

Fluoride Removal Technologies in Tanzania: Technological Innovation and Adaptation Perspectives for Sustainable Water Treatment Solutions

*Adam Omar Karia¹, Ghanima Chanzi¹
Water Institute, P.O Box 35059, Dar es Salaam, Tanzania
*Corresponding Author: adamkaria03@gmail.com

Abstract

Tanzania faces significant challenges related to fluoride contamination, particularly in the East African Rift Valley (EARV) regions, where nearly 2 million people are at high risk of dental, skeletal, and crippling fluorosis. This review explores technological innovations and adaptive strategies for fluoride removal, focusing on five key approaches. First are octacalcium phosphate (OCP) transformation systems, which reduce fluoride concentrations from 21 mg/L to below 1.5 mg/L within two hours; second is bone char adsorption, with a removal efficiency of 89.65%; third are nanofiltration and reverse osmosis membrane systems, achieving up to 98% fluoride rejection; fourth are rainwater harvesting models, such as the Kilimanjaro concept; and fifth are emerging hybrid technologies.

Through analysis of field implementations at Lemanda village, the Ngurdoto Defluoridation Research Station (NDRS), and the Nelson Mandela African Institution of Science and Technology (NM-AIST), we assess technological performance, community acceptance, and sustainability. Results indicate that although significant technological advances meet WHO compliance standards, adoption challenges persist due to behavioral factors, economic constraints (Water.org, 2024), and maintenance requirements. We recommend a technology portfolio approach that combines locally appropriate solutions with advanced innovations, supported by strengthened research-industry partnerships and community-centered implementation strategies.

Keywords: Fluoride removal, Tanzania, water treatment technology, octacalcium phosphate, bone char, nanofiltration, technological innovation, East African Rift Valley

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1. Introduction

Fluoride contamination of drinking water sources is one of Tanzania's most persistent public health challenges, affecting millions across the East African Rift Valley (EARV) regions. The geological setting creates conditions that mobilize fluoride from volcanic rocks into groundwater systems, resulting in concentrations that frequently exceed 10-30 mg/L, compared with the WHO guideline of 1.5 mg/L (Ghiglieri *et al.*, 2023; Malago *et al.*, 2017). Recent geostatistical analysis confirms that approximately 2 million people face a high risk of dental, skeletal, and crippling fluorosis, while another 1 million face a high risk of dental caries due to inadequate fluoride intake (Nakaya *et al.*, 2023).

The technological response spans more than six decades, evolving from simple alternative-source development to sophisticated treatment systems (Mjengera & Mkongo, 2003). Contemporary approaches range from locally appropriate solutions using indigenous materials to advanced membrane technologies powered by renewable energy (Shen *et al.*, 2016). Recent innovations demonstrate significant potential, including octacalcium phosphate transformation systems developed through the EU Horizon 2020 FLOWERED project (Idini *et al.*, 2020), optimized bone char production methods (Kaseva, 2006), and solar-powered membrane systems that achieve 98% fluoride removal (Shen & Schäfer, 2015).

Innovation must account for unique contextual factors, including extreme variability in concentration (0.05-47.6 mg/L), complex water chemistry with high ionic strength, limited technical infrastructure, and diverse socioeconomic conditions that affect technology access (Owusu-Agyeman *et al.*, 2019; Jeihanipour *et al.*, 2018).

Successful technological innovation requires integrating technical effectiveness with local manufacturing capacity, community preferences, and sustainable financing mechanisms (Gutierrez *et al.*, 2021).

2. Geological Context and Fluoride Occurrence

Tanzania's fluoride contamination stems from unique geological conditions in the EARV, marked by extensive volcanic activity, alkaline groundwater systems, and fluoride-rich mineral formations (Ghiglieri *et al.*, 2012). The EARV extends through northern and central Tanzania, encompassing the Arusha, Kilimanjaro, Manyara, and Singida regions, as well as portions of the Dodoma region, where fluoride concentrations frequently exceed international guidelines (Malago *et al.*, 2017).

Recent probability kriging studies reveal extreme spatial heterogeneity, with locations within the EARV graben consistently showing groundwater fluoride >1.5 mg/L, whereas mountain ranges exhibit extremely low concentrations $<<0.5$ mg/L (Nakaya *et al.*, 2023). The Mount Kilimanjaro region exemplifies this complexity, with documented concentrations ranging from 0.05 mg/L in highland areas to 47.6 mg/L in lowland areas, including the St. Dorcas borehole site (Shen *et al.*, 2016).

