Journal of
Water, Sanitation & Hygiene for Development

IWA PUBLISHING

 Journal of Water, Sanitation and Hygiene for Development Vol 00 No 0, 1 doi: 10.2166/washdev.2023.233

Research Paper

Understanding small NGOs' access to and use of geological data and expertise in delivering SDG 6 in eastern Africa

Brenda Wagaba[a], Caner Sayan[a,b], Hannah Haemmerli[c], Joel Gill[c,d] and Alison Parker[a,*]

[a] Cranfield University, Cranfield MK43 0AL, UK
[b] Department of Politics, Philosophy and International Relations, Swansea University, UK
[c] Geology for Global Development, UK
[d] School of Earth and Environmental Sciences, Cardiff University, UK
*Corresponding author. E-mail: a.parker@cranfield.ac.uk

AP, 0000-0001-7370-6758

ABSTRACT

Groundwater resources have the potential to meet the water demands of vulnerable communities in eastern Africa. To ensure such groundwater resources are managed sustainably, robust geological knowledge must be available and utilised by those managing groundwater. Small NGOs are one type of practitioner working on water-related projects with remote and vulnerable communities. This study aimed to understand the access to and use of geological data and expertise by small NGOs involved in water-related projects, through an online survey and key-informant interviews. The study revealed that small NGOS want to use geological data but bureaucracy makes it difficult to access free, existing government geological data sources, and that datasets are not always stored appropriately. Funding constraints hinder the ability of small NGOs to access quality geological data from other sources and to hire appropriate expertise. Donors' lack of understanding of the value of geological data affects the ability of small NGOs' to budget for and include the time needed to collect or access geological data. There is a need to recognise these barriers to the usability and accessibility of geological data and expertise by key actors working on water challenges, such as small NGOs, and take steps to address them.

Key words: eastern Africa, geological data, groundwater, hydrogeology, knowledge, NGOs

HIGHLIGHTS

- Small NGOs obtain geological data from the government and online sources, though access is affected by bureaucratic systems.
- There are geological experts available, and these are not adequately budgeted for hire by small NGOs so projects are planned without relevant expertise .
- Donors do not provide adequate resources for small NGOs to use geological data and expertise.

INTRODUCTION

Groundwater use can be a sustainable way of improving access to clean water for vulnerable and poor communities in rural Africa (MacDonald & Calow 2009). Population growth, increasing food insecurity, and climate change impacts make the importance of groundwater resources and their careful management critical to the delivery of the 2030 Agenda for Sustainable Development, as highlighted during World Water Day in 2022 (United Nations 2022).

Using groundwater resources to help achieve the ambitions of sustainable development goal (SDG) 6 – clean water and sanitation for all – will require geological data and expertise (Upton & MacDonald 2021). Geologists (sometimes referred to as Earth scientists or geoscientists) understand Earth and environmental processes and how these might affect groundwater availability and quality (Lubchenco *et al.* 2015; Gill 2017; Omisore 2018; Upton & MacDonald 2021). Without effective monitoring and management, there is the potential for the abstraction of more water than is sustainable (Foster *et al.* 2008; MacDonald & Calow 2009) or contamination either through human activities including farming (Lapworth

et al. 2017) and poor sanitation (Gabrielsson *et al.* 2020) or from geogenic sources (Kut *et al.* 2016). Poor understanding of hydrogeological conditions before drilling can result in boreholes failing quickly (Pavelic *et al.* 2012).

Such geological knowledge – though critical to effective water resource management – is not always understood, accessible, or used (Robbins *et al.* 2006; Liu *et al.* 2008; Howard & Bartram 2010) by other stakeholders. Organisations such as the British Geological Survey (BGS), International Water Management Institute (IWMI), Groundwater Relief, and UNESCO have programmes to increase access to and use of free geological data and expertise for the sustainable development of water resources in Africa (UNESCO 2009; Martínez-Frías & Mogessie 2012; BGS 2017). These initiatives, while important, do not yet have full coverage across the continent and are typically not at the scale required for local-level decision making. The lack of access to data is exacerbated by weaknesses in data collection and management. For example, boreholes are drilled with no central records of the underlying geology encountered during drilling being kept (Chakava *et al.* 2014), meaning that repeated exploratory drilling needs to take place (Macdonald & Davies 2000).

