

Resilience in Groundwater Supply Systems: Integrating Resource Based Approaches With Agency, Behaviour and Choice (RIGSS)

Summary Paper

Led by

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1. Introduction

Improving access to safe and reliable water supplies is one of the central goals of the global agenda for sustainable development (United Nations, 2015). It is estimated that, globally, some 663m people lack access to safe drinking water, of whom almost half live in Africa (JMP, 2015). This limits the ability for people to move out of poverty as well as impacting on health and well-being (Grey and Sadoff, 2007; Hunter et al, 2010).

The vital role that groundwater reserves can play as part of resilient water supply services is increasingly recognised across the developing world (Howard et al 2016, MacDonald et al, 2011). For many communities, groundwater resources are the principal source of water available to households. Typically, groundwater is accessed from local wells or boreholes by local households, either individually, through their own borehole, or well, or collectively via community boreholes, trucks or carts. For other communities groundwater can form part of mixed supply system, where it is combined with surface water collection systems, often from more distant locations, and piped to households as part of a municipal water supply system.

Although measurement of supply is notoriously poor/difficult, it is estimated that across Africa groundwater meets around 75% of domestic water demands (reported in Danert and Canuto, 2016). This has been enabled through a significant increase in water wells, or boreholes, financed by governmental development programmes and NGOs as well as investments by water users and local businesses (Danert and Canuto, 2016). One challenge for data collection is that households who purchase their water from private or public intermediaries, may not know the source of the water itself. This makes estimating the dependence on groundwater resources more difficult (Grönwall et al, 2010). Lack of awareness of the source of water may also impact on the trust communities have of particular supplies.

The development of groundwater resources has been driven partly by its widespread occurrence relative to surface waters, and by lower levels of contamination, reducing the need for water treatment (MacDonald and Calow, 2009). As the costs of exploiting groundwater resources fall, and awareness of the resource grows, so does the provision of groundwater supplies. The lack of a reliable (and trusted) public water supply system also drives many communities and households to source their own supplies through tapping into groundwater resources, often facilitated by the active support of NGOs and developmental bodies.

Water use is set to increase markedly over the coming decades as a consequence of population growth and anticipated increases in irrigation (Vörösmarty et al, 2005). To this we can also add increasing demands as lifestyles and expectations change with increasing incomes. In a context of growing populations, increasing urbanisation and expanding societal expectations, the resilience of water supplies in the face of sudden or slow-onset environmental hazards is a matter of interest for those responsible for the management of resources. It is also a concern for the future resilience of communities that rely on these sources of water.

Developing effective groundwater management approaches is challenging, not least given the range of different agents involved, their competing interests and demands, and variations in the hydrogeological environment (IAH, 2015). Choices being made now in the siting of wells, the quality and form of their construction and the levels of abstraction, have long-term impacts on the quality of the groundwater resource (locally and more widely), the quantity available for abstraction, the accessibility of supplies to different societal groups and the vulnerability of the resource to future shocks. Yet the nature and drivers of these choices are poorly understood (Kumpel et al, 2014). Understanding the complex processes at work requires a strong interdisciplinary dimension and argues for new perspectives as to how the resilience of communities and societies might be built.

One of the factors that complicates an already complex management environment is the increasing tendency for the development of wells and boreholes by private actors. Broadly termed as 'self-supply' or 'individual-supply' this independent development of water resources can be defined as improvements to household or community water supplies that are financed by the owners themselves and which supply drinking-water to a limited number of premises only (RWSN¹).

Commissioning and management of an individual supply is typically the responsibility of one individual who is not a water management professional. Individual supplies may serve more than one household and may supply commercial premises (such as hotels, restaurants and food production sites) with drinking water. In these instances, neither governments nor NGOs provide subsidies for capital investment or for operation and maintenance. However, in

¹[http://www.rural-water-supply.net/en/self-supply and](http://www.rural-water-supply.net/en/self-supply-and)
http://www.euro.who.int/_data/assets/pdf_file/0012/320511/Status-SSW-supplies-results-survey-en.pdf?ua=1

a significant extension of this trend for the private development of water supplies, commercial property developers are also entering the market, on a smaller or larger scale, to secure access to groundwater-supplies for their residential developments.

In appropriate locations, groundwater resources can be a strong feature in the development of individual-supply options. As household incomes rise, the cost of drilling technologies fall, and the expertise to successfully drill boreholes becomes more widely available, there is a rising trend towards the exploitation of groundwater resources and the development of self-supply solutions. This is exemplified in Nigeria where there has been a rapid expansion in the numbers and scale of privately-developed wells and boreholes over the past two decades (WHO/UNICEF, 2016; IAH, 2015). Whilst this can have a positive impact on improving access to safe and affordable water supplies, the lack of regulation and governance of the practice presents risks both to the quality and the quantity of the groundwater supply (IAH, 2015). The risk is that parts of Africa follow trends in Asia where more than half the groundwater reserves are now reported to be too contaminated to use for drinking (Guardian, 30/8/16; MacDonald et al, 2016). This may result in challenges to the future resilience of water supplies and the communities that rely upon these and could increase susceptibility to natural or anthropogenic environmental shocks as well as constraining the ability to meet wider development goals.

Consideration of the resilience of groundwater supplies has traditionally taken an ecological perspective, emphasising the security of the quantity or quality of the supply. Yet, insights from resilience studies in social science emphasise how the resilience of ecological resources is critically linked to the adaptive capacity of social systems and their agents (Bristow and Healy, 2014). This highlights the importance of human dimensions and processes in adaptive management policies and processes, notably shared interpretations of risks, the importance of understanding desirable adaptive behaviours, and potential temporal trade-offs alongside balancing individual vs collective interests (Bristow and Healy 2014).

Deepening our understanding of the factors that influence the choices of different actors is perhaps the greatest challenge facing those seeking to ensure the development of water supply systems that are resilient to future environmental challenges. To do so, involves not only understanding economic and technical attributes but also the social conditioning of risk perceptions, including the role of different media in constructing (communicative) narratives (Allan, 2002, 2013), These dynamics influence future expectations by cultivating collaboration over individualism in the face of moral hazard and social dilemmas within lived communities (Capstick, 2013; Howell et al, 2016).

The RIGSS project was designed to address this substantial challenge. Focusing on groundwater supplies, RIGSS explores how the interplay between environmental resources, social systems and behavioural choices affects the use of groundwater supplies. It focuses on the case of Nigeria as a means of piloting research approaches and exploring wider conceptual issues. The approach combines perspectives on the interplay of factors influencing choice and behaviour including: the nature of the hydrogeological resource, the perceptions of identified actors, actors' engagement with news and information resources, socio-economic and political factors, psychological factors and the role of coping and survival strategies in the face of shocks and anticipated events.

Two key dimensions underpin the RIGSS project:

- Firstly, an examination of the implications of the rise in privately developed wells for domestic water consumption for the resilience of the communities concerned, and the choices and behaviours associated with this, and
- secondly, strengthening our knowledge of the key factors required for building the resilience of groundwater resources in the face of environmental hazards, through integrating resource-based approaches with a stronger appreciation of the influence of choices made by people and organisations.

Together, these contribute to a greater understanding of how sustainable development goals might be met - particularly those aimed at ensuring the availability and sustainable management of water and sanitation for all, and making cities and human settlements inclusive, safe, resilient and sustainable.

Objectives

The project had 4 principal objectives:

1. To foster new concepts and insights in this critical field through developing and testing an innovative interdisciplinary framework for understanding the interplay between environmental resources, social systems and behavioural choices affecting the resilience of groundwater supplies through:
 - a) Developing common tools and approaches to examine the implications of the rise in privately developed wells for domestic water consumption on the resilience of the communities concerned, and the choices and behaviours associated with this.

- b) Trialling these tools in different contexts through three linked pilot studies in Nigeria.
- c) Refining the tools in the light of the pilot studies so that they can be scaled up and applied in other contexts.

2. To establish a new, and lasting, interdisciplinary research-led collaboration between academics in the UK and in Nigeria.

3. To develop long-lasting partnerships with key policy and practice communities, to contribute to the debate on how to build the resilience of societies to natural and anthropogenic environmental hazards in the field of water supply.

4. To define a future research agenda that identifies research and innovation questions that integrate resource-based approaches for managing the resilience of groundwater supplies with a stronger appreciation of the influence of human agency.

The remainder of this paper is structured as follows:

Section 2 describes the main activities undertaken by the project followed by an assessment of the achievement of the project's objectives in Section 3. Section 4 then introduces the principal findings of each of the main elements of the project dealing first with the pilot studies, followed by the survey of households in Lagos to provide a greater granularity, and then the survey of water professionals across Africa, which gives a broader contextual setting. Section 5 draws together some common conclusions from the work as a whole, followed by the identification of some key emerging research questions. Detailed reports on the individual pilot studies, the Household Survey and the Survey of Water Professionals are included in Annexes to this paper.

2. Activities undertaken

The RIGSS project adopted a multi-disciplinary, mixed-methods approach, focusing on the case of Nigeria. Nigeria was selected as it exhibits a number of features that capture issues of groundwater resilience, including a rapidly rising uptake of privately-developed wells, multiple cultural contexts, and rising levels of urbanisation and prosperity (combined with poverty and income uncertainty). As such, it was believed to offer insights of relevance to a wider African context.

The project brought together a unique interdisciplinary collaboration between academics in the fields of economic geography, psychology, hydrogeology and journalism studies from the UK (British Geological Survey and Cardiff University) and Nigeria (University of Ibadan and University of Maiduguri). The project was supported by SKAT Foundation (Switzerland), which provided expertise, insights and access to the Rural Water Supply Network (RWSN) - an international network of practitioners and policy-makers. Survey support was provided by Qualtrics, an international survey company.

The project was primarily structured around pilot studies in three parts of Nigeria. This fieldwork was complemented by an internet-based survey of households in Lagos plus a global internet survey of water professionals who are members of the Rural Water Supply Network. A series of engagement events with key stakeholders formed the final aspects of the project's activities. A short description of each of these activities follows.

Pilot studies

Fieldwork was undertaken in three areas of Nigeria forming a north-east to south-west transect (Figure 2.1). The areas were Borno State (focusing on the city of Maiduguri and its surroundings); Nasarawa State (focusing on the rural areas around the administrative capital of Lafia), and Lagos State (focusing on the greater metropolitan area of the city of Lagos).

Figure 2.1 Pilot Study Sites in Nigeria



The three pilot studies were undertaken during the months of April and May 2017. Each location was designed to provide a contrasting set of conditions, in order that comparative findings could be drawn (Table 2.1). The original proposal was for the pilot activities to be undertaken in Lagos State, Benue State and Borno State. Owing to the security situation, the rural pilot planned for Benue State was replaced by the neighbouring Nasarawa State. The timing of the pilot studies was informed by the overall project timetable but was also timed to avoid the onset of the wet season and the beginning of Ramadan.

Table 2.1 Characteristics of selected study areas

<i>Context</i>	<i>Borno State</i>	<i>Lagos State</i>	<i>Nasarawa State</i>
Meteorological	Hot semi-arid	Tropical savanna	Tropical sub-humid
Hydrogeology	Sedimentary	Sedimentary	Basement& Sedimentary
Urban-Rural	Mixed urban rural geography	Urban communities, ranging from dense inner urban to more extensive peri-urban	Remoter rural communities
Geographical	Inland location	Coastal location	Inland location
Conflict	Endemic conflict (ongoing insurgency)	None reported	Episodes of inter-communal violence

A mixed-methods approach was adopted for each of the pilot studies, this included:

- The gathering of information on the hydrogeological conditions available at each site. Techniques used included desk-based analysis (interpretation of geological maps and climate data), supplemented by field-based techniques (including permeability testing, measuring depth to water-table and water chemistry).
- Qualitative (semi-structured interview and focus groups) research to capture the perspectives of water users (community groups, households), government actors, donor and humanitarian bodies, and drilling-sector organisations.

