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Sandec Department of Sanitation, Water and Solid Waste for Development

Assessing climate resilience of water, sanitation and solid waste services in Ugandan small towns

Flooded handpump in Kakooge.

Climate change exacerbates vulnerabilities in water, sanitation, hygiene (WASH) and solid waste services, particularly in underserved small towns where interdependencies amplify risks and limit adaptive capacities. This research brief examines these aspects in two central Ugandan towns, namely Kakooge (Nakasongola district) and Wobulenzi (Luwero district), with a focus on the impacts of intensified rainfall, droughts, and flooding.

Using climate predictive modelling of rainfall patterns, spatial flood mapping, expert interviews, and field observations, along with existing data on service levels of water, sanitation and solid waste, the study uncovers specific challenges. Kakooge faces potential challenges from physical damage from both droughts and floods, with low adaptive capacity exhibited from current practices, which include reliance on maladaptive practices like pit abandonment. Wobulenzi has slightly more advanced technical adaptations for flooding through raised latrines, active dumpsite management, but faces increased groundwater contamination, currently being addressed through lined pits. Systemic interlinkages—such as waste blocking drains leading to water contamination and sanitation overflows—compound risks. A drought-flood paradox that exists in these towns reveals communities prioritising drought measures despite equal risks due to floods.

These findings highlight the need for integrated, context-specific strategies to build climate resilience in the water, sanitation and solid waste sectors. Key recommendations include: investing in low-cost adaptable infrastructure (e.g., flood-resilient sanitation in Kakooge); integrating WASH and solid waste planning across sectors to address identified interdependencies; strengthening early warning systems; and aligning external support with local capacities to close adaptation gaps. Implementing these can safeguard services, reduce health risks, and enhance equity in climate-vulnerable communities.

eawag aquatic research

Introduction

Climate change is shifting Uganda's rainfall patterns, increasing variability and raising risk of both droughts and floods. These changes threaten essential services, including water, sanitation, hygiene (WASH) and solid waste, particularly in small towns where infrastructure and institutional capacity are constrained. This research, conducted under Eawag's WABES (Water, Behavior Change and Environmental Sanitation) project, in collaboration with Makerere University, provides evidence to guide climate-resilient investments in Uganda's rapidly growing small towns.

Given that WASH and solid waste services are deeply interconnected, climate-related stress on water supply, sanitation, or solid waste services can quickly cascade into health crises, social disruptions, and economic losses (Narayan & Boller, 2023). For example, accumulated mismanaged waste can block drainage channels, worsen flooding and contaminate water sources. Inadequate sanitation contaminates groundwater, which communities rely on during dry spells (Howard et al., 2016).

Despite these risks, planning and investment often remain sectoral, with water, sanitation, and waste managed separately. This siloed approach misses critical interdependencies and can lead to maladaptive outcomes—for example, installing a new borehole without accounting for nearby pit latrines that may contaminate it during floods.

Key Vulnerabilities from Literature

A review of recent studies highlights common climate vulnerabilities across WASH and solid waste services. The following points are important to keep in mind for floods and droughts when planning local site visits and data collection (**Table 1**).

Table 1: Vulnerabilities of water supply, sanitation, and solid waste management systems to floods and droughts identified through the literature review.

Sector	Floods	Droughts
Water Supply	• Surface water intakes get clogged with debris; treatment plants are overwhelmed (Barbetta et al., 2022). • Groundwater sources (wells, boreholes) are contaminated by floodwater carrying sewage and chemicals (Pieper et al., 2021). • Rainwater tanks are submerged, leading to backflow and contamination (Barbetta et al., 2022).	• Surface water levels drop, reducing supply and concentrating pollutants (S. Zhang et al., 2025; X. Zhang et al., 2013). • Groundwater tables fall, causing wells to run dry (Brakenhoff et al., 2022). • Rainwater tanks empty, forcing reliance on unsafe alternatives (Becher et al., 2024).
Sanitation	• Pit latrines overflow, contaminating surroundings and groundwater (Tillett, 2013). • Sewer systems are inundated, causing backflows and treatment failures (Hyde-Smith et al., 2022).	• Pits dry out, making emptying difficult and reducing functionality (Hyde-Smith et al., 2022). • Low wastewater flows concentrate pollutants, challenging treatment (Kando, 2020).
Solid Waste Management	• Waste blocks drains, worsening flooding (Alimuddin et al., 2025). • Collection routes are impassable, and dumpsites are flooded, spreading contamination (Abubakar et al., 2022).	• Dry waste increases fire risk at dumpsites (Chavan et al., 2022). • Heat stress reduces collection efficiency; waste accumulates (Dias et al., 2023)