While evidence suggests that practitioners are unable to access good quality geological (including groundwater) data and expertise (Acreman 2005), the extent of and reasons for this challenge are largely unknown. Nussbaumer *et al.* (2016) examined groundwater management by water service providers in the peri-urban areas of Lusaka, Zambia and showed that there were limitations in the use of existing hydrogeological information due to a lack of capacity to interpret monitoring data. Robbins *et al.* (2006) reported that periods of past decentralisation and fragmentation of groundwater monitoring and management in southern and eastern Africa also led to challenges in developing, archiving, and using hydrogeologic data for groundwater management. Water practitioners can vary significantly, and this paper focuses on the use of geological data, and barriers preventing access and use, by small NGOs. Small NGOs can be dynamic actors in delivering clean water and sanitation services to the poorest sectors of society and have the potential to be cost-effective and efficient (Lewis 2015). Small NGOs can have strong grassroots links and the potential to innovate and adapt quickly, reaching areas less accessible by governments (James 2013). Technologies for assessment and exploration of groundwater resources are both relatively expensive and require specific expertise to produce satisfactory projections of groundwater availability which may be beyond the capacity of small NGOs (Pavelic *et al.* 2012).

In this context, the aim of this study is to understand whether small NGOs in eastern Africa have access to and use geological information and expertise to deliver clean water and sanitation services. Identifying barriers preventing access to and use of geological information and expertise can inform the design of actions and the revision of processes and systems to improve access and use and support realisation of the ambitions of SDG 6.

METHODS

A mixed-methods approach that entailed both an online survey and key-informant interviews to collect and analyse qualitative and quantitative data in a single study was used (Creswell & Clark 2017). This methodology provided insights into the access to and use of geological data and expertise by small NGOs in eastern Africa where literature and scientific evidence were limited (Schwartz *et al.* 2001; Cossham & Johanson 2019).

Both the survey and interviews targeted practitioners that had participated in the delivery of clean water and sanitation services in eastern Africa while working within or in partnership with small NGOs. Eastern Africa was loosely defined to entail the majority of the countries that are geographically located in the east of Africa including Uganda, Kenya, Tanzania, South Sudan, Ethiopia, Burundi, Rwanda, Mozambique, Madagascar, Zambia, Zimbabwe, Eritrea, and Malawi. Similarly, it was difficult to define 'small NGO' by any internationally recognised manner, so this was left to respondents to interpret in their own context to maximise the possible number of respondents.

The interview guide and online survey questions were developed to obtain information to help answer the following questions:

- What types of geological data do small NGOs use to inform their decision making, in the context of water and sanitation programmes?
- How and where do small NGOs access these geological data?
- How do small NGOs use geological data in their water and sanitation programmes?
- What support do small NGOs receive from geologists in academia, governmental institutions, the private sector, and other NGOs?
- Does success and sustainability of implemented programmes correlate with the use of geological data and expertise?

- What actions (and by whom) could improve this science-to-practice interface?

The online survey was made available on the Qualtrics platform (Mc Elhinney *et al.* 2016) from June to mid-July 2021. The link to the survey was shared via social media groups such as the Community of Women in Water, Rural Water Supply Network (in particular its Sustainable Groundwater group), alumni groups of Cranfield University, and on platforms such as LinkedIn. As a result, 44 respondents completed the online survey. We anonymised survey participants by numbering them as 'Respondent #' when presenting their responses in later sections.

The in-depth, semi-structured interviews were carried out via Microsoft Teams concurrently with the online survey, from June to July 2021. Convenience sampling was done through the voluntary recruitment of participants who attempted the online survey. Snowball sampling was also adopted when participants referred colleagues in similar fields. As a result, 16 semi-structured interviews were conducted with key informants, including geologists, WASH practitioners, and academics working with or in small NGOs in eastern Africa contributing to the provision of clean water services.

Results indicate that survey respondents and key informants had all used or attempted to use geologic data while carrying out water projects. A bias of the sampling strategy was that people working in small NGOs that had not used geological data either did not attempt the survey or dropped out halfway through. Their participation would have helped to understand why geologic data are not used and the challenges faced by their small NGOs in terms of access to and use of geological data and expertise. Overall, it was difficult to assist the respondents via the online survey that was advertised via various social media platforms as it was left to their judgement on whether they had relevant experiences to share. Only fully completed surveys were included in our analysis as they resulted in the extraction of meaningful information since the questions were linked in terms of flow and obtaining tangible results. Respondents from Uganda were overrepresented as the link was shared across the principal author's social media platform with most contacts being from Uganda.

All recorded interviews were transcribed and then underwent conventional content analysis as a flexible method of analysing text data (Cavanagh 1997). The conventional content analysis allowed categories to emerge from the data (Hsieh & Shannon 2005). This was done by reading all the data repeatedly to obtain a sense of the content (Tesch 1990). Then data were scanned to extract codes by highlighting text that appeared to capture key concepts. Similar codes were then grouped under themes and subheadings (Hsieh & Shannon 2005). These themes were then used to inform the results (Greter *et al.* 2021).