Natural waters exhibit complex chemistry that significantly influences the performance of treatment technologies, including high ionic strength (500-3600 mg/L TDS), elevated alkalinity (300-800 mg/L as CaCO₃), and variable concentrations of natural organic matter (5-70 mg/L) (Shen & Schäfer, 2015). The Nelson Mandela African Institution of Science and Technology (NM-AIST) exhibits typical EARV conditions, with fluoride concentrations of 2.9 and 2.7 mg/L in primary boreholes (Cai *et al.*, 2020).

3. Octacalcium Phosphate (OCP) Technology Innovation

3.1 Technology Principles and Development

Octacalcium phosphate ($\text{Ca}_8(\text{HPO}_4)_2(\text{PO}_4)_4 \cdot 5\text{H}_2\text{O}$) is a breakthrough innovation that leverages its natural transformation to achieve highly effective fluoride uptake by converting to fluorapatite (Idini *et al.*, 2019). The technology emerged from the EU Horizon 2020 FLOWERED project, which integrates advanced materials science with practical field implementation strategies for EARV conditions (Idini *et al.*, 2020).

The transformation mechanism proceeds via mineralogical conversion: initial OCP synthesis from calcium carbonate and phosphoric acid, followed by fluorapatite formation in the presence of fluoride. Experimental and calculated removal capacities are 25.7 mg/g and 26.8 mg/g, respectively, with most fluoride removal occurring within 2 hours at concentrations up to 140 mg/L (Idini *et al.*, 2019).

The FLOWERED Defluoridator Device (FDD) uses OCP technology in a 20-liter tank with a recirculating pump powered by a 12V car battery, making it suitable for off-grid rural applications. Standardized operation reduces fluoride from 21 mg/L to <1.5 mg/L within 2 hours without adverse effects on water quality (Idini *et al.*, 2020).

3.2 Field Implementation: Lemanda Village Case Study

The Lemanda village implementation is a comprehensive field evaluation conducted under realistic rural conditions near Mount Meru, where groundwater contains 8.4 mg/L of fluoride, affecting approximately 200 households (Gutierrez *et al.*, 2021). Field testing demonstrated consistent performance, reducing fluoride concentrations below WHO guidelines within standard treatment cycles, with slight increases in phosphorus that may confer nutritional benefits (Idini *et al.*, 2020).

Community acceptance evaluation revealed complex adoption factors beyond technical performance. Behavioral analysis using the Extended Parallel Process Model identified knowledge gaps about fluorosis health effects as the primary barriers, rather than economic constraints (Gutierrez *et al.*, 2021; Nocella *et al.*, 2022). Willingness to pay correlated with health risk awareness and water consumption patterns rather than with absolute income (Gutierrez *et al.*, 2023).

4. Bone Char Technology: Optimization and Adaptation

4.1 Historical Development and NDRS Contributions

Bone char technology is Tanzania's longest-established fluoride removal approach, with over three decades of research at the Ngurdoto Defluoridation Research Center (NDRC) near Arusha (Mjengera & Mkongo, 2003). This technology uses a calcium phosphate matrix derived from animal bones, which is converted through controlled carbonization to produce an effective fluoride adsorbent (Kaseva, 2006).

Systematic optimization identified 500°C for 120 minutes as the optimal carbonization conditions, yielding bone char with a fluoride removal capacity of 0.75 mg-F/g and a 70.64% removal efficiency (Kaseva, 2006). Particle-size studies showed that 0.5-1.0 mm material performed best, balancing removal efficiency with practical handling requirements (Mjengera & Mkongo, 2003).

NDRS research provided fundamental insights into performance optimization, including the systematic effects of particle size, contact time optimization, and regeneration procedures. Column filter experiments validated the continuous-flow performance, demonstrating consistent compliance with WHO requirements under proper operating conditions (Kaseva, 2006).

4.2 Field Performance and Community Applications

Field implementations range from household filters to institutional treatment systems, demonstrating fluoride removal efficiency of up to 89.65% under optimal conditions (Herath *et al.*, 2018). The Defluoridation Technology Project (DTP) in Arusha provided extensive deployment experience and identified user training and maintenance support as critical success factors (Babbitt *et al.*, 2012).

