentation entitled "The Transport Behavior Mysteries of PHA Membranes." In this talk, I summarized the three main areas of work: MWCO testing, compaction tests, and salt rejections, along with the unexpected anomalies and the hypotheses we developed to explain them. I also suggested next steps for the research, such as continuing MWCO experiments with dextran.

The concrete outputs of my internship included: experimental datasets (PEG MWCO, PWP flux cycles, and salt rejection values), literature reviews on PEG–membrane interactions and magnesium behavior, the final presentation to the Membrane Group, and this internship report.





EVALUATION AND REFLECTION

Achieved Learning Outcomes

One of the central goals of my internship was to gain practical experience in a laboratory environment. Over the summer, I became proficient in general laboratory techniques such as pipetting, preparing samples for ion chromatography (IC), and working safely with membrane equipment. More specifically, I learned how to carry out nanofiltration experiments, measure pure water permeability, and evaluate salt rejections.

Beyond practical skills, I developed my scientific reasoning. Many of my results differed from expectations, such as the negative PEG rejections and the unusual effects of magnesium salts. These challenges taught me to approach data critically: to question results, review literature, form hypotheses, and design follow-up experiments.

I also strengthened my data analysis and reporting abilities. Working with Excel and Python improved my confidence in processing data, creating clear figures, and spotting patterns. Communicating these findings in both written form and my final presentation helped me translate complex results into a clear narrative for others.

Finally, I made significant progress in research literacy. Engaging with chemistry and materials science literature introduced me to technical terminology that was initially unfamiliar, and learning to navigate this gave me the tools to connect GRL's interdisciplinary language with that of laboratory science.

Contribution to the Organization

My work contributed to the Membrane Group in several ways. I identified the limitations of PEG as a probe for molecular weight cut-off testing, paving the way for dextran experiments. I helped confirm compaction effects in PWP tests with structured protocols. Most notably, I highlighted the "magnesium mystery," where flux and rejection behaved unexpectedly, which has relevance for ongoing studies on divalent ion transport. Alongside this, I supported colleagues by preparing IC samples, sharing ideas, and helping with making videocontent for an event, which made me feel part of the wider Wetsus community.

Reflection on GRL Knowledge

The GRL programme equipped me with tools that were highly relevant during my internship. My background in systems thinking and critical reflection helped me interpret unexpected results in their wider context, while my communication training enabled me to present technical findings clearly to an expert audience. The sustainability perspective from GRL also guided me in keeping the bigger picture in mind: PHBV membranes are not only a technical challenge but part of the global transition toward biodegradable materials in water treatment.

At the same time, this internship exposed me to a completely different side of research. Instead of working primarily on interdisciplinary or policy questions, I immersed myself in hands-on laboratory work, data analysis, and technical literature. This gave me a more complete picture of what it means to be involved in scientific innovation.

Competencies

Over the course of my internship, I developed a set of competencies that extend beyond the technical details of the experiments:

- Research competence: designing experiments, identifying sources of error, and interpreting complex results.
- Analytical competence: using Python and Excel to process and visualize data.
- Communication competence: presenting technical findings to a professional research group.
- Collaborative competence: working effectively with PhD students, chemists, and interns in an interdisciplinary team.
- Reflective competence: evaluating my strengths and weaknesses and situating my growth in relation to my future studies and career.

Future Outlook

This internship made me realize the value of combining my GRL background with a more technical education. GRL has given me the ability to evaluate innovations in terms of sustainability, leadership, and societal impact. By adding technical expertise, for example through a Master in Water Technology, I will also be able to conduct and fully understand the research itself.

I believe this combination, bridging sustainability leadership with technical science, will equip me with a versatile skill set. It will allow me not only to contribute to advanced research but also to translate scientific results into solutions that matter for policy, business, and society. This insight has given me confidence in the direction I am taking for my future career.

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