Participants' consent was sought prior to surveys (via the completion of a form prior to beginning the survey) and interviews (via email before the interview took place). All respondents were informed of the study's rationale and that their involvement was voluntary. The study was reviewed and approved by Cranfield University Ethics (CURES) system (CURES/13856/2021) to ensure that the research met appropriate ethical principles and standards. All information was used for its intended and agreed purpose, with processes in place to ensure contributions could not be traced back to an individual.

RESULTS

Description of survey respondents and interviewees

There were 16 KIIs and 44 online survey respondents which should give a broad impression from small NGOs. All 16 KI interviewees and 39 out of 44 online survey respondents worked on projects that aimed at delivering clean water, sanitation, and hygiene in eastern Africa while collaborating with or working for a small NGO. Seven of 16 interviewees had a geological background and 7 of 16 were WASH experts (this included 1 person who sat in both groups, that is with both a geological background and who identified as a WASH expert). Of the 39 online survey respondents that carried out projects across eastern Africa more than half ($n = 23$) of the respondents contributed to projects carried out in Uganda. Of the 16 interviewees, the majority ($n = 11$) had carried out projects in Uganda, with other countries of focus including Kenya ($n = 6$), Tanzania ($n = 3$), and also South Sudan, Ethiopia, Burundi, Rwanda, Mozambique, Madagascar, Zambia, Zimbabwe, Eritrea, and Malawi. Some survey respondents and interviewees had worked in multiple countries. A total of 21 out of the 39 survey respondents working on water projects, and all of the interviewees, worked in a rural setting. The average size of the NGOs that implemented these water projects ranged from 10 to 20 employees. Twenty-nine of the 39 respondents used geological data and/or expertise in WASH projects, and all of the interviewees were either geological experts or had used geological data in WASH projects.

Data types, sources, handling, and management

A total of 25 out of 39 survey respondents and 12 out of 16 interviewees stated that small NGOs in eastern Africa had access to several geological data sources. The geological data sources most frequently mentioned by the respondents and interviewees included national government institutions, particularly water resources departments in respective countries, and open online sources that used tools such as GIS (Esri 2022), and the Groundwater Atlas (BGS 2020).

All respondents and interviewees pointed out that these sources could provide relevant geological data supporting water and sanitation-related activities such as hydrogeology data, geophysical assessments, borehole records, pumping test data, groundwater monitoring records, water quality and quantity data, remote sensing data, and geological maps. Such data were used for groundwater management, conservation of water resources, construction of sand dams, and catchment protection. Moreover, interviewees 7 and 11 highlighted the role of geological data sources and tools for sanitation projects, such as creating open defaecation maps and the siting of septic systems:

> *'…. if you're putting in a septic system …., you need to know the general groundwater flow direction so a hydrogeologist would be able to produce that…. how easy or how hard if you poured water on the ground, would it dissipate and or flow from there and so that is arguably hydrogeologic information.'* **Interviewee 7**

> *'So there, they wanted us to go and map different things for example villages* [in Uganda] *that had attained ODF* [Open Defecation Free] *status verses villages that had been triggered. So, GIS [tool] helps us to bring out this spatial relationship in assessing achievements.'* **Interviewee 11**

A total of 29 out of 39 respondents used geological data and/or expertise in WASH projects. Twenty respondents mentioned facing challenges while trying to access and use geological data for projects including nine who said that access to data was impossible or limited. According to respondent 12 and interviewee 4, the geographical setting influenced how much data were accessible to small NGOs in eastern Africa:

> *' …it depends on the country and for many of the fragile states in which we work* [South Sudan] *there is really surprisingly very little data and it might be because they are geographically limited.'* **Interviewee 4**

> *'Detailed maps of aquifers in African setting are difficult to access, and if present do not have very detailed scale, especially for shallower aquifers.'* **Respondent 12**

Respondents and interviewees also raised issues about the geological data quality, particularly of data released by governments and free online sources for the use of small NGOs. Four respondents and four interviewees called these data 'incomplete', 'unreliable', and 'outdated'. Interviewee 3, for example, explained that the available data within certain countries was not only outdated but covering only a small area. So even when small NGOs accessed the data, they had to supplement it with their own fieldwork:

> *'We had to search for over two days to get the actual map that was made maybe in 1986 and had not been updated until now.'* **Interviewee 3**