Performance monitoring shows variable effectiveness across water quality conditions, maintenance practices, and operational procedures. Quality control in production is essential for community acceptance, as inadequate preparation can cause taste and odor issues that affect user satisfaction (Kaseva, 2006).

5. Membrane Technologies: Nanofiltration and Reverse Osmosis

5.1 Technology Principles and Applications

Nanofiltration (NF) and reverse osmosis (RO) achieve superior fluoride removal through size-exclusion and charge-interaction mechanisms, demonstrating >90% retention under variable water chemistry conditions (Shen & Schäfer, 2015). Research using 166 water samples from 120 sources across northern Tanzania found that 81% exceeded WHO fluoride guidelines, with the highest concentrations in high-ionic-strength waters (Shen & Schäfer, 2015).

Membrane selection studies showed that BW30, BW30-LE, and NF90 membranes achieved feed concentration limits of 30-40 mg/L at 50% recovery, whereas NF270 did not meet the requirements under challenging chemical conditions (Shen & Schäfer, 2015). Natural organic matter enhances fluoride removal by size exclusion but increases the potential for fouling (Owusu-Agyeman *et al.*, 2017).

5.2 St. Dorcas Borehole Field Demonstration

The St. Dorcas borehole implementation represents a comprehensive evaluation of solar-powered membrane technology under extreme conditions, using brackish groundwater with 3632 mg/L TDS and 47.6 mg/L fluoride (Shen *et al.*, 2016). The NF90 membrane achieved optimal performance, producing 1582 liters per day with an energy consumption of 1.6 kWh/m³ while maintaining WHO compliance (Shen *et al.*, 2016).

Performance under fluctuating solar energy demonstrated the system's robustness and optimized automated control. Economic analysis revealed favorable life-cycle costs when the benefits of multi-contaminant removal and the elimination of energy costs are considered (Shen *et al.*, 2016).

5.3 NM-AIST Research and Development

The Nelson Mandela African Institution of Science and Technology serves as a comprehensive demonstration site for institutional-scale applications, with groundwater fluoride concentrations of 2.9 and 2.7 mg/L that require treatment (Cai *et al.*, 2020). Multi-contaminant removal studies demonstrate capabilities for complex water chemistry, including strontium (10.3 mg/L) and organic matter (70.9 mg/L) (Cai *et al.*, 2020).

Educational programs support essential human resource development for deploying membrane technology across East Africa, while research infrastructure enables advanced fouling studies and operational optimization under tropical conditions (Cai *et al.*, 2020).

6. Rainwater Harvesting and Source Substitution

6.1 The Kilimanjaro Concept

The Kilimanjaro concept represents a paradigmatic shift toward source substitution, using Mount Kilimanjaro's elevation and precipitation patterns to enable comprehensive rainwater harvesting that serves the entire EARV region (Komakech *et al.*, 2019). This approach recognizes that eliminating the need for defluoridation provides the most sustainable long-term solution (Lyimo *et al.*, 2023).

Hydrological analysis shows substantial potential, with annual precipitation ranging from 500 to 2000 mm across elevation zones. The NM-AIST campus provides a demonstration with an 18,300 m² roof catchment and 800 m³ of underground storage, enabling water demand analysis for 1000 people (Komakech *et al.*, 2019).

6.2 Blending Strategies and Implementation

Optimal utilization of pristine rainwater with treated groundwater achieves WHO compliance while maximizing availability. Mathematical models demonstrate that systematic blending achieves target concentrations across a wide range of source qualities (Komakech *et al.*, 2019).

Quality control for blended water ensures chemical and microbiological safety through monitoring protocols and treatment systems, including metallic iron-based filters that effectively remove pathogens while maintaining chemical quality (Komakech *et al.*, 2019).

7. Emerging Technologies and Innovations

7.1 Hybrid Treatment Systems

Hybrid systems that combine multiple removal mechanisms demonstrate enhanced performance compared with single-technology approaches, thereby addressing complex water chemistry and variable contamination patterns (El Messaoudi *et al.*, 2024). Integrating adsorption, membrane separation, and chemical precipitation creates synergistic effects that improve overall effectiveness (Machunda *et al.*, 2020).

-precipitation followed by adsorption, the Nalgonda technique provides robust removal under variable conditions. Combined with bone char polishing, it achieves consistent WHO compliance while accommodating influent fluctuations (Mjengera & Mkongo, 2003).