Each pilot study involved visits to a number of individual communities, where waterpoints would be tested and community members would be interviewed. The community-centred research was primarily undertaken in the Hausa and Yoruba languages. Researchers based within local universities, or from government ministries, supported the research team. Semi-structured interviews were undertaken with NGOs, government actors, journalists and drilling contractors. These were led by the research team and were undertaken in English. Team members from the British Geological Survey were unable to join the field-teams owing to the prevailing security situation in Nigeria at the time.

Table 2.2 Summary data of pilot studies

	Borno State	Lagos State	Nasarawa State	Total
Communities visited	1*	4	8	13*
Waterpoints tested	29	47	16	92
Community Group interviews	4	4	9	17
Household interviews	10	16	10	36
Government interviews	1	-	1 **	2**
NGO interviews	1	2	2	5
Journalism interviews	2	2	2	6
Driller interviews	2	5	8	15

* Interviews carried out across a wide area of Maiduguri and surrounds

**One focus group involving 12 persons

Internet-based household survey

A quantitative panel-based survey of 500 residents in Lagos State was undertaken to assess water resource considerations from a demand-side perspective. Quota sampling was utilised in order to obtain as representative a sample as possible in terms of age and gender. The questionnaire was structured using mostly closed-ended items, with several open-ended questions also used where spontaneous responses were sought. Survey respondents were asked to answer questions relating to their use and attitudes towards a range of water supplies, with a particular emphasis placed on groundwater use. Respondents were also asked about their environmental risk perceptions and for demographic information. The survey was administered during April and May 2017, and the final survey sample comprised 539 individuals.

Global survey of water professionals

A quantitative on-line survey was undertaken of members of the Rural Water Supply Network (RWSN), an international grouping of individuals with a professional interest in the supply of water. The survey was administered in French and in English to achieve a wider coverage and the questionnaire was structured using mostly closed-ended items. An invitation to participate in the survey was sent to 9,965 network members, located in 151 countries. The survey was open for two weeks during May 2017 and received 115 responses. Although the response rate is low, it is believed to be reasonable given the niche subject area of the survey. The total number of responses slightly exceeds the number anticipated in the original study-design (100).

Stakeholder engagement activities

A number of stakeholder engagement activities were undertaken, in Nigeria, the UK and more widely in both Africa and Europe.

- The project participated in the 7th quinquennial RWSN Forum, held in Côte D'Ivoire in 2016. This provided an opportunity to raise awareness of the project amongst the 600 participants and to provide inputs into the development of the research methodology.
- The project contributed to two webinars (one in French and the second in English), hosted by the RWSN, on the theme of "Using groundwater in urban and slum areas: experiences from Africa". Taken together the webinars engaged with some 55 external participants, stimulating debate, shared experiences and a request to adopt the study methodology in a fourth location (Port Harcourt, Nigeria).
- An initial workshop was held in Lagos in March 2017. This brought together some 44 representatives of community groups, government agencies, NGOs, drilling contractors and academics. The workshop was interactive and participatory and involved working groups and drama sessions as well as short presentations introducing the study. A short report on the workshop was provided to all participants.
- The emerging findings of the study were shared at an in-country workshop held in Lagos in July 2017. This brought together some 40 individuals from a diverse range of backgrounds including community representatives, government officials, NGOs, drilling contractors and the UK Deputy High Commission (Science and Innovation Network). It provided a forum to

discuss the research findings, to test possible conclusions and to provide greater ownership of the results amongst participants.

- A final event in Cardiff presented the findings of the project to a more academic audience and discussed strengthening the recognition of the role of human agency in building resilience.
- The project presented a paper at the WEDC conference, held in Loughborough in July 2017. The annual conference provided an opportunity to present the main findings of the research to an audience to one of the premier events in this field. Findings were also presented to the annual conference of the International Association of Hydrogeologists (Dubrovnik, Croatia, September 2017), providing a valuable opportunity to engage a more technical audience.
- Dr. Adrian Healy was invited to provide a guest lecture at the University of Ibadan, Nigeria, to staff and students at the Department of Geology and the Department of Geography, in July 2017. This provided a valuable opportunity to introduce conceptual and empirical findings from the research to a wider academic audience. He has also been invited to present the annual Burdon Memorial Lecture to the Irish Chapter of the International Association of Hydrogeologists.

Deliverables

Two deliverables have been completed, as anticipated in the project application.

- an initial Position Paper setting out key research questions, their implications for policy and practice and led into the development of the research tools, and
- a Final Position paper (this document) that sets out the main results of the project.

3. Achievement of objectives

The project has strengthened our knowledge for building the resilience of groundwater abstraction in the face of environmental hazards, through integrating resource-based approaches with a stronger appreciation of the influence of human agency. It is hoped that this can contribute to a greater understanding of how key sustainable development goals might be met - particularly those aimed at ensuring the availability and sustainable management of water and sanitation for all, and making cities and human settlements inclusive, safe, resilient and sustainable.

Taking each of the four objectives in turn:

1. The study has developed and tested an innovative interdisciplinary framework to understand the interplay between environmental resources, social systems and behavioural choices affecting the resilience of groundwater supplies. This has helped foster new concepts and insights in this field. In particular, RIGSS has developed common tools and approaches to examine the implications of the rise in privately developed wells for domestic water consumption on the resilience of the communities concerned, and the choices and behaviours associated with this. These include a survey instrument for an internet-based survey of households; an assessment procedure for waterpoints; a semi-structured survey instrument to be used with individual households and a semi-structured survey instrument to be used with community focus groups. A narrative-technique approach was initially also piloted but this proved to be unsuited to the context in which it was to be applied.

Each of the tools was trialled through the three pilot studies. Taken together this has provided a rigorous test of the applicability of these tools, as well as providing a robust empirical evidence base. One tool – a narrative technique approach – was found to be poorly suited to the context in which it was being applied. Further work will be required to develop this approach. The initial workshop held in Lagos (March 2017) trialled the use of improvised drama as a novel participative technique. This proved to be highly successful, both for stimulating involvement and generating valuable insights into policy and practice considerations.

The tools have since been refined in the light of the pilot studies. It is intended that these might then be applied in other contexts. The qualitative Household survey instrument has also been adapted and it is proposed that this will be applied further in each of the project study areas through working with students in the University of Maiduguri, the University of Ibadan and Nasarawa State

University, Keffi. The tools have also been shared with researchers from the University of Namibia who are applying them to assist in their work on public health in Namibia.

2. A new interdisciplinary research-led collaboration has been established between academics in the UK and in Nigeria as a consequence of the RIGSS project. Opportunities to extend the current collaboration are being sought, including through the development of research instruments that can be applied in Nigeria as part of student-based activities. Collaboration has been extended beyond the two Universities named in the RIGSS project bid to include Nasarawa State University, Keffi. This indicates the wider relevance of this work.

Work is ongoing to extend the network further, to include researchers in other networks such as the DFID/NERC/ESRC-funded UPGro Programme. The project has also enabled the researchers to establish links into the GW4 Water Securities Alliance research network. This is comprised of researchers active in this field from the Universities of Bath, Bristol, Cardiff and Exeter, some of whom attended the project's final event in Cardiff University. These links are new and are directly attributable to RIGSS award.

3. RIGSS has enabled team members to develop new partnerships with key policy and practice communities. This ranges from international organisations, such as OXFAM, Wateraid and UNICEF, to government bodies and NGOs in Nigeria, including the Lagos State Ministry of Environment, Lagos State Water Corporation and Commissioner for Water in the State Government of Nasarawa State. These have the potential to develop into long-lasting partnerships. These new partnerships remain developmental as the policy and practice debate is only gradually recognising the significance of the need to build the resilience of societies to natural and anthropogenic environmental hazards in the field of water supply. Informing this debate at such a crucial juncture is one of the key achievements of the RIGSS project and builds the foundations for strong partnerships for future activity. Work to extend the reach of the RIGSS project, and its potential impact, will continue.

4. RIGSS has defined a powerful future research agenda. This identifies research and innovation questions that integrate resource-based approaches for managing the resilience of groundwater supplies with a stronger appreciation of the influence of human agency. RIGSS team members are currently in the process of working with policy and practice communities to refine this agenda further.

5. There has been an active programme of dissemination of the findings of the project to a diverse audience of academics, practitioners and policy makers. These include presentations at the 2017 WEDC conference and the 2017 IAH conference, plus a poster contribution to the annual INESON lecture in London (October 2017). Presentations continue following the close of the project, including the annual Burdon Memorial lecture at the Geological Survey of Ireland in February 2018.

6. A number of additional outcomes can also be identified as a consequence of the RIGSS project. These include the involvement of the researchers in the Urban Groundwater Network of the IAH, the inclusion of the findings of the project in the forthcoming revision to the Africa Groundwater Atlas and the extension of the project and its methodology to the city of Windhoek, Namibia and Cape Town, South Africa, involving the development of new collaborations with researchers in these countries. The study has also influenced the content of student research projects being undertaken by Cardiff University in Jakarta, Indonesia.

4 Findings

In the following section we report on the findings of the three principal elements of the project: the three pilot studies, the survey of households in Lagos and the global survey of water professionals. Full reports on each of these are included in accompanying annexes.

4.1 Findings from three pilot studies

Three pilot studies were undertaken for the RIGSS project, involving water point testing and analysis, assessment of hydrogeological conditions and qualitative discussions with community groups and households. The following sub-section presents the main findings of this work, assessing areas of commonality and difference across the three study areas. It is structured around short descriptions of: the sources of water used by households, reported trends in the development of domestic boreholes, analysis of the quality of the borehole and well waters tested alongside the quality perceived by users, a synthesis of the main reported drivers underpinning the development of domestic boreholes, the benefits and risks associated with borehole development by communities, the (dis)incentives for the development of boreholes, the reported governance structures appertaining to the development of boreholes, and the nature and role of communication in this field.

4.1.1 Sources of water used

The principle source of water in all three pilot areas was from boreholes or hand-dug wells. Unimproved surface water sources (rivers, streams and springs) were used in more rural areas, but tended not to be utilised in urban areas where they were more obviously polluted. In rural areas, competition for surface waters with cattle herders can be problematic.

Some urban areas also have access to piped public water supplies. This was most notably so in Lagos, Lafia and Maiduguri. However, in all cases the public supply was reported to be inadequate, failing to supply most of the urban populations. In Lagos, it was estimated that the public supply probably reaches 10-15% of all households. It was also noted that public supplies tended to be erratic and unreliable, leading many households to also invest in a domestic borehole.