Interviewee 3 also pointed out the poor storage conditions of datasets at government level citing an example of the data records in a few districts in Uganda that were still in paper form and had been eaten by rodents:

> *'In a scenario where these small organisations find this data at the district…., and they look through his* [district water engineer] *dusty box files trying to find if this data actually exists, and if it exists, maybe a section of it is already eaten by rats, or some information is already covered by mould because of the cold and the moist, and you do not seem to make sense out of it.'* **Interviewee 3**

Another challenge raised by two respondents and three interviewees in accessing geological data was data secrecy among different stakeholders to gain an advantage in the competition for grants at the expense of others:

'I mean NGOs tend to keep information to themselves ……. where an NGO can be very pleased with the results they are getting 90% success rates but they won't tell anyone else why their success rates are so high and what they are doing. It is a selling point; don't give other guys any money, give it to me because I have got a better drilling success rate. You might not want to tell anyone [about the data used] *because other people will get funded.'* **Interviewee 16**

Interviewee 16 explained that data secrecy caused problems in determining who was drilling wells and which areas had potential for groundwater.'

Cost of accessing data and expertise

Eight respondents and 10 interviewees singled out cost as a significant barrier for small NGOs to access data and expertise, as exemplified by respondent 15:

'Small NGOs do not have enough income base to pay real geologists with the right expertise on the subject.' **Respondent 15**

There were frequent statements about how expensive it was to hire geological experts. In Uganda, rates for a survey ranged between 800 and 1,000 USD per site for expert surveyors or 100 and 300 USD for inexperienced surveyors who might end up 'water witching' or 'dowsing' – a technique not based on any scientific principles (Deming 2002), according to Interviewee 3.

A total of 20 respondents mentioned that government and most online sources were free. This was, however, disputed by two respondents who had faced challenges regarding data access, while two interviewees claimed that they needed to bribe the person in charge of the data to speed up the process despite the government data being free:

'But even then, the person [in charge of data at the government department] *that you make the phone calls to will ask you for some airtime or money to get this information? And you wonder is this the government* [context Uganda] *we pay all our taxes to?'* **Interviewee 3**

'Similar reluctance to release data on the grounds that it should be paid for' **Respondent 11**

However, interviewees 8 and 9 who are hydrogeological experts and consultants working with small NGOs in eastern Africa (Kenya, Malawi, and Uganda) supported the idea of paying a fee to access the data, as it costs money, personnel, time, and effort to manage databases. They argued that it would improve the quality of databases that could be used by small NGOs in the future. They highlighted the need for small NGOs to plan for such expenses in their budgets, citing that the availability of geological data and expertise from the government involved facilitation by government personnel.

Bureaucracy

Nine interviewees named bureaucracy (difficulty navigating government processes) as a barrier for small NGOs to access geological data. In particular, interviewee 3 highlighted the long process of receiving clearance, petitioning, and making requests at each level of the bureaucracy. Data were restricted to only government officials, although it was supposed to be readily available for all, including small NGOs:

'But a common Ugandan or a smaller NGO or even bigger NGOs find a lot of trouble accessing this data. It's like it's only restricted to the ministry or to a specific department who can have access over this data. So other small NGOs have a lot of trouble accessing this data.' **Interviewee 3**

Lack of awareness of what data or expertise they need'

Nine respondents and nine interviewees pointed out the inability of small NGOs to interpret the available data records or to be able to utilise the open online data sources to make informed decisions when planning water and sanitation programmes. Respondents 10 and 15 exemplify this as follows:

'We don't know how geological data can be used. There is no prior understanding of the relationship of geological data and WASH projects.' **Respondent 10**

"For the case of the organisation I work for, we could benefit in knowing the location of underground water sources and their quality because we mostly rely on these to construct gravity flow schemes for the rural communities in Southwestern Uganda. We usually find that the water contains mineral deposits many months after the infrastructure has been put up…. If the location and properties of these underground water sources could be established beforehand, it would eliminate many of such occurrences.' **Respondent 15**

Moreover, due to a lack of knowledge of what data or expertise they needed, respondents and interviewees indicated that small NGOs did not plan or budget well for this aspect of water programmes thus receiving limited funds. Additionally, interviewees 3 and 8 pointed to incidents in which small NGOs in Uganda and Kenya were scammed due to the lack of knowledge on what data were relevant for their work. Interviewee 14 also stated that small NGOs in East Africa called experts on board after making mistakes in the implementation, like drilling a few dry wells at the start and realising that they needed additional expertise.