Methodology: Accessing Resilience

A mixed-methods approach was used, combining:

- **Climate modelling:** Projected rainfall for 2025–2050 using climate models.
- **Flood vulnerability mapping**: Identified flood-prone areas by applying projected rainfall to digital elevation maps.
- **Expert interviews**: Conducted with 14 stakeholders (town engineers, health officers, operators, community representatives) to understand vulnerabilities and adaptive practices.
- **Observations**: Visited 15+ sites in each town to verify interview findings and document infrastructure conditions.

This approach ensured findings were grounded in both scientific data and local experience.

Figure 1: Map of the two locations in Uganda (*Source : Adapted from NordNordWest/*

Modelling and Mapping Findings

1. Rainfall projections for both towns indicate significant climate shifts by 2050.

Climate modelling focused on precipitation projected more intense rainfalls with wetter October-November seasons and drier July-August seasons. This indicates strong variability and more intensity.

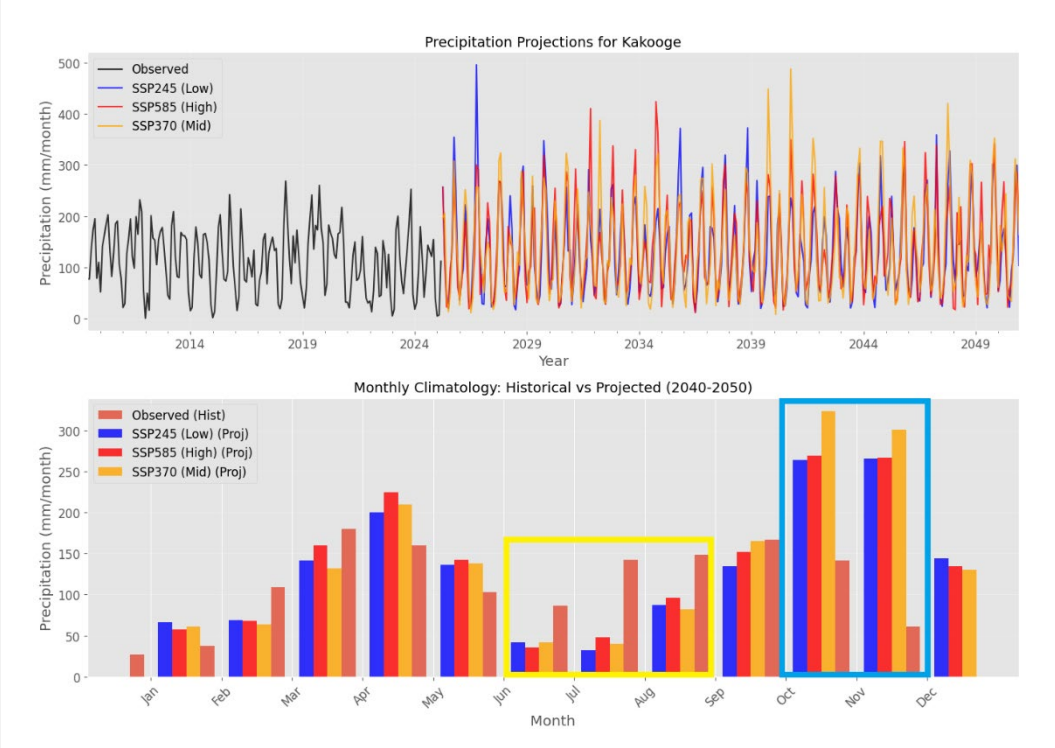


Figure 2: Rainfall Projections for Kakooge

The upper panel shows monthly rainfall from 2009-2050 under different climate scenarios; the lower panel compares historical vs. projected seasonal patterns. Highlighted areas show the variability in rainfall mentioned beforehand.

A similar pattern was found in Wobulenzi.