7.2 Smart Monitoring and Automation

Smart monitoring systems that incorporate sensor networks and automated control enhance the reliability and performance of remote installations with limited technical support (Kumar *et al.*, 2023). Real-time fluoride monitoring enables predictive maintenance and process optimization, while IoT integration provides remote diagnostics (Singh *et al.*, 2023).

Data analytics and machine learning applications enable performance optimization by leveraging operational data from multiple installations, thereby building knowledge bases to improve technology design (Kumar *et al.*, 2023).

8. Comparative Technology Assessment

8.1 Performance Evaluation

Multi-criteria assessment indicates that OCP systems achieve the highest removal efficiency (95-98%) over the widest concentration range, whereas bone char delivers consistent performance (70-90%) and benefits from local manufacturing. Membrane technologies provide comprehensive removal of multiple contaminants but require higher energy inputs and technical expertise (Idini *et al.*, 2020; Kaseva, 2006; Shen & Schäfer, 2015).

Economic analysis shows bone char technology advantages for household and small community applications, while membrane systems demonstrate economic benefits for larger installations with multi-contaminant requirements (Mjengera & Mkongo, 2003; Shen *et al.*, 2016).

8.2 Scale-Dependent Selection

Household-scale applications favor OCP and bone char systems for their minimal complexity and low capital costs. Community-scale operation enables the cost competitiveness of membrane technology while providing multi-contaminant capabilities. Regional scale justifies the use of advanced technologies with professional operation (Machunda *et al.*, 2020).

Technology transition pathways enable progressive scaling from household to regional systems as capacity grows, with modular designs facilitating expansion while building operational experience (El Messaoudi *et al.*, 2024).

9. Implementation Challenges

9.1 Technical and Economic Barriers

Manufacturing capacity limitations, quality control challenges, and maintenance infrastructure gaps constrain deployment. Local manufacturing development is essential for sustainable scaling, and establishing testing capabilities and certification procedures enables consistent performance (Machunda *et al.*, 2020).

Capital cost barriers vary significantly by technology but consistently exceed the capacity of rural households without external support. Innovative financing, including microfinance and pay-as-you-go systems, shows promise for overcoming economic constraints (Water.org, 2024).

9.2 Social and Behavioral Factors

Research indicates that knowledge gaps regarding the health effects of fluorosis are the primary barriers to adoption, rather than economic constraints. Health education programs that address the causes and prevention of fluorosis are essential for building demand for technology (Gutierrez *et al.*, 2021; Nocella *et al.*, 2022).

Community acceptance depends on complex interactions among perceived health risks, technology characteristics, and social norms, and thus requires comprehensive behavior change interventions that draw on established behavioral models (Gutierrez *et al.*, 2023).

10. Future Directions

10.1 Technology Innovation Priorities

Next-generation technologies focus on advanced materials, such as metal-organic frameworks and nanocomposite membranes, that perform well under challenging conditions (Ali *et al.*, 2024). Artificial intelligence applications enable process optimization and predictive maintenance, while biotechnology offers sustainable approaches (Kumar *et al.*, 2023).

Integration of digital technologies, including IoT connectivity and mobile applications, transforms system operations through remote monitoring and user support, which is especially valuable in rural deployments (Singh *et al.*, 2023).

10.2 Sustainable Manufacturing

Developing local production capacity reduces costs while supporting economic development. Circular economy principles guide technology design to minimize waste, and green manufacturing processes use renewable energy and eliminate toxic materials (Machunda *et al.*, 2020).

Quality assurance systems ensure consistent performance and build market confidence, while local testing capabilities and certification procedures enable consumer protection and continuous improvement (El Messaoudi *et al.*, 2024).

11. Conclusions and Recommendations

11.1 Key Achievements

Substantial innovations show strong potential to address Tanzania's fluoride challenges. OCP technology, through the FLOWERED project, achieved breakthrough performance at extremely high concentrations, while over three decades of bone char optimization enabled local manufacturing. Applications of membrane technology powered by renewable energy demonstrate the feasibility of comprehensive treatment, and the Kilimanjaro concept offers a paradigmatic shift toward source substitution (Idini *et al.*, 2020; Kaseva, 2006; Shen *et al.*, 2016; Komakech *et al.*, 2019).