Donor influence

Eight interviewees highlighted the influential role of donors for small NGOs in eastern Africa, as they were the main source of the finances required to deliver programmes. Interviewee 3 explained how donors influenced the fixed budget and timeframes within which small NGOs executed projects through an example of a project carried out in northern Uganda:

'So, when you were first costing the budget, you did not tell the donor that there would be a dry borehole because they wouldn't want to hear that. So, the moment you find a dry well you know you have already spent more than a quarter of the budget line for that well…… you go back to the donor and tell them you know what we had these challenges here and there and they will be like but you have a budget line, what do you want us to do? Deliver the project.' **Interviewee 3**

Interviewee 4, on the other hand, mentioned about delayed timeframes due to small NGOs' funding restrictions in obtaining and generating high-quality geological data and expertise:'

'One of the big thing that always comes up in NGO groundwater work is that you don't know when proposal calls come in ……or begin funding and might be that a particular call comes in at a time where it could be the rainy season and that you have to say look at this point in time in the year to do any surveying or hydrological testing surveying is not going to yield really test borehole work that is going to really inform us the sustainability of this project.' **Interviewee 4**

In some instances, small NGOs chose to leave a hydrogeologist out (despite their need for hydrogeology experts) due to time constraints imposed on them by donors, as mentioned by interviewee 3. Eight interviewees called for donors to be more flexible when funding small NGOs' work in eastern Africa, appreciating uncertainties in groundwater management and being more supportive towards implementing partners:'

'"And actually, coming back to the donors …… if they are asking for a call or support around groundwater supply, they are conscious, flexible and supportive of the need to be sure that the implementing partners which they are potentially going to fund have the time, space and the knowledge.' **Interviewee 4**

Interviewee 12, who is a donor for many WASH programmes in eastern Africa, did not respond to any of these points but highlighted that most funders focused on building new infrastructure rather than its sustainability.

Challenges with local expertise

Seven respondents and four interviewees argued that there were few geological experts in eastern Africa, as exemplified by Interviewee 13:

'Mostly I think we have issues of not having expertise…. Because having an expert gives you the maximum interpretation of what you want to know…….' **Interviewee 13**

Local geological expertise is also referred to as being a male-dominated field. Interviewee 3 (male) argued that woman in the geological profession in Uganda were few:'

'"And this field is mostly left to the gentlemen. Here in Uganda, it's mostly men who are doing this kind of job. But I do wish that more women could come into this sector and into this world of geology, water…… At least maybe we have a broader spectrum where the experts can come from.' **Interviewee 3**

Another key issue raised by seven interviewees regarding local expertise was on the local experts' preference to work for big projects that pay better when compared to small-scale projects:

'…. *They* [expertise in Uganda] *wouldn't come to your work to spend a day or two on 200 USD when they have a contract of 10 sites that is worth 10000 USD that they can do in a period of a week. They will say 200 USD is child's play, look for someone else. They are very arrogant like 'look for someone else. I don't want that job'.* **Interviewee 3**

However, based on testimonies of two interviewees, one from a geological consultancy and another from an international NGO, it can be inferred that local expertise was available but not supported. One specified that NGOs preferred to use expatriates rather than their local geologists, despite their higher costs, which discourages local geological capacity building.

Four interviewees highlighted the lack of trust between small NGOs and local geologists, particularly raising concerns about the quality of work provided by hydrogeologists to small NGOs. They claimed that most hydrogeological experts were focused more on money than the quality of work. Interviewee 3 reported that geological consultancies offered only junior experts to small NGOs, influencing the quality of work produced. Interviewee 2 also highlighted that the lack of trust was fuelled by tensions between hydrogeologists and drillers:

'"… They [the drillers] *said as we are drilling, we are able to see that we have 3.2 cubic meters per hour. So even after developing this well…., we are not likely to get more than 4.5 cubic meters per hour…., while the Hydrogeologist, was insisting no, we shall be able to get more than five. But we realised that the Hydrogeologist had his interest because if we don't develop the well, we don't pay him what we ought to have paid him so, so he was struggling to defend his job.'* **Interviewee 2'**

Conflicts of interest can of course be held by any party – hydrogeologist, driller, or supervising NGO – and if not identified, declared, and managed correctly can be detrimental to effective water resource management.

DISCUSSION

The results set out in the previous section must be set into the context of the completeness and reliability of the data collected. While the extent of data collected does not allow a broad generalisation of the issues hindering small NGOs' access to and use of geological data and expertise for water projects in eastern Africa, it does provide a useful scoping study to identify initial themes for further interrogation. This additional data exploration would need to include a greater diversity of research participants, in terms of gender, country they are operating in, and experience using geological data.

