
*SCOPE FOR FUTURE
RESEARCH*

7. Scope for future research

Using solar energy for dehydrating urine presents the best pathway to make the circular drying setup energy efficient. The primary benefits of solar drying include substantial energy savings, sustainability, cost-effectiveness and off-grid capability (Andharia et al., 2024). Solar drying dramatically reduces energy consumption by utilizing natural sunlight, thereby decreasing reliance on conventional electrical power. This would also contribute towards environmental sustainability and reducing carbon footprint (Khan & Arsalan, 2016). While the initial setup may involve higher costs, operational expenses remain minimal since sunlight is abundant and free in many regions. Additionally, solar drying systems can operate independently of the electrical grid, making them suitable for remote or off-grid locations (Khan & Arsalan, 2016).

Despite its benefits, solar drying faces challenges such as inconsistent solar availability, system efficiency, initial investment, and control and monitoring (Ronald, 2020). Solar energy availability can be inconsistent due to weather conditions and seasonal variations. To mitigate this, integrating thermal storage systems that store excess heat during sunny periods and release it during cloudy or night time conditions can ensure continuous operation. Enhancing system design with features like reflectors, glazing, and proper insulation can improve efficiency (Ronald, 2020).

Optimizing solar drying involves several strategies. Effective solar collector design, such as using flat-plate or parabolic trough collectors, can enhance solar energy concentration and uniform heat distribution (Zziwa et al., 2023). Implementing a greenhouse effect with transparent covers can trap solar radiation, increasing internal temperature and promoting efficient drying. Incorporating materials with high thermal mass, such as water tanks or phase change materials (PCMs), can store solar energy during the day and release it when sunlight is unavailable (Angula & Inambao, 2020). Enhanced airflow through natural convection or solar-powered fans ensures efficient moisture removal and uniform temperature distribution (Adefemi & Ilesanmi, 2018). Additionally, hybrid systems combining solar drying with conventional methods, such as electrical heating or dehumidification, can ensure consistent performance by using solar energy as the primary source and activating backup systems during insufficient solar availability (Zziwa et al., 2023).

Other opportunities for future research are:

1. **Extended Degradation Studies:** Future research should focus on longer-term studies to understand the complete degradation profiles of these polymers in urine, particularly for applications involving extended storage or usage periods.
2. **Advanced Polymer Composites:** Developing new polymer composites with tailored degradation rates and by-products could provide more control over the environmental impact and functionality of materials used in urine and wastewater treatment.
3. **Optimization of Passive Dosing Systems:** Further optimization of PLLA-based passive dosing systems is needed to extend their operational duration and improve the consistency of chemical release. Exploring different polymer structures, thicknesses, and layering techniques will be crucial.
4. **Enhanced SAP Performance:** Investigating the development of superabsorbent polymers with higher moisture absorption rates and greater resistance to thermal degradation will enhance the efficiency of water extraction systems. New materials that can effectively remove a broader range of organic micropollutants should also be explored.
5. **Energy Efficiency Improvements:** Future studies should aim to enhance the energy efficiency of circular-urine dehydrating systems. This includes exploring alternative heating methods, such as solar energy, and improving the thermal insulation and airflow dynamics within the system.
6. **Environmental Impact Assessment:** Comprehensive life cycle assessments of these polymer films and dehydration systems will provide a better understanding of their environmental impacts, guiding sustainable development and application strategies.
7. **Integration with Wastewater Treatment:** Exploring the integration of these findings with existing wastewater treatment processes can help develop more efficient and sustainable solutions for managing human waste and recovering valuable resources.