2. Terrain impacts flood vulnerability with low-lying areas particularly vulnerable.

Flood vulnerability maps translate these rainfall projections into spatial risk. These maps provide essential spatial guidance for prioritising infrastructure protection and adaptation investments

- In **Kakooge** (flat, wetland areas): Flooding concentrates around buildings and in low-lying areas. The town's topography creates standing water that poses direct risks to WASH infrastructure.
- In **Wobulenzi** (hilly terrain): Faster runoff reduces standing water but increases erosion and contamination pathways. Flood risk is more dispersed along drainage channels.

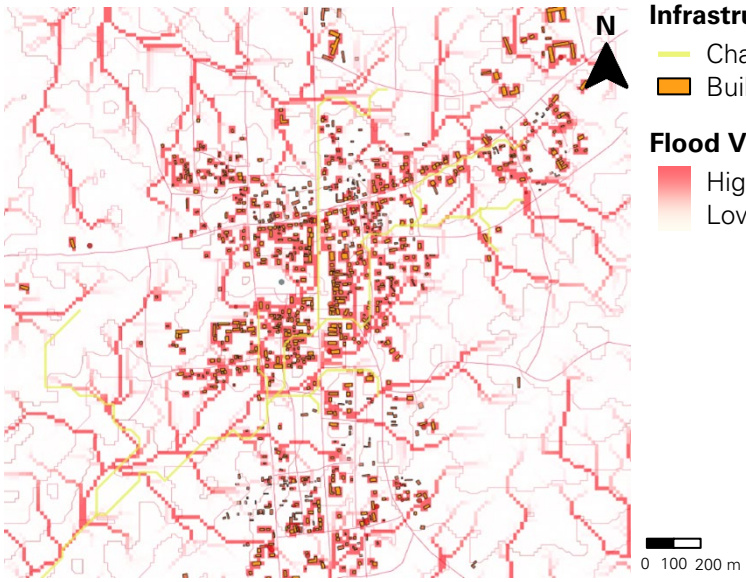


Figure 3: Flood Vulnerability Map for Kakooge *Shows areas at the highest flood risk when 129 mm/day rainfall is applied. Darker red areas indicate higher vulnerability. In yellow, you can see the water channels identified in Kakooge, and in orange, the buildings added to the digital elevation model. Vulnerability is mostly around the buildings and in between them because they act as barriers, and there is an accumulation of water seen by the model. Topography is the main driver in this method.*

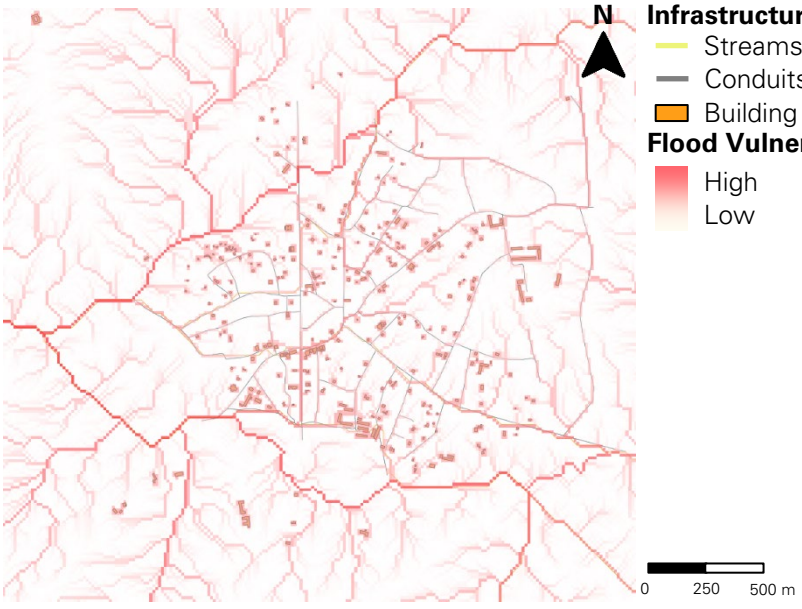


Figure 4: Flood Vulnerability Map for Wobulenzi *Shows flood risk under 157.6 mm/day rainfall. Hilly terrain creates different vulnerability patterns compared to Kakooge. Again, streams and conduits are added to the map, as well as buildings in orange. Vulnerability is shown as a spectrum from white to red. As in Kakooge, there is an accumulation of water around the buildings, but there is overall less vulnerability in Wobulenzi because of the hilly terrain. They experience more flash floods due to the topography.*

Triangulated Insights

Bringing together the interviews and observations, the analysis compared climate-related vulnerabilities and adaptive capacities of water supply, sanitation, and solid waste management systems in Kakooge and Wobulenzi.