In this study, participants suggested that there are cases of unreliable, incomplete, and out-of-date geological data provided by governments, making it difficult to comprehend and use. Since small NGOs may prefer to use government data as it is typically free, it places them at a disadvantage in accessing the good quality data required to successfully site boreholes exploiting groundwater resources.

Several participants raised concerns about the collection, management, monitoring, storage, and professionalism in handling geological data by governments in eastern Africa. Concerns could be attributed to a lack of knowledgeable personnel handling these data or to inadequate data systems. Adelana *et al.* (2009) reported similar findings, with staff failing to record or archive critical data sets (for example, drilling logs and pumping tests). Training and capacity building is needed for people working on government geoscience databases. This requires investment, which could come from the government or charges applied to NGOs who use the database. For NGOs to be willing to pay for access to data, they would need to have confidence that it is useful and useable. They would also need fees to be set at affordable and realistic levels. Participants mentioned that small NGOs sometimes lack the financial resources required to establish their own databases or access

high-quality data. Those NGOs with greater financial resources (often larger NGOs) may have a greater capacity to collect and establish their own databases. Participants highlighted that such organisations opt to keep their geological data private, contributing to the lack of information available to other NGOs. Facilitating cooperation and promoting the benefits of data sharing and transparency may help to overcome this issue and improve the planning, implementation, and monitoring of water programmes.

Nonetheless, there is a push to digitise geological databases, for example, the Africa Groundwater Atlas now contains digital African country hydrogeology maps (BGS 2020). This is improving data quality, accessibility, and record management. It also addresses storage issues explored earlier and identified in previous work (e.g., see Gill *et al.* 2019). However, digitisation necessitates capacity building and training to ensure its long-term viability. Domini *et al.* (2017) have reservations about digitising data because it cannot be used in remote areas of eastern Africa where electricity supplies are lacking or unreliable.

The findings suggest that there were few local hydrogeologists in eastern Africa. As a result, small NGOs had difficulties to find local geologists to support their work. If they did find local geologists, they were either expensive or preferred larger projects. Relying on drillers to site and supervise borehole construction resulted in a high number of water point failures in Uganda. Many geological courses exist in eastern Africa (Pozzi & Hurman 2022), suggesting the existence of a substantial geological community. NGOs may not have access to or may not choose to use this local expertise.

Although only one interviewee mentioned the lack of women working with geological data in the water sector, it is noteworthy that all interviewees were men. This could be attributed to patriarchal societies in Africa where technical jobs are gendered, leaving women as home caregivers rather than field workers (Prozesky & Mouton 2019). Furthermore, sociological, political, and logistical challenges faced by women geologists worldwide from the late 18th to the mid-20th centuries, such as inappropriate clothing or sexual harassment in field sites, remain an issue (Burek & Kölbl-Ebert 2007). However, with increased advocacy for gender equality and the protection of women's rights, women should venture beyond their roles on Water User Committees (WUCs) and into science-based work, thereby increasing local geological expertise. However, it should be noted that the lack of representation of women was only noticed late in the study so was not explored very extensively.

Finally, most of the geological data mentioned were physical hydrogeology and water *quantity* data, with interviewees' major ambition in using this being that they did not drill dry boreholes. Water *quality* data or the links between groundwater and sanitation were not discussed by many participants and yet eastern Africa is currently being affected by geogenic and water quality challenges (Ligate *et al.* 2021) GIS was only mentioned by one respondent, which may simply reflect that people do not consider GIS as part of geoscience.

CONCLUSION

This study highlights that small NGOs want to use geological data but several factors influenced the access to and use of geological data and expertise by small NGOs delivering water projects in eastern Africa:

- Bureaucratic hurdles make it difficult for small NGOs to access free government geological data sources, and datasets are not always stored appropriately.
- Cost constraints hinder the ability of small NGOs to access quality geological data from other sources and to hire appropriate expertise to support the delivery of water services. Economies of scale favour organisations delivering larger scale programmes.
- Donors' lack of understanding of geological data affects the ability of small NGOs to budget for and include the time needed to collect or access geological data.

Addressing these challenges, there is a need to strengthen awareness of those working in or with small NGOs on the relevance of geological data and expertise to the delivery of water programmes. There is also a need to make geological data usable, accessible, and affordable to small NGOs, in the context of underfunded government services and lack of investment in data management. The professional geological community should consider what steps they can take to ensure their expertise is readily available to small NGOs, given their mutual role in the implementation of SDG 6, supporting an effective science-practice interface in eastern Africa. It is hoped that further exploration of the themes identified in this study will help to understand the extent to which they are relevant, the scales of their impacts, and the most appropriate way to implement the recommendations in this paragraph to improve the delivery of SDG 6.

