CONCLUSIONS

6. Conclusion

The comprehensive evaluation of various polymers in Experiment I provides valuable insights into their degradation behavior when stored in urine over 16 days. The observed degradation of these polymers contributed to a significant decrease in urine pH, with specific degradation pathways identified for each polymer type. Polypropylene (PP) degraded through the formation of carbonyls and hydroperoxides, while polylactic acid (PLA) and polycaprolactone (PCL) underwent hydrolysis of ester bonds, producing various acidic by-products. Polyvinyl alcohol (PVOH) exhibited substantial swelling and the highest degradation rates due to the formation of hydrogen bonding with water in urine, resulting in significant weight loss and potential persistence as microplastics.

Among the polymers, PLA demonstrated the greatest weight loss, primarily due to hydrolysis facilitated by its carboxyl end groups, which autocatalyze the degradation process. PCL, conversely, exhibited lower weight loss due to its higher hydrophobicity and crystallinity, which reduce its susceptibility to hydrolytic degradation. PP showed negligible weight loss, reinforcing its known chemical and solvent resistance. Experiment II examined the degradation rate of PLLA as a factor urine temperature, pH, and the thickness of the films. Elevated temperatures accelerated degradation, while salts and ions in urine facilitated water sorption and hydrolysis. The study also revealed that the degradation of PLLA under alkaline conditions in presence of cations resulted in the formation of lactic acid and lactate salts, further decreasing the pH. It also highlighted the potential applications for PLLA in controlled-release systems for urine and wastewater treatment.

Experiment III examined the efficacy of passive chemical dosing systems utilizing PLLA pouches in maintaining stable pH levels in dehydrating urine. The release rate of encapsulated chemicals such as KOH was directly proportional to the number of PLLA pouch layers, with thicker pouches extending the duration of pH stabilization. This passive dosing system can be optimized for long-term applications by adjusting the thickness and layering of PLLA films.

The circular alkaline dehydrating setup of Experiment IV demonstrated effectiveness in maintaining a safe pH level during urine dehydration, preventing pH decreases observed in linear setup due to carbonic acid formation. However, the circular system exhibited a reduced drying rate, which can be improved by optimizing the absorption chamber design and enhancing the surface area interaction between SAPs and humid air. The application of SAPs for extracting reusable water and removing organic metabolites from urine demonstrated promising results. Both potassium polyacrylate (KPAc) and sodium polyacrylate (NaPAc) exhibited commendable moisture absorption capacities, with KPAc demonstrating marginally superior performance. The degradation of SAPs over repeated drying cycles resulted in a decrease in absorption efficiency; however, water extraction remained above 90% in the majority of cases. The SAPs effectively removed a substantial portion of organic metabolites, particularly positively charged and non-polar compounds.

Energy efficiency analysis of the circular-urine dehydrating system identified areas for improvement. The current configuration exhibited low efficiency, with significant heat losses through conduction and convection. Upscaling the setup would necessitate substantial modifications to increase the efficiency of the system. Implementation of insulation, optimization of heating, and enhancement of air circulation could improve system efficiency and reduce energy demand.

There are advantages and disadvantages associated with both strategies discussed in the thesis to buffer the pH of the dehydrating urine. PLLA pouches, fabricated from biodegradable polymers, offer a passive, customizable, and environmentally sustainable solution for small-scale applications, although their performance may vary with environmental conditions, and they can be costly. The circular system, suitable for larger-scale use, provides stable pH control and efficient dehydration with low energy consumption; however, it is complex, costly, and requires reliable energy. PLLA pouches are optimal for low-maintenance, small-scale setups, while the circular system is more appropriate for urban areas and large institutions with consistent energy access.

Here are 5 take-home points that summarize the findings of the thesis:

1. **Polymer Degradation in Urine**: Different polymers exhibit distinct degradation behaviours in urine. PLA showed the highest weight loss, while PP demonstrated strong resistance to degradation.

2. **PLLA's Role in Controlled Release**: The degradation rate of PLLA is influenced by environmental factors like temperature, pH and ionic concentration, making it suitable for controlled-release systems in urine and wastewater treatment.
3. **PLLA Pouch Customization**: The thickness and layering of PLLA pouches can be adjusted to control the release rate of chemicals, allowing for effective pH stabilization in urine over extended periods.
4. **Circular System Efficiency**: The circular alkaline dehydration setup efficiently maintains a safe urine pH and recycle water, but requires design optimizations to improve drying rates and overall energy efficiency.
5. **Application Suitability**: PLLA pouches are ideal for small-scale, low-maintenance applications, while the circular system is more suited for large-scale operations where energy reliability and higher capacity are needed.