Kakooge faces more acute, physically driven disruptions with mainly reactive responses, while Wobulenzi experiences chronic contamination challenges but shows more proactive and technological adaptation strategies.

Water Supply

Town	Main Vulnerabilities	Observed Adaptations
Kakooge	• Boreholes inundated during floods • Wells run dry during droughts	• Digging drainage channels around boreholes • Switching to alternative (often unsafe) sources
Wobulenzi	• Springs contaminated by runoff • Reduced piped water yield during droughts	• Protecting springs with structures • Using deep boreholes (70m) for piped water to avoid flood contamination

This trio of images illustrates contrasting water supply infrastructures and their exposure to flooding in Kakooge and Wobulenzi.

The first image, taken in Kakooge, shows a borehole that becomes inundated during every flooding event; a drainage channel has been constructed in front of the borehole as an adaptive measure to divert water discharged during the pumping to avoid stagnant water, although the source remains highly vulnerable.

The second image, from Wobulenzi, depicts an unprotected water source that is regularly contaminated during flooding events due to direct exposure to runoff and sediment.

The third image shows a 70 m deep borehole in Wobulenzi supplying the town's piped water system, which is effectively protected from flooding, illustrating how depth and appropriate infrastructure design can significantly enhance the resilience of water supply systems to flood events

Sanitation

Town	Main Vulnerabilities	Observed Adaptations
Kakooge	• Pit latrines flood and overflow • Heavy reliance on pit abandonment (maladaptive)	• Trenches dug around latrines • Relocating latrines away from flood-prone areas
Wobulenzi	• Groundwater contamination from pit latrines • High water table causes rapid filling	• Lined pits to reduce leakage • Raised latrine slabs • Mechanised emptying services

This trio of photos presents examples of sanitation infrastructure adaptations to flooding in Wobulenzi and Kakooge.

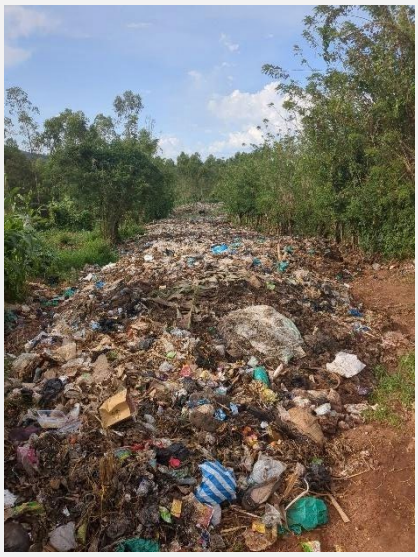
The first two images, taken in Wobulenzi, show raised pit latrines designed to reduce the risk of overflow during flood events by elevating the superstructure above the surrounding ground level. Despite this adaptation, these facilities remain exposed in areas with high water tables.

The third image, from Kakooge, shows a pit latrine with a drainage channel constructed alongside it to limit flood-related damage by diverting surface runoff, highlighting a more reactive, site-specific measure to cope with recurring flood impacts.

Solid Waste

Town	Main Vulnerabilities	Observed Adaptations
Kakooge	• The dumpsite in the wetland becomes inaccessible during rain. • The collection is also limited due to flooded roads. • Waste blocks drainage channels	• Limited adaptive practices observed. • Some community sensitisation against dumping in drains. Drainage rakes installed.
Wobulenzi	• Waste washes into drains, worsening floods • Slippery access roads disrupt collection	• Active dumpsite management with bulldozers • Informal recycling sector adapts during droughts

These images illustrate solid waste management practices in Wobulenzi. The first image shows the municipal dumpsite, which is located in a flood-prone area and is directly affected during heavy rainfall events, increasing the risk of waste being washed into drainage channels and nearby water sources.



Critical Interlinkages Between Services

Failures cascade across systems: Climate-related stresses do not affect water supply, sanitation, and solid waste management in isolation. Instead, disruptions in one service often propagate to others, creating compounding impacts on infrastructure, service delivery, and public health.