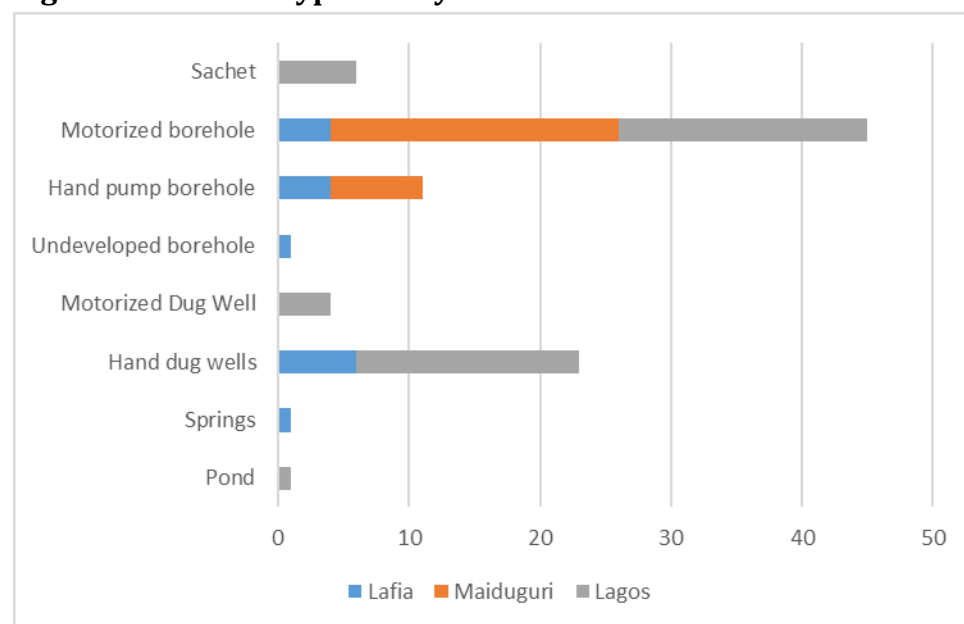
In urban areas bottled and, more especially, sachet water is an important source of drinking water. These tend not to be present in rural areas, owing to cost and distribution issues. Other water sources such as tanker supplies and water-vendors using handcarts are also present and can be important sources for

particular household groups. All tend to use boreholes as their primary source of supply.

Finally, rainfall collection was noted as a source of supply in both rural areas and small towns. However, storage of rainfall water tends to be limited, meaning that this source is only available during periods of rainfall and for the following day or two. The use of rainfall collection is also not very systematic, with only the occasional example of substantive collection and storage noted in each location.

Detailed water point surveys were undertaken at 77 sources across the three pilot study areas, with additional water quality testing undertaken at a further 15 sources in Maiduguri (Borno State) (Figure 4.1). Motorised boreholes and hand dug wells were the dominant water source across the three regions. Of all the sources analysed, 70% of these were private.

Figure 4.1: Source types analysed across the 3 field areas



4.1.2 Trends in development of domestic boreholes

Across the pilot study areas, a rising trend in the development of privately-commissioned domestic boreholes is apparent in urban areas. This is most marked in Lagos but it is also notable in the towns of Maiduguri and, reportedly, in Lafia. There is no source of data as to the precise number of boreholes commissioned by households, but in Lafia, drilling contractors report the numbers to be in the thousands over the past ten years. In Lagos, the State Water Corporation estimates that there are approaching 200,000 domestic

boreholes in the State (with twice that number of abandoned boreholes), although many commentators regard this as a gross underestimation.

In more rural areas, there is a very limited presence of privately-commissioned boreholes by households. In these areas, some boreholes have been commissioned by individuals (often politicians or village chiefs/elders) but these tend to be available for community use. There are anecdotal reports that urban householders are commissioning boreholes at their homes in their family village, but no evidence for this was seen during this pilot study.

The prevailing geology has an influence on the development of domestic boreholes and wells. Shallow sedimentary or weathered basement formations tend to be more heavily exploited by hand dug wells or manually drilled boreholes due to the lower costs of accessing groundwater in these areas; to the availability of the technologies to drill boreholes in these terrains and to the number of available drilling contractors. However, as technologies improve and drilling costs fall, the commissioning of domestic boreholes become feasible to more and more households even in more complex geologies. Examples of households using two boreholes on their property can also be found, although most have only one.

4.1.3 Observations on borehole construction

The quality of the construction of the boreholes themselves could not be assessed as part of this pilot study. However, there were anecdotal reports of poor construction practices by many contractors, particularly in Lagos. This includes the use of inappropriate construction techniques and inappropriate linings.

An assessment of each borehole and hand dug well was undertaken to determine the overall vulnerability to contamination for the water point. This looked at pollution sources and ponding of surface water close to the water point, and whether the water point was suitably protected with a concrete apron, cover, and fence.

Assessment of the vulnerability of sources illustrates that boreholes tend to be less vulnerable than hand dug wells, with 43% of hand dug wells classed as highly vulnerable compared to only 18% of boreholes. The most significant factors contributing to a "highly vulnerable" classification were a missing or damaged apron and the presence of a pollution source within 10m of the water point. . Several water points were poorly sited, located overly-close to potential sources of pollution (most notably latrines and soakaways). Several boreholes

also demonstrated poor finishing of aprons, often – it was suggested – as a result of cost-cutting exercises because available budgets had been reduced.

Amongst community representatives there was a broad understanding of the importance of good siting, although many reported that amongst the population more generally awareness was low. It was apparent however, that whilst many of these individuals, and some drilling contractors, were aware that boreholes should not be sited near to latrines and soakaways, they were less aware of the reasons for this.

4.1.4 Observations on functionality of boreholes

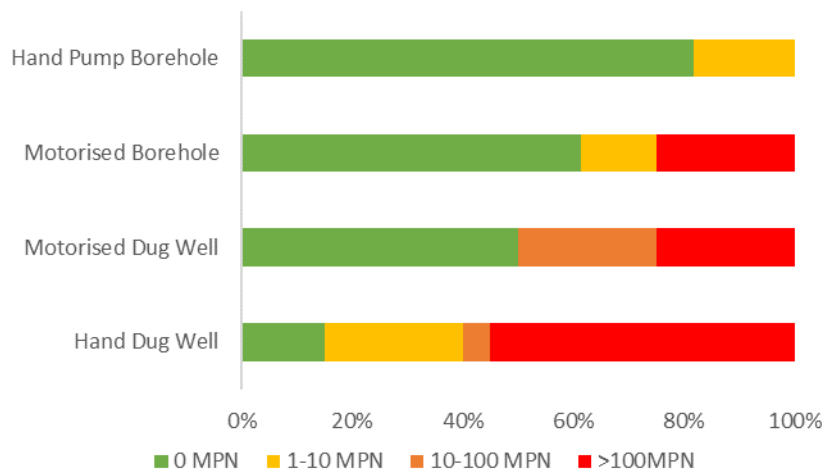
There were relatively few functionality issues reported across the 3 study areas. In Lagos and Maiduguri, 95% and 85% of sources provide water all year round, respectively, and drought was not generally perceived as a significant problem. Issues with water availability were reported for shallow hand dug wells in Lagos and for motorised boreholes located in IDP camps in Maiduguri, where the population is high, thus demand exceeds the available supply. Five sources were reported to have broken in the last year in both Lagos and Maiduguri; the majority were private sources which were fixed within days.

In Lafia, just over 60% of sources were reported to provide water all year round. Issues with water availability and drought were limited to shallow hand pump boreholes and hand dug wells. All hand pump boreholes surveyed in Lafia had broken down within the last year. None of these were private sources and the time for them to be fixed ranged from less than one month to 12 months.

4.1.5 Water quality

According to WHO guidelines, drinking water should not contain any pathogenic organisms, or any bacteria indicative of faecal contamination. The detection of E. Coli provides evidence of faecal pollution and can be used to classify a drinking water source as safe, intermediate risk, high risk, or very high risk. E. Coli testing was undertaken at 79 sources using the MPN method. Based on the World Health Organisation Drinking Water Standards, 52% of the sources were classed as safe, 16% as intermediate risk, 3% as high risk, and 29% as very high risk. Figure 4.2 shows that the majority of boreholes (both hand pump and motorised boreholes) are classified as safe or intermediate risk, while hand dug wells are more likely to be high or very high risk.

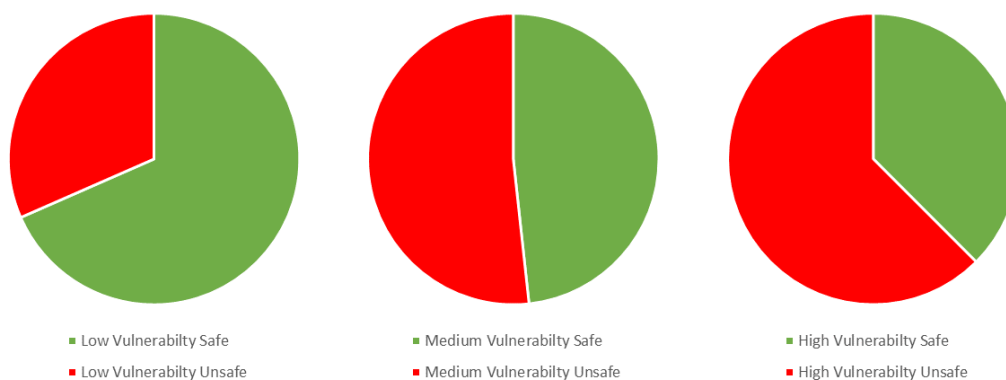
Figure 4.2: E. Coli classification by source type



WHO Drinking Water Standards class 0 MPN as safe, 1-10 MPN as intermediate risk, 10-100 MPN as high risk and >100 MPN as very high risk.

Figure 4.3 demonstrates that, across the 3 pilot study areas, the vulnerability score is a reasonably good indicator of whether a source is likely to be safe or not, with almost 70% of low vulnerability sources classified as safe and 63% of high vulnerability sources classed as unsafe. Within the vulnerability assessment, the clearest indicators of whether a source was free from faecal contamination were the presence of a pollution source within 10m of the water point and the absence of a cover.

Figure 4.3 Comparison of vulnerability score and water point risk according to the E. Coli MPN method



sources with MPN > 0 are classed as unsafe

4.1.6 Perceptions of comparative water quality

In terms of people’s perceptions of water point quality, 86% of motorised boreholes, 67% of hand pump boreholes, and 77% of hand dug wells are

perceived as good quality (Figure 4.4). However, people’s perceptions of water quality from different source types does not always match the actual quality of water from the source when considering faecal contamination: in reality, 69% of motorised boreholes, 83% of hand pump boreholes, and 18% of hand dug wells are classed as safe from faecal contamination. This is highlighted in Figure 4.5, which shows that almost 10% of safe sources are perceived as poor quality, while 70% of unsafe sources are perceived as good quality (it should however be noted that the majority of these are hand dug wells, which are generally less preferred as a source of drinking water than boreholes).