ACKNOWLEDGEMENTS

Funding for this project was received from *Geology for Global Development*, supported financially by the International Union of Geological Sciences (IUGS). The authors would like to thank May Sule and Ian Holman for their constructive comments on earlier versions of this work and to Adrian Mallory for his contribution to scope this project in its earlier stages. Finally, thanks are given to all those who responded to surveys and agreed to be interviewed for generously sharing their knowledge.

DATA AVAILABILITY STATEMENT

Data cannot be made publicly available; readers should contact the corresponding author for details.

CONFLICT OF INTEREST

The authors declare there is no conflict.

REFERENCES

Acreman, M. 2005 Linking science and decision-making: features and experience from environmental river flow setting. *Environmental Modelling & Software* **20** (2), 99–109.

Adelana, S. M. A., Taylor, R., Tindimugaya, C., Owor, M. & Shamsudduha, M. 2009 Monitoring groundwater resources in sub-Saharan Africa: issues and challenges. *IAHS Red Book Publication* 103–113.

BGS 2017 *Africa Groundwater*. Available from: https://www2.bgs.ac.uk/africagroundwateratlas/ (accessed: 25 June 2021).

BGS 2020 *Download Digital Country Hydrogeology Maps of Africa From the Africa Groundwater Atlas – UPGro – African Groundwater 2020*. Available from: https://upgro.org/2019/09/24/download-digital-country-hydrogeology-maps-of-africa-from-the-africa-groundwater-atlas/ (accessed 27 August 2021).

Bonsor, H. C., Oates, N., Chilton, P. J., Carter, R. C., Casey, V., MacDonald, A. M., Calow, R., Alowo, R., Wilson, P., Tumutungire, M. & Bennie, M. 2015 A hidden crisis: strengthening the evidence base on the sustainability of rural groundwater supplies: results from a pilot study in Uganda.

Burek, C. V. & Kölbl-Ebert, M. 2007 The historical problems of travel for women undertaking geological fieldwork. *Geological Society, London, Special Publications* **281** (1), 115–122. doi: 10.1144/SP281.7 (accessed 3 September 2021).

Cavanagh, S. 1997 Content analysis: concepts, methods and applications. *Nurse Researcher* **4** (3), 5–16.

Chakava, Y., Franceys, R. & Parker, A. 2014 Private boreholes for Nairobi's urban poor: the stop-gap or the solution? *Habitat International* **43**, 108–116.

Cossham, A. & Johanson, G. 2019 The benefits and limitations of using key informants in library and information studies research. *Information Research* **24** (3), 15.

Creswell, J. W. & Clark, V. L. P. 2017 *Designing and Conducting Mixed Methods Research*. Sage Publications.

Domini, M., Gibellini, S., Villa, F., Vidoni, A., Di Francesco, L., Sorlini, S. & Vaccari, M. 2017 *The Challenge of Sharing Data in Cooperation Projects: Cause for Reflection*. Congress Coordination University Development Cooperation, Milano, Italy.

Esri 2022 *GIS Mapping Software, Location Intelligence & Spatial Analytics | Esri*. Available from: https://www.esri.com/en-us/home

Foster, S. S. D., Tuinhof, A. & Garduño, H. 2008 Groundwater in Sub-Saharan Africa: a strategic overview of developmental issues. *Applied Groundwater Studies in Africa* 19–34.

Gabrielsson, S., Huston, A. & Gaskin, S. 2020 Reframing the challenges and opportunities for improved sanitation services in eastern Africa through sustainability science. In: *Sustainability Challenges in Sub-Saharan Africa II*. Springer, Singapore, pp. 83–111.

Gill, J. C. 2017 Geology and the sustainable development goals. *Episodes* **40** (1), 70–76.

Gill, J. C., Mankelow, J. & Mills, K. 2019 The role of earth and environmental science in addressing sustainable development priorities in Eastern Africa. *Environmental Development* **30**, 3–20.

Greter, H., Ivol, S., Mathieu, V. O., Erismann, S., Prytherch, H. & Steinmann, P. 2021 Heterologous vaccine regimen: stakeholder acceptance and implementation considerations. *Vaccine* **39** (3), 580–587.

Howard, G. & Bartram, J. 2010 The resilience of water supply and sanitation in the face of climate change technical report. *Who Vis* **2030**, 42.

Hsieh, H. F. & Shannon, S. E. 2005 Three approaches to qualitative content analysis. *Qualitative Health Research* **15** (9), 1277–1288.

