ABSTRACT

This thesis titled *"A Circular Approach to Alkaline Urine Dehydration: Polymer-Based Solutions for pH Buffering, Water Recycling and Reduced Energy Footprint"* addresses a significant gap in the field of sustainable water management and sanitation. This research explores the application of bio-polymers in the fabrication of a passive chemical delivery system to buffer the declining pH of urine during alkaline dehydration of urine, thus optimizing the dehydration process and facilitating efficient recycling of plant essential nutrients. The thesis also examines the usage of Super Absorbent Polymers (SAPs) in a circular urine dehydrating setup to buffer the pH of urine and recycling of non-potable water for domestic purposes and explore ways of reducing the overall energy footprint of the process.

The research evaluates the degradation of four polymers polypropylene (PP), polylactic acid (PLA), polycaprolactone (PCL), and polyvinyl alcohol (PVOH) in calcium hydroxide-treated urine to identify suitable candidate for a passive chemical dosing system. PLA exhibited the highest weight loss of 26% after 16 days, forming non-toxic by-products. PVOH showed the greatest pH drop (from 12 to 9.8) due to rapid degradation, while PP displayed minimal weight loss (<1%) and pH change, highlighting its stability. These findings guided the selection of polymers for the continual buffering of alkaline urine during dehydration.

The study also explored the impact of polymer film thickness, urine temperature, and pH on the degradation rate of Poly-L-Lactic Acid (PLLA) based films. Thicker films (0.25 mm) degraded slower than thinner ones (0.05 mm), while higher temperatures (45°C) accelerated degradation compared to ambient conditions (20°C). Results showed a degradation rate was faster with higher temperature and that amorphous segments degraded first. In the presence of cations, such as Ca^{2+} and Na^{+}, by-products like lactate salts were formed, which are environmentally nontoxic.

A key innovation in this thesis was the design of PLLA pouches for controlled chemical release. These pouches, containing potassium hydroxide (KOH), effectively maintained urine pH above 10 for up to 32 days. Layered pouches demonstrated prolonged chemical release; single-layer pouches released KOH within 8 days, while three-layer configurations extended the release period up to 32 days. This controlled buffering

mitigated the pH drop caused by carbonation during urine dehydration, ensuring process stability and reduced nitrogen loss.

The thesis also evaluated a circular urine dehydration system employing superabsorbent polymers (SAPs) such as sodium polyacrylate (NaPAc) and potassium polyacrylate (KPAc) to dehumidify moist air and recycle water. SAPs absorbed 46 g of moisture per drying cycle and facilitated the recovery of 80% of the absorbed water through desorption. The recycled water effectively removed organic metabolites, reducing their concentration by 78%, making it suitable for non-potable domestic uses such as gardening. However, the system exhibited an energy efficiency of only 30%, with significant heat loss, suggesting a need for further optimization.

In conclusion, this thesis presents a comprehensive examination of the role of polymers in buffering the pH and value addition during alkaline urine dehydration. The innovative strategy of employing polymer-based solutions to optimize alkaline urine dehydration and facilitate water recycling offers a promising solution to global water and sanitation challenges. The findings of this thesis underline the potential of these systems in providing sustainable, efficient, and scalable solutions for water management, particularly in resource-constrained environments. The research advocates for continued exploration and development of advanced polymer materials, energy-efficient methods, and integrated systems to further enhance the performance and sustainability of urine dehydration processes. By addressing the multifaceted aspects of polymer degradation, pH regulation, and water recovery, this study contributes to the advancement of knowledge and technology in the field of sustainable sanitation and water management.