Figure 4.4: Perceptions of water quality by source type

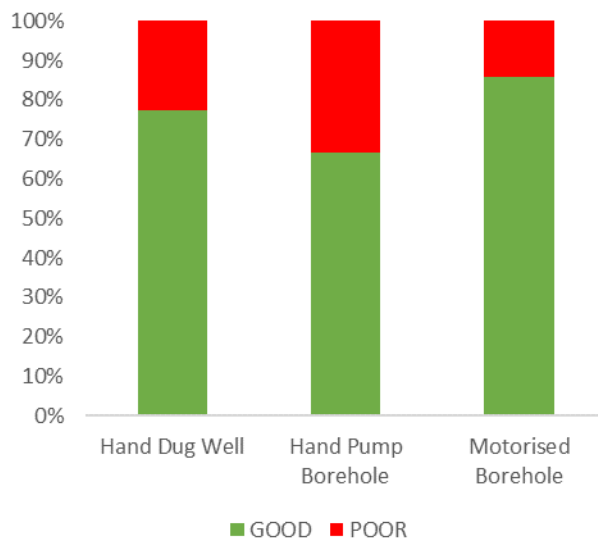
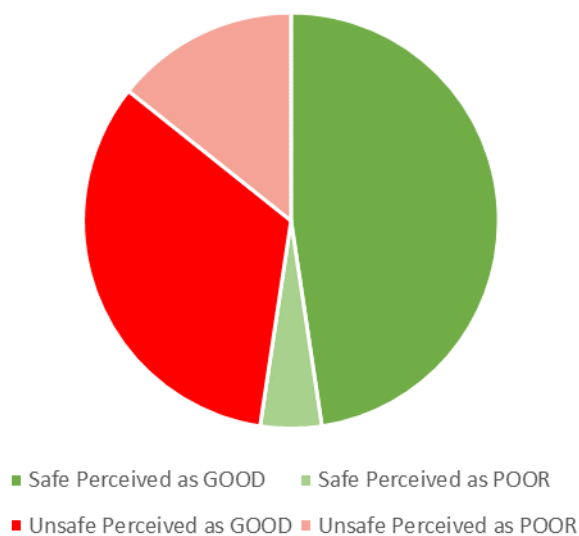


Figure 4.5: Perceptions of safe (MPN = 0) and unsafe (MPN > 0) sources according to the E. Coli results



It is notable that respondents' perceptions of the quality of water sources tends to be based on physical characteristics (taste/appearance) rather than chemical or microbiological characteristics. However, historic knowledge of observed water quality and water collection practices (such as the use of multiple 'dippers' for collecting water and the associated risk of cross-contamination) were also found to influence attitudes to particular water sources. For many, aesthetic characteristics also influenced their choice between different sources, particularly whether water was cold or warm to drink. This was an explanation for uses of sachet water (which could be refrigerated) and for a preference for well-drawn water over that sourced from an overhead tank (which warmed in the sun).

Across household interviews there is a strong presumption that the quality of groundwater is very good and suitable for drinking and other uses. As a consequence there is very little evidence of household water treatment being practiced. It is only where the taste or appearance of water is below an accepted quality that groundwater will be perceived as not fit for use or direct consumption.

4.1.7 Trends in water consumption

The study did not seek to independently measure water consumption, but respondents reported that where water sources were readily available, levels of consumption tended to rise. This was particularly so where domestic boreholes made access to water very convenient.

In rural areas, where there was a greater dependency on a more limited number of waterpoints, the cost of accessing water tended to constrain water consumption. In areas with limited access to water, levels of daily consumption are particularly low. It was also noted that where water points failed, forcing households to use less convenient sources then total consumption tended to fall.

From the responses available to the study, it is apparent that levels of water consumption depend upon the availability and cost of accessible water supplies. Where water is perceived to be plentiful, water conservation techniques are not practiced and overall consumption is increasing both on a per capita basis and absolutely as population numbers continue to rise.

4.1.8 Underlying drivers of domestic borehole development

One of the key drivers underlying the proliferation of domestic boreholes is the rapid expansion of urban centres in Nigeria. Rising population pressure and the spread of the urban area (to include a more dispersed development pattern with growing numbers of private housing estates) has led to an increase in demand for water supplies across a wider geography which existing supply infrastructures are not set up to meet. Why, though, has this demand been met through the development of privately-commissioned boreholes, rather than other potential supply options?

The proliferation of domestic boreholes is firmly ascribed to '**government failure**' by the majority of respondents, including many representatives of government bodies. Essentially, the public sector has proved unable to meet the increasing levels of demand arising from rapid urbanisation leaving households and communities to have to find their own solutions. This is apparent across the urban centres in all three pilot study areas. Not only is the capacity of the public water supply insufficient to meet demand, it also does not reach many communities as investment has failed to keep up with the expansion of the urban area. In addition, even where public water supplies are available, they are regarded as unreliable as they suffer from regular shutoffs owing to failures of power supplies or shortages of essential inputs.

In more rural areas, the difficulty (and expense) of providing a public water supply means that there is a reliance on the development of boreholes as a primary means of community-based water supply. However, this has not yet evolved into individual supply solutions in the study areas. Although a strong self-supply movement, often driven by NGOs, is forming in many parts of Africa, evidence of this was not visible in the rural communities involved in this study.

A third feature of government failure can also be identified as a potential driver of the proliferation of domestic boreholes. That is the lack of an enforced regulatory environment. At present, domestic households are not required to seek any official permissions to develop their own boreholes, either due to the lack of such provisions in the regulatory environment or because the appropriate regulations are not enforced. Examples of both are apparent in the pilot studies. This provides a very permissive environment allowing something of a 'free-for-all' in the development of domestic boreholes.

Whilst most observers alight on Institutional factors, such as government failure, as the key contributory factor, other drivers are also present. The following five are perhaps the most significant

Prevailing hydrogeological conditions play an important role in mediating access to groundwater. In the coastal plains of Lagos, access to an unconfined upper aquifer at shallow depths makes shallow hand-dug wells highly feasible but vulnerable to contamination from surface activities. A semi-confined aquifer lies beneath this, which is accessible cost-effectively through manually or mechanically-drilled boreholes. It is susceptible to saline intrusion but less at risk of direct contamination from surface activities. Similarly in and around Maiduguri, the sedimentary formations provide access to groundwater through shallow hand-dug wells and manually or mechanically-drilled boreholes.

In contrast, across much of Nasarawa State, the basement lithology precludes shallow hand-dug wells, forcing a reliance on surface waters or deeper (and more expensive) mechanically-drilled boreholes. The higher cost of drilling boreholes in these hydrogeologies, and limited capacity of contractors, limits their prevalence, to higher income groups or geographical areas, such as Lafia, where sedimentary formations provide easier access to available groundwater.

Access to **alternative sources** of water also influences the decisions made by households as to whether to invest in a borehole or not. Where alternative sources are more readily available (and are accepted as viable sources) then households are less likely to take the investment decision.

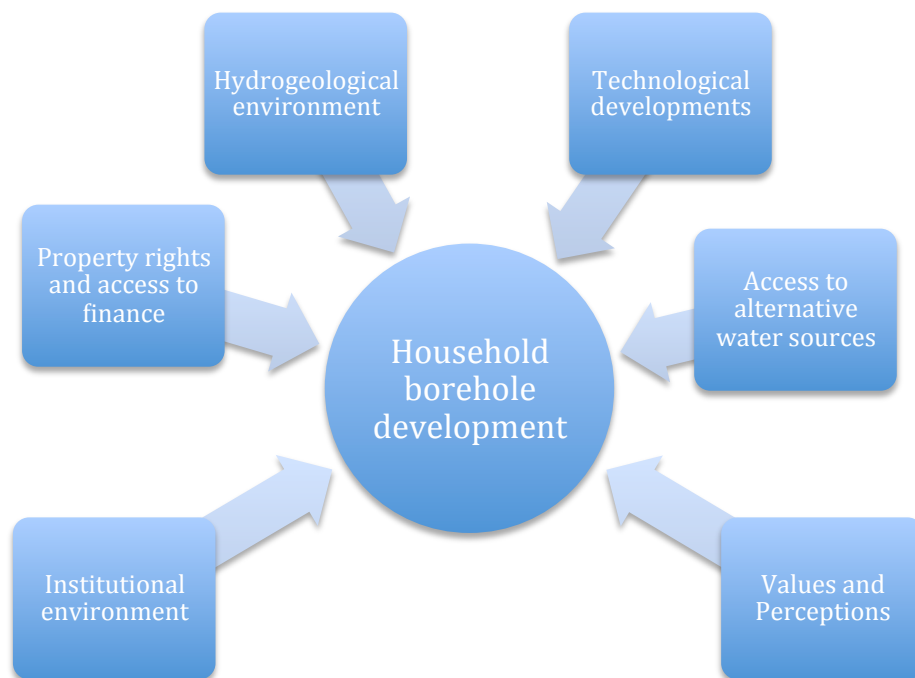
A third dimension in the rapid proliferation of domestic boreholes in recent years has been the impact of **technological advances**. Through the importation, adaptation and introduction of novel technologies and processes contractors have been able to reduce the costs of accessing groundwater reserves at increasing depths and in more challenging hydrogeological environments. Concurrently, reductions in the technical barriers to entry to the drilling market has led to a rapid expansion in the supply of contractors available for the drilling of boreholes. This is particularly the case in those areas, such as Lagos, where the hydrogeological conditions enables the entry of contractors with limited skills and expertise to enter the market with low cost equipment.

The fourth dimension underpinning the rise in privately-commissioned boreholes is often ascribed to rising **incomes** and aspirations. This is certainly a factor, and underlies the proliferation of boreholes amongst middle-class households, but is insufficient as an explanation on its own. Anecdotal evidence from the community interviews in Lagos suggested that **access to credit**, through established credit and thrift co-operatives, enabled many to invest in their own household boreholes. The advantage of these co-operatives is that credit is available on very easy repayment terms. The system is more developed in some parts of Nigeria than others and is less prevalent in rural areas, providing a further explanation for emergent geographies of borehole

development. The availability of credit lines may provide an explanation as to why income was not an explanatory variable in the development of boreholes by households in the Household Survey, but that *property rights* were.

Finally, there is the important role played by the **values and perceptions** amongst households and prevailing in the community as a whole. These set the context for the acceptability of private borehole development as a means of household domestic water supply.

Figure 4.6 Factors influencing the development of household boreholes



4.1.9 Benefits/risks associated with domestic borehole development

Overall, there was a mixed awareness of the importance of borehole siting and construction amongst community representatives and households. Awareness tended to be stronger amongst those engaged in the pilot study in Lagos, in comparison to both other pilot areas. However, in practice, it is apparent that good practices are not always observed. Many boreholes are closely sited to potential sources of contamination, particularly soakaways.

Respondents stressed the significant preference amongst householders to site boreholes in convenient locations. This tends to be within their own compound. Boreholes provided by NGOs, government or donated by individuals tend to be

sunk close to the centre of population to be served or, very often, in or close to the house or compound of prominent citizens, such as the traditional ruler.

For private households, most boreholes are sunk some time after the house is completed, and the location of such services was not considered at time of development. For others, the available space for the sinking of a borehole is restricted, which tends to determine where the borehole will be located. Drilling contractors reported that in most instances, the will of the householder was the most important determinant of the location of the borehole that they sunk. This approach is more prevalent in areas where access to groundwater is relatively ubiquitous.

From the qualitative data available, it is apparent that many boreholes are not well-maintained with a limited (if any) programme of maintenance and cleaning. Many householders reported that overhead tanks were only occasionally cleaned (if at all) and many filters on tanks (where present) were observed to be clogged. Many boreholes were observed to be constructed using substandard materials and several lacked sanitary pads or cement grouting. However, it is also fair to note that privately-owned boreholes appeared to be less susceptible to failure and mechanical breakdown, potentially owing to the less intensive levels of use compared to community boreholes, which tended to be in continuous use unless actively managed by the community (as was the case in one community in the Nasarawa pilot study which restricted use to the hours of 6am to 6pm in order not to overload the functionality of the borehole and its mechanisms).

As most boreholes explored during the study tended to be shallow-drilled, there was an enhanced susceptibility to contamination from soakaways and poorly constructed septic tanks, as well as other possible sources of surface contamination.