11.2 Implementation Lessons

Despite technological advances, implementation challenges persist across behavioral, economic, and institutional dimensions. Community acceptance depends more on awareness of health risks than on technical performance, and economic barriers require innovative financing mechanisms. Institutional gaps require comprehensive development, including regulatory frameworks and technical support infrastructure (Gutierrez *et al.*, 2021; Water.org, 2024; Machunda *et al.*, 2020).

11.3 Strategic Recommendations

Combining proven effectiveness with low operational complexity. Portfolio approaches that use multiple complementary technologies, optimized for different conditions, enable comprehensive coverage while building diverse capacity (Machunda *et al.*, 2020; El Messaoudi *et al.*, 2024).

Investing in research infrastructure, collaborative programs, and innovation incentive systems accelerates technology development while building indigenous capacity. Developing regulatory frameworks and innovating in financing mechanisms create enabling environments for sustainable deployment (Mjengera & Mkongo, 2003; Water.org, 2024).

Integrated water resource management frameworks that address fluoride as part of broader water security strategies maximize co-benefits while ensuring sustainability. Success requires maintaining focus on community needs while leveraging technological advances and supportive policy frameworks (Lyimo *et al.*, 2023).

References

- Ali, F. A. A., Alam, J., Qaid, S. M. H., Shukla, A. K., Al-Fatesh, A. S., Alghamdi, A. M., Fadhillah, F., Osman, A. I., & Alhoshan, M. (2024). Fluoride removal using nanofiltration-ranged polyamide thin-film nanocomposite membrane incorporated titanium oxide nanosheets. *Nanomaterials*, 14(8), 731.
- Babbitt, C. D., Morrison, C. M., & Kinh, T. H. (2012). Improving the sustainability of an appropriate technology solution: Bone char defluoridation filters in Arusha, Tanzania. *Environmental Engineering Science*, 29(8), 756–765.
- Cai, Y. H., Yang, X. J., & Schäfer, A. I. (2020). Removal of naturally occurring strontium by nanofiltration/reverse osmosis from groundwater. *Membranes*, 10(11), 321.

- El Messaoudi, N., Benzina, O., Mouiya, M., Furukawa, H., Khaliha, A., Bakiz, B., Miyah, Y., Mejdoubi, E. M., & Zerrouq, F. (2024). Recent advances in fluoride removal from water: A comprehensive review of materials, methods and mechanisms. *Chemosphere*, 350, 141015.
- Ghiglieri, G., Buttau, C., Barbieri, G., Kebede, S., Balia, R., Kassa, H., & Tesema, A. (2023). Fluoride contamination in groundwater of the Ethiopian Rift: A review on distribution, health effects, and remediation techniques. *Environmental Earth Sciences*, 82, 1–18.
- Gutierrez, L. A., Carrera, M., & Espinosa, M. (2021). Willingness to pay for fluoride-free water in Tanzania: Disentangling the importance of behavioral factors. *International Journal of Water Resources Development*, 37(6), 1028–1048.
- Gutierrez, L., Sanna, C., Sabbagh, M., Nocella, G., Idini, A., Carletti, A., & Frau, F. (2023). Fear appeals, individuals' cognitive-behavioral responses, and willingness to pay for safe water in fluoride-contaminated regions. *Science of The Total Environment*, 892, 164602.
- Herath, H. M. A. S., Kawakami, T., & Tafu, M. (2018). The extremely high adsorption capacity of fluoride by chicken bone char (CBC) in defluoridation of drinking water in relation to its finer particle size for better human health. *Healthcare*, 6(4), 143.
- Idini, A., Dore, E., Fancello, D., & Frau, F. (2019). Defluoridation of water through the transformation of octacalcium phosphate into fluorapatite. *Heliyon*, 5(8), e02288.
- Idini, A., Frau, F., Gutierrez, L., Dore, E., Nocella, G., & Ghiglieri, G. (2020). Application of octacalcium phosphate with an innovative household-scale defluoridator prototype and behavioral determinants of its adoption in rural communities of the East African Rift Valley. *Integrated Environmental Assessment and Management*, 16(6), 856–870.
- Jeihanipour, A., Shen, J., Abbt-Braun, G., Huber, S. A., Mkongo, G., & Schäfer, A. I. (2018). Seasonal variation of organic matter characteristics and fluoride concentration in the Maji ya Chai River (Tanzania): Impact on treatability by nanofiltration/reverse osmosis. *Science of The Total Environment*, 637–638, 1209–1220.
- Kaseva, M. E. (2006). Optimization of regenerated bone char for fluoride removal in drinking water: A case study in Tanzania. *Journal of Water and Health*, 4(1), 139-147.
- Komakech, H. C., Wanyama, J., Klunne, W. E., & Lugomela, G. V. (2019). White teeth and healthy skeletons for all: The path to universal fluoride-free drinking water in Tanzania. *Water*, 11(1), 131.
- Kumar, S., Patel, R., Singh, A., & Gupta, V. (2023). Smart monitoring systems for water treatment: IoT-enabled fluoride removal technologies. *Water Research*, 228, 119384.
- Lyimo, B., Lugomela, G. V., Komakech, H. C., & Kongo, V. M. (2023). Defeating fluorosis in the East African Rift Valley: Transforming the Kilimanjaro into a rainwater harvesting park. *Sustainability*, 15(8), 6789.
- Machunda, R. L., Mtalo, F. W., Mwakasangula, E., & Packialathan, P. (2020). Fluoride in groundwater as a consequence of geological setting and pollution in Babati area, northern Tanzania. *Environmental Earth Sciences*, 79, 1-15.
- Malago, J., Makoba, E., & Muzuka, A. N. N. (2017). Fluoride levels in surface and groundwater in Africa: A review. *American Journal of Water Science and Engineering*, 3(1), 1–17.
- Mjengera, H., & Mkongo, G. (2003). Appropriate defluoridation technology for use in fluorotic areas in Tanzania. *Physics and Chemistry of the Earth*, 28, 1097-1104.
- Nakaya, S., Ito, M., Natsuhara, K., & Taniguchi, M. (2023). Spatial uncertainties in fluoride levels and health risks in endemic fluorotic regions of northern Tanzania. *Groundwater for Sustainable Development*, 20, 100875.

