Technical Report

State of Readiness of 3D-Printed Water Recycling Technology

1. Technology Overview

The 3D-printed water recycling technology is a decentralized wastewater treatment system designed for rural communities in South Africa. The system uses 3D-printed components to treat greywater from household activities, making it suitable for irrigation and other non-potable purposes.

2. Current State of Development

2.1 Model development in Autodesk Inventor

The system was designed using Autodesk Inventor, with components such as elbows, tees, and valves created to meet ASME standards, Figure 1.

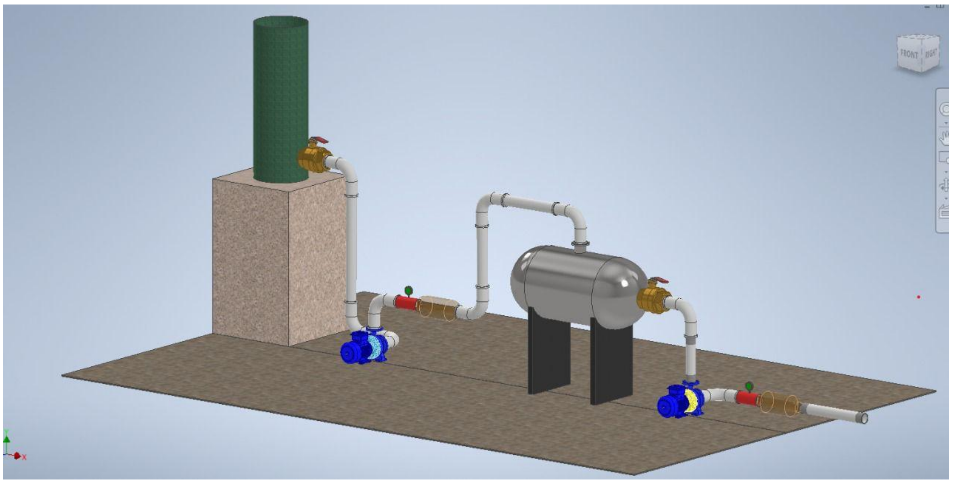

Figure 1: Model of the garden irrigation system here.

2.2 Model development via 3D printing

The designed components were fabricated using 3D printing techniques, including Fused Deposition Modeling (FDM) and Selective Laser Sintering (SLS). This task was carried out at the University of Johannesburg 3D Printing Laboratory, Figure 2.

Figure 2: Some of the 3D printed substructures.

3. Technology Readiness Level (TRL) Assessment

The technology has been built and installed at a rural home in Kgopaneng village, Limpopo Province, South Africa, and has undergone testing and validation, Figures 3 and 4.

TRL Level: 6 (Technology Demonstrated in Relevant Environment)