The potential for over-abstraction was widely recognised, with falling water tables reported in all pilot study locations where privately-commissioned boreholes were proliferating. In only one pilot area (Maiduguri) was this linked to potential negative consequences in terms of falling soil moisture levels and risks of desertification. This connection is most probably owing to the more arid climatic conditions in this area compared to Lagos and Nasarawa State (where high levels of rainfall are expected to recharge groundwater supplies). In all three pilot areas over-abstraction was regarded as a necessity owing to levels of demand compared to available supply. The impact of this tended to be viewed in terms of a need to increase the depth of wells and boreholes to reach available groundwater, rather than any recognition of potential issues of water scarcity. Overall, the consensus is that there are unlimited stocks of groundwater available for domestic use.

There is a stronger concern over the quality of the groundwater available. However, this tends to be framed in terms of a concern for the future, rather than a real risk at the current time. As such, it is seen in rather more abstract terms, with most respondents recognising the possibility of contamination but uncertain of what this might mean in practice. Drilling contractors in Lagos are reporting anecdotal evidence of saline intrusion at deeper depths and of encountering anthropogenic contaminants at relatively deep depths in the vicinity of major waste sites. The latter is ascribed to the proliferation of boreholes in proximity to these sites, which is enabling the transmission of contaminants despite good management practices by the waste authorities themselves.

In practice, levels of abstraction and overall water quality remain an unknown quantity, as respondents were not aware of any monitoring of these attributes. Similarly, there was no awareness of any active management of the groundwater resource, with respondents generally reporting that this was not practiced.

A final element that emerged through the study is how the proliferation of domestic boreholes may affect the distribution of access to water. Although this was not a focus for the study, certain issues have emerged which are worthy of further consideration. Most directly, the urban poor are unable to secure their own water supplies through developing boreholes owing both to the cost of such an investment and, crucially, a lack of property rights. This often means that the poor have access to water of a lower quality and at a higher cost than other members of the wider community. This is less of an issue in rural areas, where access to water remains a collective good rather than the emergent individualised good witnessed in urban areas. A secondary effect of the individualisation of water supplies may be the reduced capacity of a public water utility to supply those on lower incomes, owing to a reduced ability to cross-subsidise. As more wealthy consumers source their own water supplies, there is anecdotal evidence of this having a negative impact on their willingness to pay collective water charges, so reducing the income of a water utility and (potentially) increasing the marginal cost of supplying water to poorer parts of the community.

4.1.10 Differential (dis)incentives for development

The qualitative interviews undertaken indicate that the choice of water source is a complex mix of decisions of households based on availability, desired use, cost of access and personal preferences. This means that most users access water from multiple sources. Availability of alternative sources is dependent on location. In the rural areas of Nasarawa State, alternatives tended to be limited

to communal boreholes (typically hand pumps) and unimproved surface water sources, in urban areas such as Lagos and Maiduguri, a wider range of alternatives were often available, including sachet/bottled water, private boreholes (commercial and non-commercial), public piped water supplies (although in no way ubiquitous), and hand-dug wells.

Some patterns in source choices can be witnessed. In Lagos, water from private domestic boreholes is typically used for all household uses including drinking and cooking (but water from communal boreholes less so). Households in Maiduguri reported that domestic boreholes tended not to be used for drinking owing to its taste. Here, consumers tended to prefer to use sachet water for drinking purposes. In Nasarawa State, water from communal boreholes was typically used for drinking and cooking purposes, as the only alternative sources are unimproved surface waters. However, in some cases where households reported the borehole water tasted unpleasant unimproved surface waters were used for drinking purposes.

Households and respondents reported no strong water conservancy, this is partly because of the fact that usage rates amongst many households are already low, with limited water being used only for essential activities. However, this lack of sensitivity to the conservation of water appears to continue once households have access to their own borehole, when many of those interviewed report limited awareness amongst the wider population of either the potential for water conservation or the need. In this regard there appears to be a strong myopia regarding the availability of groundwater supplies.

Respondents also report that overall demand for water is increasing, both because of rising populations but also because of changing lifestyles, with households more likely to take regular showers, for example, when access to water is plentiful. Other regular domestic water uses include for gardens and car washing.

Where multiple sources of water are available, the principle determinants of the choice of water tended to be based on a common set of criteria, in the form of a decision tree, including: convenience of accessing the source (often based on immediate proximity); the reliability of a supply (and the regularity with which it is available); any cost associated with the water source – although this often determined the amount used rather than whether to use the source or not; aesthetic (taste/temperature) and status criteria; perceived quality of the water available from a given source; the extent to which a particular source contributes to a sense of self-sufficiency and, to a lesser degree, the extent to which use of a source reduces potential for personal harm/insecurity.

As noted elsewhere, the overall perspective of groundwater resources is one of abundance now and in perpetuity. For many households the perceived importance of the groundwater resources was also rising, as other sources were regarded as diminishing or insufficient to meet rising demands. There was a strong sense that groundwater provides an unlimited resource, which may exhibit tendencies of decline, such as falling water tables, but that this simply means that deeper depths need to be reached. In the Maiduguri case, there is a recognition that water tables are falling - linked to observed changes such as the reported drying of Lake Chad over past decades - but a sense that such fluctuations are natural. In Lagos, there is a similar recognition of falling water tables, but here study participants argue that this does not mean there is an issue of water scarcity - using high levels of annual rainfall to bolster their case. In Nasarawa State, the public view is that the supply of groundwater is inexhaustible. Despite drilling contractors reporting an observed decline in the level of the water table in and around the town of Lafia over a ten-year period, there appears to be little formal recognition (or awareness) of this in government bodies.

Overall, participants to the study reported that access to boreholes improves the security and resilience of households. Across all study areas it is apparent that households value access to alternative sources of water, which are readily available. Households are conditioned to seek security of their water supplies.

In rural areas, where community boreholes represent the only form of improved water source, the benefits were reported to be substantial. Boreholes reduce the time spent (by some) in collecting water and so both increase the amount of water available for use and frees up time for other activities. The main benefit of this was reported to be in increasing the time children were able to spend at school. Greater levels of water security, particularly in times of climatic stress were also reported, reducing levels of stress and anxiety. Similarly, availability of non-seasonal water sources equally led to an increase in a sense of greater security.

In urban areas, where alternative forms of water are available, the gains from developing domestic boreholes by households were less remarked upon. The reliability of a source, particularly one which they had control of through moving to a their own borehole, proved to be highly valued, coupled with a greater (perceived) certainty regarding the quality of the source. Many households reported that their own borehole gave them a greater certainty of supply (and left them less susceptible to the vagaries of potential disruptions to supply). For many, the lower costs of accessing water through their own borehole also provided an economic benefit, especially where some households make a commercial return on their borehole. However, in many cases households

reported that their borehole was available to neighbours, arguably raising the water security (and so potential resilience) of the wider community. Time savings gained through increasing convenience are less remarked upon within the urban environment, owing to the proximity of multiple alternative options, although these were still present where sources might involve time spent queuing. Similarly, security gains (reducing risks of crossing roads whilst collecting water, reducing risks to women whilst collecting water) were less often remarked upon but still arose.

Across the study areas it appears that households are seeking to strengthen their resilience to short-term events in the present, there is very limited consideration of longer-term time horizons.

4.1.11 Role of governance²

Numerous bodies have responsibility for groundwater management in Nigeria. They include Federal government agencies such as:

- Nigeria Hydrological Services Agency (NIHSA) whose mandate is water resources (groundwater and surface water) assessment of the country; its quantity, quality, availability and distribution in time and space
- Nigeria Integrated Water Resources Management Commission (NIWRMC) that is responsible for regulation of water use and allocation
- The state Ministries of Water Resources and their Rural Water Supply and Sanitation Agencies (RUWATSSAN), responsible for provision of water to their various States
- All the River Basin Development Authorities, which are also parastatals of the Federal Ministry of Water Resources involved in the provision of water supply to rural environments within their catchments.

Within each State there is also a range of bodies with responsibilities over varying aspects of the groundwater resource. This has led to a situation of fragmentation of responsibilities and, to a certain extent, ambiguity in operational delivery. In practice this has meant that there is a lack of substantive regulatory oversight. Contributing to this lack of oversight is the absence of an over-arching legal framework at the Federal level. Legislation governing the development of groundwater reserves of domestic water supply has been developed, including the Water Resources Decree 101 promulgated in 1993

²Much of the factual data here is drawn from the African Groundwater Atlas (<http://www.bgs.ac.uk/africagroundwateratlas/index.cfm>).

(now referred to as Water Resources Act 100). However, as of 2017, this Act remains under review and awaiting enactment at the Federal level. The Water Resources Decree is regarded as out-dated and - in so far as it pre-dates the proliferation in domestic borehole development - is regarded as inadequate in its regulation of this trend. This has created a situation of paralysis where Government bodies are conscious of a vacuum in policy and so feel unable (and unresourced) to act.

Government bodies also appear unwilling to act, even where they may have legislative power. Many officials take the view that as government has proven unable to supply water to households, it would be wrong for them to act to stop households from securing their own water supplies, even if they had the means to do so. In a telling, and very public example of this, the Lagos State Government reviewed environmental legislation in 2017, and included the need for owners to register private boreholes. Faced with a substantial negative press reaction and popular alarm the Governor went on record to stress that, despite the reports that this applied to all private boreholes, this would apply only to private boreholes that were commercially operated, not to domestic boreholes. In other examples from this study, state officials have openly commented that it would be wrong for them to restrict the development of boreholes by households, when the government is unable to supply them with water.

Responsibility for monitoring the amount of water abstracted and its quality is also widely distributed and, arguably, largely overlooks domestic boreholes.

In terms of water quantities, the Nigeria Hydrological Services Agency (NIHSA), an agency of the Federal Ministry of Water Resources, has responsibility for groundwater monitoring. There is a national groundwater level monitoring programme with 43 monitoring points, 32 of which are equipped with data loggers. These are sited in basement and sedimentary aquifers. The frequency of monitoring at sites with data loggers is daily, and sometimes twice daily. Although, in Borno State (Maiduguri) only 3 stations have been commissioned and data is available only up to 2010. Many observers also suggest that 43 monitoring points are insufficient for a country the size of Nigeria. There were a higher number of monitoring wells in the past, but many of these were adapted to water extraction, as maintaining boreholes solely for monitoring purposes was reportedly difficult politically.

More recently, NIHSA has implemented a programme of drilling new monitoring boreholes for monitoring groundwater level. The new boreholes so far are focussed on sedimentary aquifers used for urban water supply; with borehole depths of 80 to 100 m (Ministry of Water Resources 2013). The groundwater level monitoring data are stored at NIHSA headquarters in Abuja.

The NIHSA is also responsible for water quality monitoring, but as yet a full programme is not in place due to lack of equipment. The National Water Resources Master Plan recognises current problems in the effective acquisition and management of groundwater data, and recommends strategies for improving this situation (Ministry of Water Resources 2013). However, action on this remains to be undertaken.

4.1.12 Role of communication

Communication sources on the theme of groundwater are limited. Many households tend to rely on respected contacts (such as elders, traditional chiefs or community leaders) for their information. Other common sources of information are health visitors, but this tends to focus on health related issues, particularly regarding waterborne diseases in rural areas.

Media sources such as radio, newspapers and television tend to be restricted to urban areas, or to particular segments of a community (often male) and can depend on levels of literacy. Even where media sources are available the coverage of groundwater themes tends to be restricted.