James, V. 2013 NGOs and Development.

Kut, K. M. K., Sarswat, A., Srivastava, A., Pittman Jr., C. U. & Mohan, D. 2016 A review of fluoride in African groundwater and local remediation methods. *Groundwater for Sustainable Development* **2**, 190–212.

Lapworth, D. J., Nkhuwa, D. C. W., Okotto-Okotto, J., Pedley, S., Stuart, M. E., Tijani, M. N. & Wright, J. J. H. J. 2017 Urban groundwater quality in sub-Saharan Africa: current status and implications for water security and public health. *Hydrogeology Journal* **25** (4), 1093–1116.

Lewis, D. 2015 *Non-governmental Organizations and Civil Society*. Routledge.

Ligate, F., Ijumulana, J., Ahmad, A., Kimambo, V., Irunde, R., Mtamba, J. O., Mtalo, F. & Bhattacharya, P. 2021 Groundwater resources in the East African Rift Valley: understanding the geogenic contamination and water quality challenges in Tanzania. *Scientific African* **13**, e00831.

Liu, Y., Gupta, H., Springer, E. & Wagener, T. 2008 Linking science with environmental decision making: experiences from an integrated modeling approach to supporting sustainable water resources management. *Environmental Modelling & Software* **23** (7), 846–858.

Lubchenco, J., Barner, A. K., Cerny-Chipman, E. B. & Reimer, J. N. 2015 Sustainability rooted in science. *Nature Geoscience* **8** (10), 741–745.

MacDonald, A. M. & Calow, R. C. 2009 Developing groundwater for secure rural water supplies in Africa. *Desalination* **248** (1–3), 546–556.

MacDonald, A. M. & Davies, J. 2000 A brief review of groundwater for rural water supply in sub-Saharan Africa.

MacDonald, A. M., Calow, R. C., MacDonald, D. M., Darling, W. G. & Dochartaigh, B. E. 2009 What impact will climate change have on rural groundwater supplies in Africa? *Hydrological Sciences Journal* **54** (4), 690–703.

Martínez-Frías, J. & Mogessie, A. 2012 The need for a geoscience education roadmap for Africa. *Episodes* **35** (4), 489–492.

Mc Elhinney, H., Sinclair, M. & Taylor, B. 2016 The administration of an online factorial survey using Qualtrics software. In: *International Symposium on Factorial Survey 2016*. Brunel University London.

Nussbaumer, D., Sutton, I. & Parker, A. 2016 Groundwater data management by water service providers in peri-urban areas of Lusaka. *Water* **8** (4), 135.

Omisore, A. G. 2018 Attaining sustainable development goals in sub-Saharan Africa; the need to address environmental challenges. *Environmental Development* **25**, 138–145.

Pavelic, P., Giordano, M., Keraita, B. N., Ramesh, V. & Rao, T. 2012 *Groundwater Availability and Use in Sub-Saharan Africa: A Review of 15 Countries*. International Water Management Institute.

Pozzi, L. & Hurman, G. 2022 *Database of Geoscience Higher Education Courses in Eastern and Southern Africa*. Available from: www.gfgd.org/Database-Geoscience-HEAfrica. Geology for Global Development, UK.

Prozesky, H. & Mouton, J. 2019 A gender perspective on career challenges experienced by African scientists. *South African Journal of Science* **115** (3–4), 1–5.

Robbins, N. S., Davies, J., Farr, J. L. & Calow, R. C. 2006 The changing role of hydrogeology in semi-arid southern and eastern Africa. *Hydrogeology Journal* **14** (8), 1483–1492.

Schwartz, M. R., Bridger, J. C. & Hyman, D. 2001 A validity assessment of aggregation methods for multiple key informant survey data. *Community Development* **32** (2), 226–237.

Tesch, R. 1990 *Qualitative Research: Analysis Types and Software*, 1st edn. Routledge. https://doi.org/10.4324/9781315067339

UNESCO 2009 *Earth Science Education Initiative in Africa, 2009*. Available from: http://www.unesco.org/new/en/natural-sciences/environment/earth-sciences/capacity-building/earthscienceeducation/

United Nations (The United Nations World Water Development Report). 2022 *Groundwater: Making the Invisible Visible*. UNESCO, Paris.

Upton, K. & MacDonald, A. 2021 Clean water and sanitation. In: *Geosciences and the Sustainable Development Goals*. Springer, Cham, pp. 127–158.

First received 8 November 2022; accepted in revised form 10 April 2023. Available online 27 April 2023