How do environmental factors and hazards affect the vulnerability, reliability and resilience of small-water supply infrastructure?

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The provision of safe and affordable drinking water for all by 2030 requires robust infrastructure. Small drinking-water supplies are used by millions of people and are the foundation of rural water supply. Currently, about half a billion people in Sub Saharan Africa (SSA) rely on protected and unprotected groundwater point sources for their main drinking water supplies. With the expected increases in rainfall variability due to climate change, sustainable groundwater sources will become more important in supporting resilience in the future[1]. Groundwater provides a natural buffer to climate change and natural hazards (e.g. floods and droughts) ensuring water-supply resilience[2]. However, 1:4 handpumps, which remain one of the most important technologies for accessing groundwater, are non-functional at any time across SSA, partly due to component failure or poor-quality materials. This project will investigate the reliability and resilience of infrastructure materials and components used in handpumps and other groundwater systems under normal use and during single and multi-hazard events (focusing on floods and droughts) and will formulate the changing failure mechanism under changing climate. This project makes progress towards SDG 6 and SDG 3. The objectives will be:

Objective 1: To examine existing datasets, and new qualitative data from stakeholder interviews to identify the impacts of hazards (primarily, but not exclusively, droughts and floods as well as anthropogenic hazards such as overuse) on functionality of groundwater systems. A risk classification framework will be developed and used to select field-sites for assessment of infrastructure conditions, hydrogeochemical and hydrogeological properties, and the influence of all three on infrastructure resilience and functionality. The risk framework, interview outcomes, regression analysis and/or systems thinking will be used to investigate how each factor influences infrastructure condition.

Objective 2: To formulate and quantify reliability and resilience of small water supply infrastructure through a wide range of laboratory testing of new and deteriorated infrastructure materials from field-sites and manufacturers under different mechanical load and environmental conditions. The experimental measurements will inform constitutive defect and degradation models to estimate structural performance and residual structural capacity of assets, accounting for material properties, geometry, asset-soil/water interaction, quality of manufacturing and installation, influence of internal/external loads, and material deterioration due to climatic and hazard-specific effects.

Objective 3: Developing a system-of-systems-based intervention framework that incorporates experimentally-validated constitutive models (from objective 2) and key stakeholders and end-user's input in identifying pathways that effectively improve infrastructure resilience under changing hazard profiles.

The candidate may build fragility models based on detailed modelling i.e. generate unique questionnaires to build new restoration models and lead communications of risk/ resilience and exchange information with local owners/stakeholders. Incorporating climate change scenarios will provide an opportunity to explore future challenges to drinking-water infrastructure and links with UN SDGs. We anticipate that the research will be publishable in high impact journals as well as feed into ongoing initiatives like the Uptime consortium (https://www.uptimewater.org/) and through global knowledge networks. This PhD offers the opportunity to undertake novel, interdisciplinary research with real-world impact.

Photo courtesy of R. Allan

Training opportunities:
The candidate will be based at University of Surrey but the project will offer training and opportunities for placements at both the University of Surrey, Guildford, UK and British Geological Survey (BGS) in Edinburgh, UK.

The project will include a fieldwork opportunity in Uganda. In-kind assistance and hands on experience in field and analytical methods needed to undertake the research will be provided by Surrey University and BGS.

In the first year, the student will be trained as a part of a single cohort on research methods and core skills at the University of Surrey. Throughout the PhD, the student will be offered the opportunity to attend MSc and undergraduate modules from the University of Surrey to extend their knowledge on skills related to structural mechanics and finite elements, infrastructure systems, interdependencies and resilience, environmental engineering and hydrology, numerical methods and computational fluid dynamics, global challenges facing drinking water supplies and their users, and hydraulic modelling. Specific training in lab methods for material assessment will be given by Surrey University. The student will also be included in all Departmental/group research seminars and talks relevant to their field.

In the early stages of the PhD the student will have the opportunity to spend time at BGS planning in-country data collection. Where practical BGS will provide access to existing and surplus field equipment for key field activities, for example, water quality equipment and equipment for assessing the condition of water supply infrastructure. BGS will also provide training to undertake fieldwork, including adapting existing in-situ methods for functionality and resilience assessments of water supply infrastructure and groundwater resource assessments.

Later in the PhD the student will again have an opportunity to spend time at BGS and will be supported to develop analysis and interpretations of field data. BGS will help the student integrate groundwater resource data and data on water infrastructure functionality and resilience into the resilience assessment framework.

Student profile:
This PhD will suit a candidate with a background in civil and environmental engineering, hydrology or hydrogeology and an interest in improving the livelihoods of small water supply users in low income countries. The successful candidate will need:

- A willingness to undertake field work as well as laboratory work
- An ability to understand and develop software for data analysis and mapping techniques.
- An organised approach to work with strong problem-solving skills.
- Interest and enthusiasm for understanding a real-time environmental problem.
- Good oral and written communication skills and in particular the ability to work with multi-disciplinary teams.

References: (optional)

1. https://dx.doi.org/10.3390/resources9100120
2. https://dx.doi.org/10.3390/resources9120142
3. https://link.springer.com/article/10.1007/s10040-022-02534-0
4. https://www.nature.com/articles/s41467-020-14839-3

https://research.reading.ac.uk/scenario/