News media situated within the public sector appear to be suffering from a serious credibility problem where the coverage of water issues is concerned, effectively amounting to the perception - amongst the journalists interviewed - this type of reporting recurrently reflects government interests and priorities. 'Public broadcasting reports what the government wants to hear,' one interviewee stated bluntly (Journalist 2, Lagos). In contrast, private sector media were regarded as being relatively independent, and thereby better able to pursue news stories with greater vigour. 'We (private sector) have the opportunity to go in to households directly,' a Community Radio reporter (Journalist 1, Lafia) stated. 'There was a flood 2 weeks ago and we reported live as it is, as the case is, without embellishment. That is how media can step in in issues of quantity, quality and the supply of water.' Still, other interviewees expressed scepticism, observing that private media companies are reliant upon government advertising spend, which similarly influences what gets covered, how and why.

The importance of reporting on the issues confronting the country's water supply was readily acknowledged, at least in principle, although in practice the extent to which coverage influences people's personal choices was considered problematic due to practical circumstances. Boreholes, it was pointed out, are borne out of necessity, rather than by choice amongst alternatives. 'Media don't really cover domestic boreholes,' Journalist 1 (Lagos) remarked. 'When people are boxed into a corner they don't really have a choice about what they can do.'

They just dig their own borehole to get water.’ Moreover, in the absence of choice, concerns over possible water contamination – whether publicly supplied, drawn from a borehole in the local vicinity, or even packaged and sold where counterfeit bottles circulate – similarly fail to claim a purchase in news reporting. ‘If people don’t have a choice in the water they use – how do you write about this and tell them their water is not good quality?’, one journalist interviewee wondered aloud. ‘They will ask you a question – what choice do you think we have? That is the problem we face’ (Journalist 2, Lagos).

Given these longstanding concerns, journalists are unlikely to see sufficient novelty value in water issues to justify regular, in-depth coverage. ‘It’s not new, it’s not news,’ one interviewee observed (Journalist 1, Lagos). Sadly, one exception proves this general rule, namely where the spread of disease arising from water contributes to child mortality, which can sometimes garner attention due to public sympathy. More typically, however, the journalists interviewed struggled to remember the last time they read anything about the quality of water supply in the press. In addition to the other factors highlighted above, newspaper stories tend to be framed in ways which speak to the interests of those with the financial means to be regular readers, effectively precluding those living in slums or rural areas where water issues are most controversial.

How, then, to broaden the scope of news reporting when water issues are at stake? One potential story angle which surfaced in the interviews revolved around the prospect of exploring the significance of boreholes/groundwater for wider concerns about global warming. Even in this case, however, interviewees were sceptical it could be made to figure within journalistic framings with sufficient prominence. In the words of one journalist:

‘If I go to my boss and say I want to write about how climate change may affect those living or working on the coast, he will say oh really? Have you talked about health? have you talked about economy? These are immediate issues, why are you not talking about them? People want to talk about the immediate problems, the immediate issues... which is normally health, economy or corruption (Journalist 2, Lagos).

Evident here and in related statements by this study’s interviewees is a journalistic disconnect between the global and the local. While the importance of debates over global warming amongst policymakers in Lagos was recognised (issues such as deforestation, vehicle emissions, and generators being cited by way of examples), it does not readily translate into news stories with a community dimension. This disconnect is compounded by difficulties in identifying and securing local sources with sufficient expertise to offer relevant

data and informed opinions. Where qualified experts are unavailable (expertise understood in relation to experience in the field, involvement in technical design of water technologies, or possession of a pertinent academic qualification or position), other journalists may be called upon to provide supplementary detail. One risk in this regard, of course, is that conventional narratives end up being reaffirmed, even reinforced.

Journalists clearly struggle to render the water infrastructure visible for their audiences. There is some evidence in the interview data to suggest the slow pace of government action undermines reliance on community solutions, with the latter relying on a greater degree of public discussion than is typically afforded by news media. Where newspapers are concerned, one interviewee maintained, water issues typically receive scant attention, albeit with some exceptions. 'Newspapers report on quality and availability of public water supply,' Journalist 1 (Lagos) stated. 'About people getting cut off because of pipe damage, and the time it takes to reconnect. That makes a good news story.' In the case of sachet water, however, it is more likely to fail the test of newsworthiness. 'That's not a news story,' Journalist 1 (Lagos) continued, even though a lack of adequate policing of those producing sachet water clearly warrants investigation.

Government corruption is cited as a contributory factor in this regard, with private companies able to elude close regulation and monitoring. Few questions are asked about qualifications, or quality controls – what matters, it seems, is whether or not they are successful in bringing out water. Intent on maximising their profits, these entrepreneurs typically seek to minimise expenses associated with the purification process, leading to a low standard of water quality. Even then, however, it is unlikely they will be subject to criticism in the media. '[T]he way the media views the private developers/producers is they're actually serving a purpose that the government has failed at,' Journalist 2 (Lagos) pointed out. 'So it's kind of like the media is also enamoured of the private producers. So if they're saving the day why would you criticise them?'

More positively, cautious optimism was expressed regarding the potential of social media to focus and direct public interest in news stories otherwise proving difficult for journalists to establish on policy-makers' agendas. Similarly, recent growth in community journalism appears to be encouraging the mainstream media to be more responsive to local issues. 'Community journalism could make a difference, could do a lot, would change things a lot,' Journalist 2 (Lagos) believes, but such initiatives are in early stages of development, and face intense resource challenges.

4.2 Findings of Household Survey

In order to better inform our understanding of individuals' perceptions, choices and behaviour in relation to groundwater supplies, a survey questionnaire was undertaken of members of the public in Lagos, Nigeria, in April and May 2017. Quota sampling was utilised in order to obtain as representative a sample as possible in terms of age and gender. The final survey sample comprised 539 individuals. Descriptive statistics are accurate to within +/- 4% for a 50% finding and to within +/- 2.5% for a 90% finding (95% confidence intervals)³. Potential biases within the sampling frame mean that the results should be treated as strongly indicative rather than providing a definitive description of the prevalence of household boreholes (for example) across Lagos State.

The survey was administered online using survey panels; these are individuals who have previously signed up to participate in online surveys, usually for small cash incentives. The questionnaire was structured using mostly closed-ended items, with several open-ended questions also used where spontaneous responses were sought.

Survey respondents were asked to answer questions relating to their use and attitudes towards a range of water supplies, with a particular emphasis placed on groundwater use. Respondents were also asked about their environmental risk perceptions and for demographic information. The questions were grouped into four broad categories:

- Use of and attitudes towards water supplies (general)
- Use of and attitudes towards groundwater supplies
- Environmental risk perceptions
- Demographic variables

Across the sample, around half (51%) of survey respondents – 277 of the sample of 539 – reported that their main source of water was their own private borehole. A little over a third (36%) reported that their main water source was a borehole shared with others, with 13% reporting that they did not have regular access to a borehole or mainly used other sources⁴. Of the demographic factors

³This is based on a sample size of 539 and a population estimate for Lagos of 14 million, and assumes that the respondents are randomly sampled from the wider population. Given that the survey is completed online, however, caution should be exercised as to its alignment with the general population of Lagos, particularly in terms of income and associated factors (e.g. household ownership, location).

⁴ It should be noted that these figures vary with respect to others given subsequently in the report. For example, whereas half the survey sample reports that their *main* source of water is their own private borehole, elsewhere we note that three-quarters use a private borehole on at least a monthly basis. This likely reflects that some households have access to their own

measured (age, gender, income, home ownership, home type, household size), only home ownership and home type (house with garden/land) are significantly associated with private borehole ownership. We find no association between income, gender, age, or household size and borehole ownership.

The median age of private boreholes was between 5 and 6 years, with a small proportion (14%, excluding 'don't know' responses) being over 10 years of age, demonstrating the recent onset of this trend. The typical depth of private boreholes was between 100 feet and 200 feet (30 metres to 60 metres) and so taps into the middle aquifer of Lagos.

Contractors were typically identified through word of mouth: 80% of those with private boreholes reported that people they knew told them about the contractor used to carry out the work. Relatively small proportions of people (less than 10%) chose their contractor through seeing their advertisement, or having asked several contractors to quote for the work. Around two-fifths of relevant respondents stated that the contractor was officially certified and that an independent professional supervised the drilling of the borehole, suggesting that in more than half of the cases this was not so.

Our data suggest that whereas people's access to their own private borehole is commonplace, nevertheless this water source is often made available to others. Close to four in five (79%) of those whose primary water supply is their own private borehole make this available to neighbours; around a fifth (19%) make the supply available to others in the community. Most do not charge for access to their own private supply (90% said they did not do so) although others did so at times.

Amongst households, there is a strong awareness that the siting and physical condition of a borehole can affect the quality of the water provided. Responsibility for the quality of water emanating from a borehole is strongly regarded as the resting with the owner, with only 15% of respondents regarding it as the responsibility of government. Overall, the vast majority of those with their own private borehole, or access to a privately-owned borehole, agreed that they could rely on both the quality and supply of water from this.

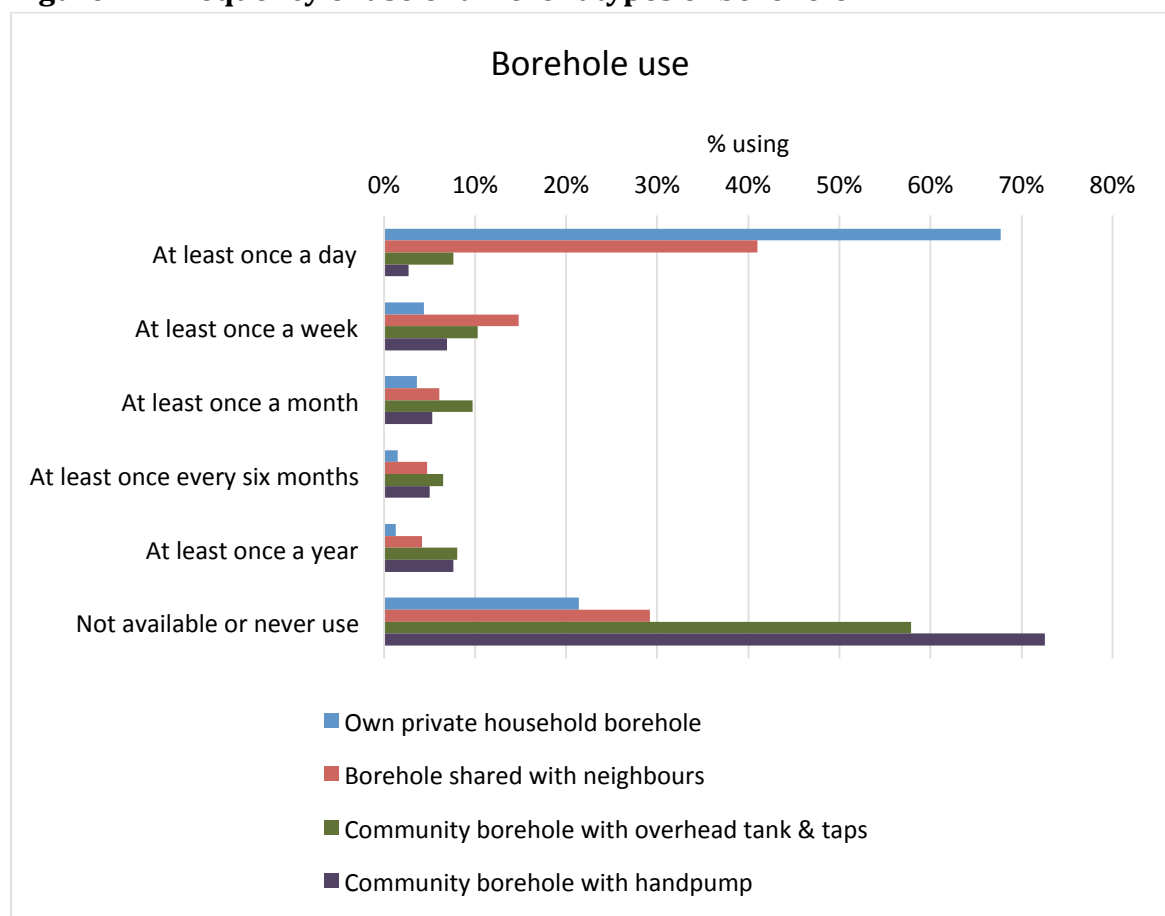
Aspirations to own a borehole are strong. Among those using a borehole shared with neighbours and other households, almost all (98%) stated that, if circumstances allowed, they would like to install a private borehole on their own property. Similarly, among those who did not have regular access to borehole

borehole, but do not use it as their primary water source. For example many of those with access to their own borehole do not typically use this to provide drinking water.

water, a majority (90%) stated that they would like to install a borehole if circumstances allowed; just 9% stated that they would not like to do so.