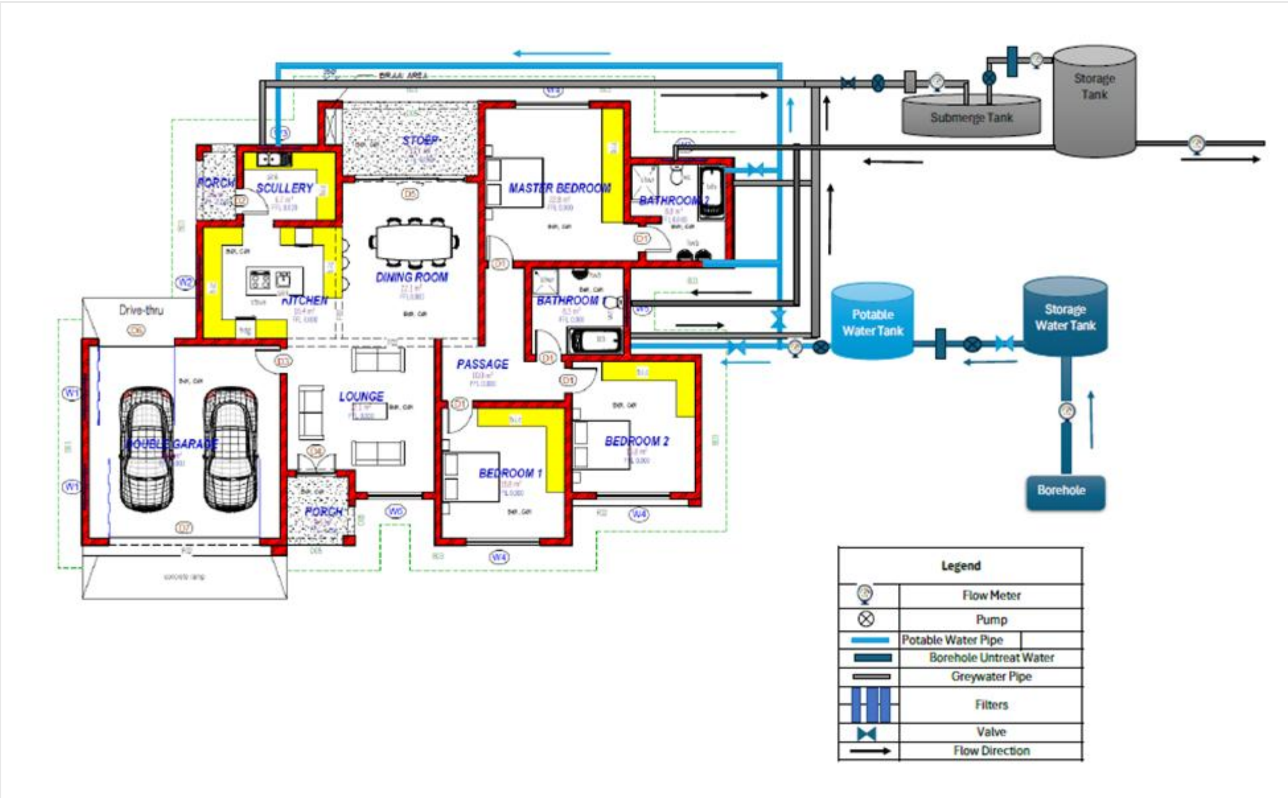

Figure 3: Plan at the installation site.

Figure 4: Various views of the wastewater treatment set up.

4. Key Technical Challenges and Risks

- Material durability and resistance to corrosion.
- Scaling up production to meet demand.
- Ensuring consistent water quality and treatment efficacy.
- Addressing regulatory and standards compliance.

5. Prototype Development and Testing

5.1 Model installation in Kgopaneng village

The system was installed at a rural home in Kgopaneng village, treating greywater from kitchen, bathroom, and laundry activities, Figure 4.

5.2 Water samples collection and testing at the CSIR

Water samples were collected and tested at the CSIR Pretoria water laboratory, showing significant removal of contaminants and improved water quality, Figure 5.

Figure 5: Sample collection before and after treatment.

5.3 Kgopaneng village home garden irrigation

Treated water was used for irrigation, with positive results on plant growth and yield, see Figures 6 and 7.

Figure *6:* Treated water being used for irrigation in month 1 of use.

Figure 7: Some vegetable growth from the garden watering system in month 3 of use.

6. Performance Metrics and Evaluation

6.1 Filtration technology

6.1.1 Wastewater sources to treated

Tub/Shower

Tub and shower wastewater is characterized by a high concentration of surfactants from soaps, shampoos, and body washes, as well as hair, skin cells, and other organic matter. The pH is typically slightly alkaline (pH 7-8) due to the presence of soap residues. Inorganic ions such as sodium, chloride, and phosphate are also present, contributing to the wastewater's ionic strength [1].

Kitchen Sink/Dishwasher

Kitchen sink and dishwasher wastewater is rich in organic matter, including food particles, grease, and oils. The pH can be variable but is often slightly acidic (pH 5-7) due to the presence of food acids and other organic compounds. Surfactants from dish soap and other cleaning agents are also present, as well as inorganic ions like sodium, chloride, and phosphate [2].

Washing Machine

Washing machine wastewater is characterized by a high concentration of surfactants from laundry detergent, as well as suspended solids like fabric fibers and soil particles. The pH is typically alkaline (pH 8-10) due to the presence of alkaline builders in laundry detergent. Inorganic ions like sodium, chloride, and phosphate are also present, contributing to the wastewater's ionic strength [3].

6.1.2 Filtration technologies used

Tub/Shower

Grey water from tubs and showers can be treated using a combination of physical and biological processes. The treatment train included a sedimentation tank (receiver tank), followed by a 12L mineral filter (design by Puritech water purification) containing activated alumina, zeolite, and sand, and then disinfected using chlorine [4].