These interdependencies mean that a failure in one sector can rapidly trigger or exacerbate failures in others, particularly during floods or prolonged droughts. They suggest that isolated, sector-specific interventions are likely to fail (Narayan et al., 2021).

- **Solid Waste** → **Water**/**Sanitation**: Blocked drains worsen flooding, contaminating water sources and overflowing latrines.
- **Sanitation** → **Water** : Pit latrines contaminate groundwater, affecting wells used during droughts.
- **Water** → **Sanitation** : Water scarcity reduces functionality of flush toilets and handwashing.
- **Flooding** → **All services**: In Kakooge, intense floods simultaneously disrupt boreholes, latrines, and solid waste collection.

Key Conclusions

This study shows that climate vulnerability in small towns is strongly shaped by local physical conditions, infrastructure design, and governance capacity. Kakooge and Wobulenzi face distinct climate risks and therefore require differentiated adaptation strategies.

Kakooge is exposed to acute impacts from both floods and droughts, leading to repeated and simultaneous failures of water, sanitation, and solid waste services. Flooded boreholes, overflowing pit latrines, and an inundated dump site highlight the need for foundational infrastructure to protect basic services and reduce recurring damage, for example, deep boreholes and an piped system, raised and lined pit latrines and planned dumpsite management (Akandi et al., 2022; Mwangi et al., 2016).

Wobulenzi faces chronic contamination and system inefficiencies, particularly groundwater pollution from sanitation facilities and intermittent water supply during droughts. While vulnerabilities persist, the town demonstrates higher adaptive capacity through deeper boreholes, lined pit latrines, and mechanised waste management. (Masindi & Foteinis, 2021).

Across both towns, the findings confirm that WASH and solid waste services are highly interdependent. Failures in one sector routinely exacerbate risks in others, underscoring the need for integrated, system-wide adaptation rather than sector-specific interventions.

Recommendations

National Interventions

- **Prioritise foundational infrastructure in high-risk towns** such as Kakooge, including flood-protected boreholes, lined sanitation facilities, permanent drainage systems, and relocation of waste disposal sites away from flood-prone areas.
- **Tailor financing and technical support** to local vulnerability profiles, distinguishing between towns needing basic service protection and those requiring system optimisation.
- **Promote nature-based solutions** such as wetland protection, catchment restoration, and natural drainage retention to reduce flood risks and protect water sources.
- **Mainstream climate resilience** into national WASH and solid waste implementation policies, while building on the existing WASH National Adaptation Plan for Uganda.

Town Councils

- **Use vulnerability maps based on climate and hydrological data to guide infrastructure planning**, protection, and future urban development.
- **Integrate climate risk assessments** into the planning and budgeting of WASH and solid waste infrastructure
- **Elevate or flood-proof critical infrastructure**, such as pit latrines and boreholes.
- **Introduce simple preventive maintenance schedules** for critical infrastructure before rainy seasons, such as drain clearance or installing and maintaining waste traps/screens
- **Address the drought–flood paradox** through planning and community awareness, recognising that both hazards affect the same systems differently (Weber, 2006).
- **Engage informal actors**, such as waste pickers and water vendors, as part of climate adaptation and service delivery strategies.
- **Improve solid waste collection reliability** by strengthening infrastructure (drainage improvements, targeted road upgrades) and operations in flood-prone areas.
- **Upgrade, compact, and stabilise waste disposal sites** to reduce waste displacement and runoff during floods.
- **Fund locally tailored behaviour change campaigns** to encourage correct disposal and discourage dumping **for Future Projects**
- **Apply the integrated assessment framework** used in this study (climate modelling, interviews, observations) to diagnose risks in other small towns.
- **Support a shift from reactive coping to sustainable adaptation**, reducing reliance on maladaptive practices such as pit abandonment.

Way Forward

Building climate-resilient WASH and solid waste systems in Uganda's small towns is both important and achievable. This research provides a practical framework for diagnosing the vulnerabilities and adaptive capacities of small towns towards floods and droughts, and a set of contextualised recommendations that build on existing systems. By investing in integrated, locally tailored solutions, while recognising the interconnected nature of water, sanitation, and solid waste services, policymakers and practitioners can safeguard basic services for growing urban populations in a changing climate.