Most respondents with access to a private borehole make use of this on a regular basis (Fig. 4.7). Around two-thirds (68%) of respondents reported making use of their own private household borehole on a daily basis; two-fifths (41%) make daily use of a borehole shared with neighbours – either as well as, or instead of their private household supply. It is noticeable that use of community-boreholes tends to be on a less frequent basis, with a large proportion of the sample reporting that they never use such sources.

Figure 4.7 Frequency of use of different types of borehole.

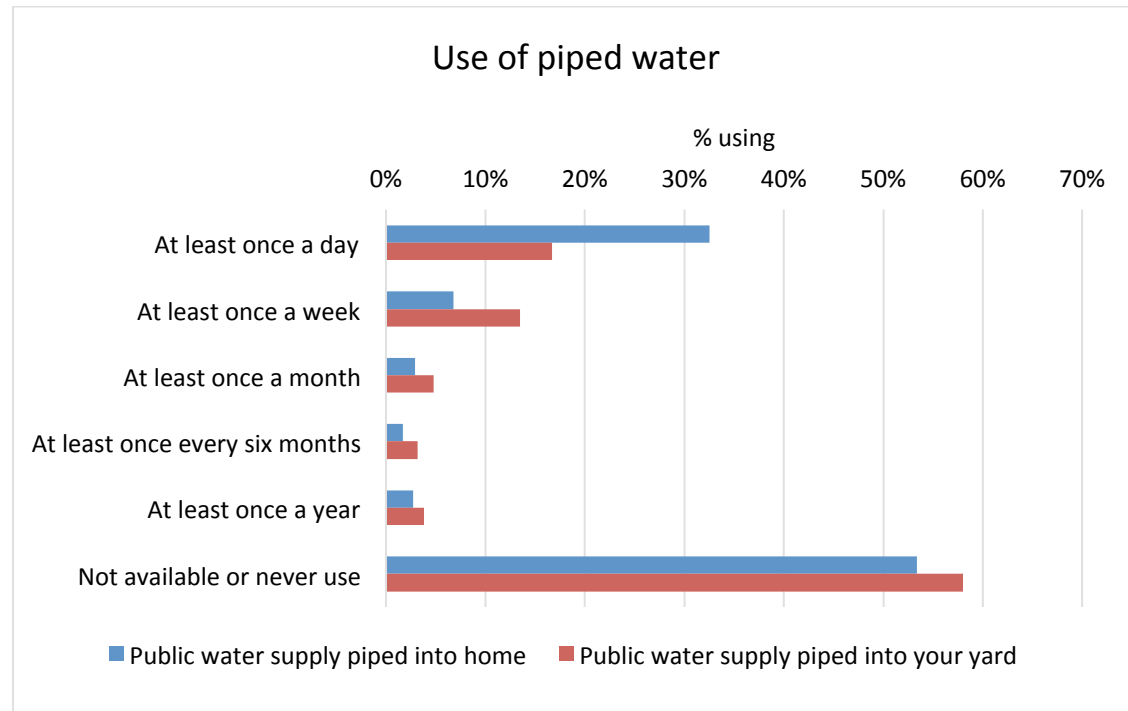


Access to a piped water supply was less common than water obtained through private or shared boreholes (Fig. 4.8). Nevertheless, in this survey sample at least, around a third of respondents (33%) indicated that they used a public water supply piped into their home on a daily basis⁵. Around one in six

⁵In testing this data with representatives of NGOs, community groups, academics and public officials there was a strong criticism of this result, with most suggesting that less than 20% of Lagosians have access to piped water. If this is so then the sampling frame may have over-sampled connected households – which makes the figures for privately-commissioned boreholes more striking.

respondents (17%) indicated that they made use of a public water supply piped into their yard. It should be noted however that for the most part these represent the same individuals (most of those completing the survey had access to both forms of piped water supply, or neither).

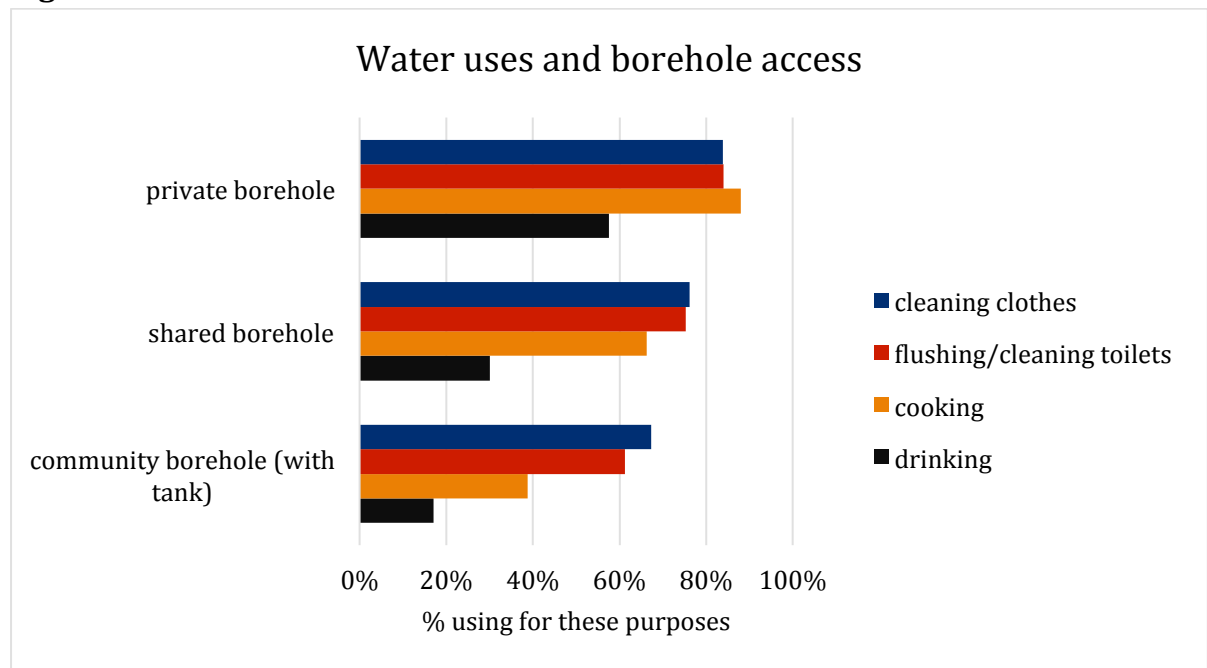
Figure 4.8 Piped water use



A very high frequency of use of pre-packaged drinking water, in the form of sachet and bottled water, was also reported. Further analysis of survey data indicates that almost all survey respondents (95%) use sachet water and/or bottled water at least once a week.

Regular users of private boreholes are more likely drink this water, compared to those regularly using boreholes shared with neighbours (Fig. 4.9). Water from community boreholes is least likely to be used for drinking purposes. Households are also more likely to drink the water taken from a private borehole than water taken from public piped supplies.

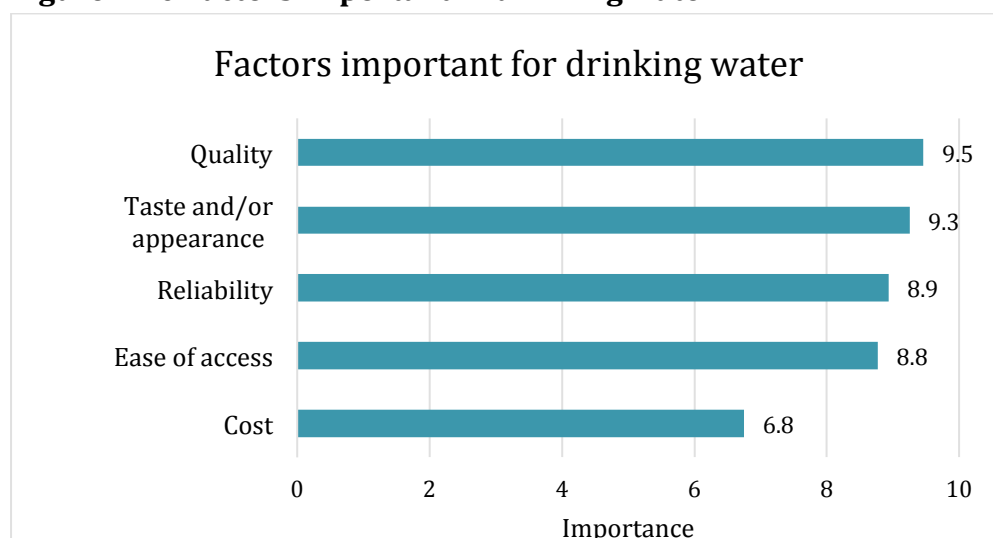
Figure 4.9 Water uses and borehole access



In common with the uses to which private borehole water supplies are put, the most common uses of piped water supplies were for cooking, flushing/cleaning toilets, bathing, and for cleaning dishes as well as clothes. Around 80% of those regularly accessing water piped into their home use their water for these purposes. By contrast, only around a third (35%) of those with regular access to piped water in the home use this for drinking purposes.

Respondents considered several factors in their choice of drinking water. Quality, taste/appearance, reliability and ease of access were all rated as very important (around 9 on a 10-point scale; Fig. 4.10). Cost was rated as somewhat less important, at 6.8 on the importance scale.