Kitchen Sink/Dishwasher

Wastewater from kitchen sinks and dishwashers requires more intensive treatment due to high levels of organic matter and grease. The treatment train included a solids filter (AnoxKaldnes™ ANITA™ Mox filter, manufactured by Veolia Water Technologies), and then a mineral filter (design by Puritech water purification) containing activated carbon, zeolite, and sand. Disinfection using chlorine [4,5].

Washing Machine

Laundry wastewater can be treated using a combination of physical and chemical processes. The treatment train included a sedimentation tank (receiver tank), followed by a coagulation/flocculation process (in the second tank), and then a mineral filter (design by Puritech water purification) containing activated alumina, zeolite, and sand. Disinfection using chlorine may also be necessary [4].

References

1. Tchobanoglous, G., Burton, F. L., & Stensel, H. D. (2003). Wastewater Engineering: Treatment and Reuse. McGraw-Hill Education.

2. Metcalf & Eddy, Inc. (2003). Wastewater Engineering: Treatment, Disposal, and Reuse. McGraw-Hill Education.

3. American Public Health Association (APHA). (2017). Standard Methods for the Examination of Water and Wastewater. 23rd Edition.

4. Puritech Water Treatment. (n.d.). EngNet South Africa. Retrieved from (link unavailable).

5. Veolia Water Technologies. (n.d.). ANITA™ Mox Anaerobic Moving Bed Biofilm Reactor (MBBR). Retrieved from (link unavailable).

6.2 Filtration results and evaluation

Parameter	Untreated Water	Treated Water	SANS Standards
E-coli (CFU/100mL)	>2419.6	<1	<1
Faecal coliforms/100mL	>2419.6	<1	<1
pH	4.4-9.3	5.5-10.5	5.5-9.5
Electrical conductivity (mS/m)	32-157	533-4041	<150

The wastewater testing results show significant improvements in E-coli and faecal coliforms after treatment, with both parameters meeting the SANS standards (<1 CFU/100mL). This indicates effective removal of pathogenic microorganisms, making the treated water safer for potential reuse in irrigation or discharge into the environment.

The pH range of the treated water (5.5-10.5) is slightly broader than the SANS standard (5.5-9.5), but still within acceptable limits. However, the electrical conductivity of the treated water (533-4041 mS/m) exceeds the SANS standard (<150 mS/m), indicating high levels of dissolved salts or ions. This could be a concern for reuse applications, such as irrigation or industrial processes, and may require additional treatment steps like desalination or blending with freshwater sources.

Overall, the treatment process is effective in removing microbial contaminants, but further treatment is needed to address the high electrical conductivity and ensure compliance with SANS standards for water reuse or discharge.

7. Scalability and Implementation Plan

- Short-term: Scale up production to meet local demand in Kgopaneng village.
- Medium-term: Expand implementation to other rural communities in South Africa.
- Long-term: Explore export opportunities to other developing countries, with particular focus on African countries.

8. Regulatory and Standards Compliance

- SANS 241:2024: Drinking Water Quality Standards.
- SANS 10252:2019: Water Quality for Irrigation.

9. **Environmental and Social Impact Assessment**

- Positive impact on water conservation and sanitation.
- Potential for job creation and economic growth.
- Community engagement and education necessary for successful implementation.

10. Cost Analysis and Economic Viability

- Estimated cost: R10,000-R20,000 per unit.
- Potential revenue streams: Water sales, irrigation services, and job creation.

11. Future Development Roadmap

- Refine design and materials for improved durability and performance.
- Conduct further testing and validation.
- Explore innovative financing models and partnerships.

12. Recommendations and Next Steps

- Scale up production and implementation.

- Conduct further research and development.
- Engage with regulatory bodies and stakeholders.
- Explore innovative financing models and partnerships.

Conclusion

In conclusion, the 3D-printed water recycling technology has demonstrated promising results in treating greywater and improving water quality, making it suitable for irrigation and other non-potable purposes. With a Technology Readiness Level (TRL) of 6, the system has been successfully tested and validated in a rural setting in South Africa. The technology has the potential to address pressing water scarcity issues in rural communities, while also promoting water conservation and sanitation. Further development and scaling up of production are necessary to make the technology more widely available and to achieve economies of scale. With continued support and collaboration, this innovative circular economy technology can contribute to improving water security and quality of life for communities in South Africa and beyond.