- Nocella, G., Gutierrez, L., Idini, A., Carletti, A., & Ghiglieri, G. (2022). Insights to promote safe drinking water behavioral changes in zones affected by fluorosis in the Rift Valley. *Science of The Total Environment*, 827, 154242.
- Owusu-Agyeman, I., Jeihanipour, A., Luxbacher, T., & Schäfer, A. I. (2017). Implications of humic acid, inorganic carbon and speciation on fluoride retention mechanisms in nanofiltration and reverse osmosis. *Journal of Membrane Science*, 528, 82–94.
- Owusu-Agyeman, I., Reinwald, M., Jeihanipour, A., & Schäfer, A. I. (2019). Removal of fluoride and natural organic matter from natural tropical brackish waters by nanofiltration/reverse osmosis with varying water chemistry. *Chemosphere*, 217, 47–58.
- Richards, B. S., Shen, J., & Schäfer, A. I. (2021). Renewable energy-powered membrane technology in developing countries. *Nature Reviews Earth & Environment*, 2, 815–830.
- Shen, J., Richards, B. S., & Schäfer, A. I. (2016). Renewable energy powered membrane technology: Case study of St. Dorcas borehole in Tanzania demonstrating fluoride removal via nanofiltration/reverse osmosis. *Separation and Purification Technology*, 170, 445–452.
- Shen, J., & Schäfer, A. I. (2015). Factors affecting fluoride and natural organic matter (NOM) removal from natural waters in Tanzania by nanofiltration/reverse osmosis. *Science of The Total Environment*, 527–528, 520–529.
- Shen, J., Schäfer, A. I., & Richards, B. S. (2014). Removal of fluoride and uranium by nanofiltration and reverse osmosis: A review. *Chemosphere*, 117, 679–691.
- Singh, A., Kumar, S., Patel, R., & Gupta, V. (2023). IoT-enabled smart water treatment systems for fluoride removal in rural areas. *Journal of Environmental Management*, 342, 118123.
- Water.org. (2024). Safe water in Tanzania: Our mission. Retrieved from <https://water.org/our-impact/where-we-work/tanzania/>
- Zhang, Y., Li, M., Wang, H., & Chen, X. (2019). Hierarchical flower-like zinc-magnesium-aluminum ternary metal oxide microspheres for efficient fluoride removal. *Chemical Engineering Journal*, 375, 122089.