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WABES integrate

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References

Abubakar et al. (2022). Environmental Sustainability Impacts of Solid Waste Management Practices in the Global South. International Journal of Environmental Research and Public Health, 19(19), 12717. https://doi.org/10.3390/ijerph191912717

Akandi et al. (2022). Modeling the impact of past and future land cover changes on a reservoir catchment hydrology in Semi-arid, Africa. https://doi.org/10.21203/rs.3.rs-1505575/v1

Alimuddin et al. (2025). Flood Mitigation through Waste Management in Rimuku, Mamuju, Indonesia. Engineering, Technology & Applied Science Research, 15(5), 26697-26702. https://doi.org/10.48084/etasr.11987

Barbetta et al. (2022). Assessment of Flooding Impact on Water Supply Systems : A Comprehensive Approach Based on DSS. Water Resources Management, 36(14), 5443-5459. https://doi.org/10.1007/s11269-022-03306-x

Becher et al. (2024). The challenge of closing the climate adaptation gap for water supply utilities. Communications Earth & Environment, 5(1),356. https://doi.org/10.1038/s43247-024-01272-3

Brakenhoff et al. (2022). Application of Time Series Analysis to Estimate Drawdown From Multiple Well Fields. Frontiers in Earth Science, 10. https://doi.org/10.3389/feart.2022.907609

Chavan et al. (2022). Estimation of spontaneous waste ignition time for prevention and control of landfill fire. Waste Management, 139, 258-268. https://doi.org/10.1016/j.wasman.2021.11.044

Dias et al. (2023). Climate-Change Impacts and Adaptation Strategies : Waste Pickers' Experiences from Brazil. WIEGO Policy Brief No. 29, WIEGO

Howard et al. (2016). Climate Change and Water and Sanitation : Likely Impacts and Emerging Trends for Action. Annual Review of Environment and Resources, 41(1). https://doi.org/10.1146/annurev-environ-110615-085856

Kando. (2020). What effects do droughts have on Wastewater Treatment Plants?

Hyde-Smith et al. (2022). Climate Change Impacts on Urban Sanitation : A Systematic Review and Failure Mode Analysis. Environmental Science & Technology, 56(9), 5306-5321. https://doi.org/10.1021/acs.est.1c07424

Pieper et al. (2021). Microbial Contamination of Drinking Water Supplied by Private Wells after Hurricane Harvey. Environmental Science & Technology. 55 (12), 8382-8392 https://pubs.acs.org/doi/10.1021/acs.est.0c07869

Masindi & Foteinis (2021). Groundwater contamination in sub-Saharan Africa : Implications for groundwater protection in developing countries. Cleaner Engineering and Technology, 2, 100038. https://doi.org/10.1016/j.clet.2020.100038

Mwangi et al. (2016). Relative contribution of land use change and climate variability on discharge of upper Mara River, Kenya. Journal of Hydrology: Regional Studies, 5, 244-260. https://doi.org/10.1016/j.ejrh.2015.12.059

Narayan & Boller. (2023). To integrate or not to integrate? Water and waste as unified basic services. PLOS Water, 2(9), e0000180. https://doi.org/10.1371/journal.pwat.0000180

Narayan et al. (2021). Advancements in and Integration of Water, Sanitation, and Solid Waste for Low- and Middle-Income Countries. Annual Review of Environment and Resources, 46(2021), 193-219. https://doi.org/10.1146/annurev-environ-030620-042304

Tillett, T. (2013). Pit Latrines and Groundwater Contamination : Negative Impacts of a Popular Sanitation Method. Environmental Health Perspectives, 121(5), a169-a169. https://doi.org/10.1289/ehp.121-a169

Weber, E. U. (2006). Experience-Based and Description-Based Perceptions of Long-Term Risk : Why Global Warming does not Scare us (Yet). Climatic Change, 77(1), 103-120. https://doi.org/10.1007/s10584-006-9060-3

Zhang et al. (2025). Climate change promotes harmful algal blooms in China's lakes and reservoirs despite significant nutrient control efforts. Water Research, 277, 123307. https://doi.org/10.1016/j.watres.2025.123307

Zhang et al. (2013). Formation of disinfection by-products : Effect of temperature and kinetic modeling. Chemosphere, 90(2), 634-639. https://doi.org/10.1016/j.chemosphere.2012.08.060