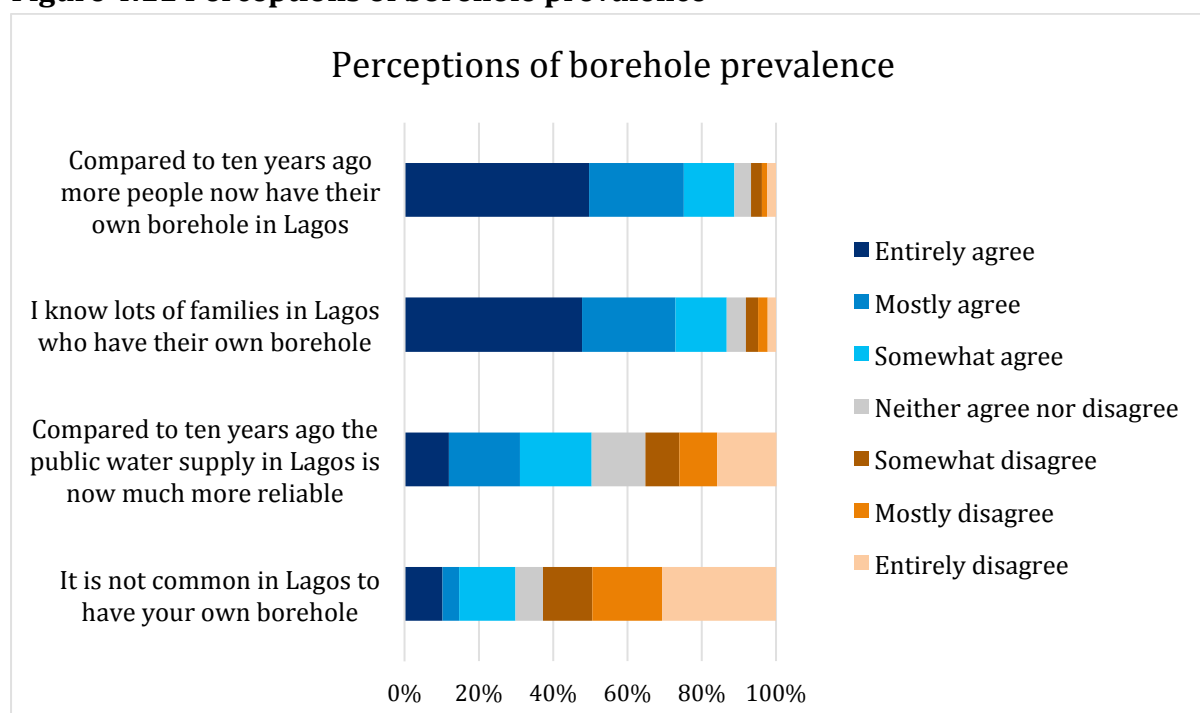
Figure 4.10 Factors important in drinking water



Most respondents report some form of household water treatment. Boiling was the most common practice for treating water, used by three in five respondents. Just under half the sample used a water filter, while one in five let water stand and settle or added bleach/chlorine to treat it. Notably, nearly one in five (17.8%) do not treat their water at all. Comparing those with versus those without their own boreholes, we see some differences in water treatment practices. Specifically, those *without* their own boreholes are significantly more likely than those with one, to boil their water (65% versus 55%; $p=.02$) and to let it stand (25% versus 14%; $p=.001$).

Respondents identify a rising trend in the prevalence of boreholes. Most (89%) agreed that more people have their own boreholes now than did ten years ago (Fig. 4.11); similarly, 87% agreed that they know lots of families in Lagos with their own borehole and 64% *disagreed* that it is uncommon in Lagos to have your own borehole. In contrast, only half the sample (50%) agreed that the public water supply is more reliable now than it was ten years ago.

Figure 4.11 Perceptions of borehole prevalence

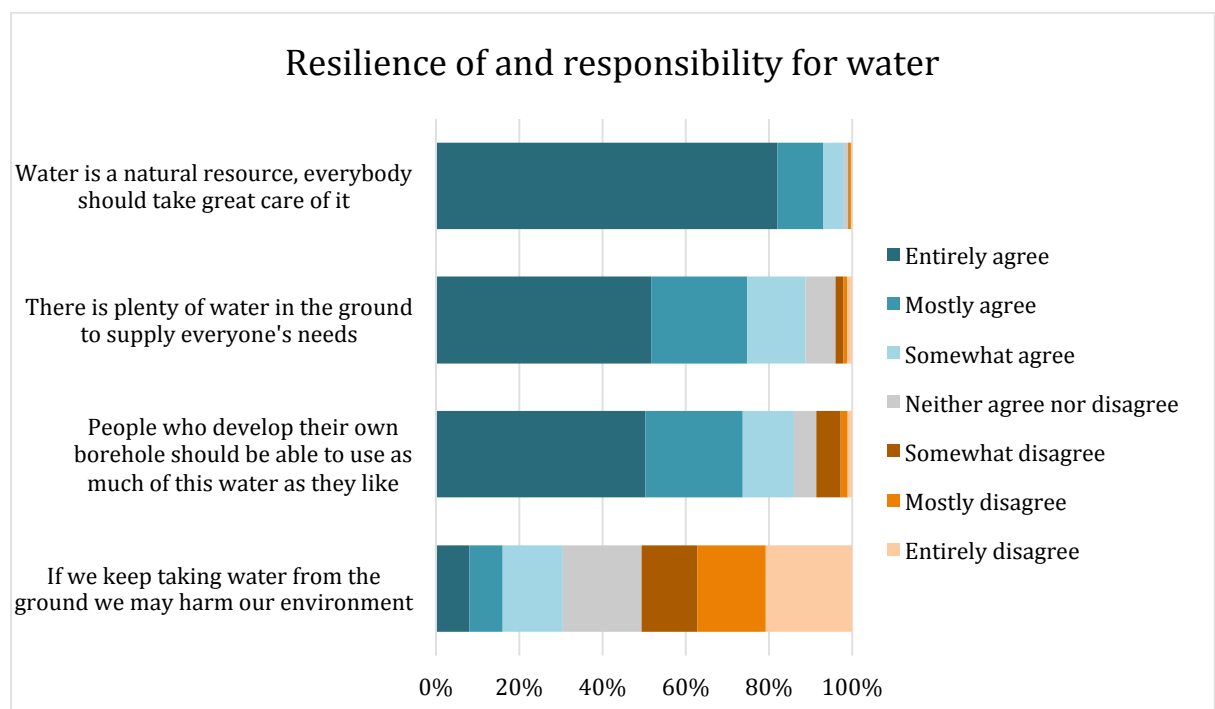


Almost all respondents (95% total agreement) agreed that ‘access to private a borehole helps families cope with possible water shortages in the future’ (Fig. 19), and nine out of ten (90%) agreed that most people would prefer their own private borehole. This compares to 62% who agreed that most people would prefer to be connected to the public water supply and only 33% who agreed most would prefer to buy water from private vendors. What comes through very

strongly in the survey is the sense that access to your own borehole provides a level of independence, control and water security for your household, as well as an (perceived) assurance of water quality and cost-effective access to water.

Respondents explicitly endorsed the view that water is plentiful and only a minority were concerned about over-abstraction (Fig. 4.12). There was not widespread agreement, however, that groundwater supplies were resilient to risks of contamination: under half the sample (46%) agreed that ‘there is little risk that underground water in Lagos will become contaminated’. Similarly, around half (51%) the sample agreed that is ‘little risk that the public water supply in Lagos is contaminated’.

Figure 4.12 Perceived resilience of groundwater supplies and responsibility for its maintenance

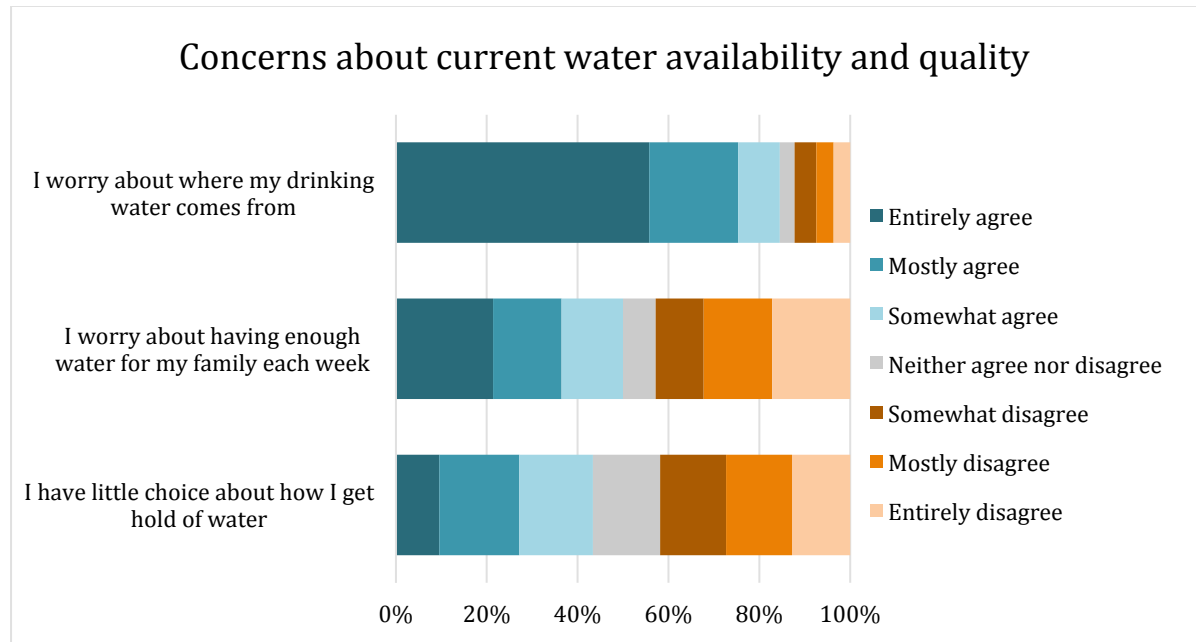


Consistent with the narrative of a water crisis in Lagos, most respondents worried about where their drinking water comes from (85% total agreement; Fig. 4.13), while half had immediate concerns about sufficient water for their family each week (50% agreement). Slightly fewer stated they had little choice over how they get their water (43% agreement), suggesting most have some degree of choice about their water source.

Looking at what might predict these attitudes, climate change concern is a significant predictor of worries about where drinking water comes from, having enough water each week, and having any choice about where to get water. That is, those more worried about climate change are also more worried about these

more immediate concerns. Home ownership and income are also negative predictors of worry about having enough water each week. Women are less worried than men about where their water comes from. Borehole ownership negatively predicts two of these concerns: having enough water each week, and worrying where their water comes from. Consistent with the positive attitudes towards boreholes expressed earlier in the survey, it seems owning a borehole mitigates general water-related worries.

Figure 4.13 Concerns about current water availability and quality



4.3 Findings of survey of water professionals

The strong progress made towards the global goal of securing access to safe drinking water for all across has often been secured through increasing exploitation of available groundwater reserves, particularly through the development of water wells, or boreholes. Across Africa, many countries are also experiencing a widening proliferation of boreholes commissioned privately by households, particularly in urban areas. This reflects the falling costs of accessing groundwater reserves, rising incomes and the greater availability of relevant drilling capacity and other expertise, as well as deficiencies in public water supplies.

The implications of the rise in private boreholes have not yet been fully considered. To address this question a survey of professionals working in the field of water supply was undertaken, drawn from the membership of the

international Rural Water Supply Network⁶. The survey was administered in French and in English to achieve a wider coverage.

The survey was open for two weeks during May 2017 and a total of 92 responses were completed from 25 countries across Africa. Country responses were broadly distributed, with a focus on Sub-Saharan Africa (Figure 4.14).

Figure 4.14 Distribution of respondents (in green).



Map created in mapchart.net

Responses demonstrate a relatively even split between those referring to urban areas (32%), rural areas (30%) and mixed urban-rural geographies (38%). The largest proportion of respondents to the survey identified their employment as an NGO (30%), closely followed by the private sector (25%). Government (15%), international bodies (14%) and academia (12%) were also well represented amongst respondents.

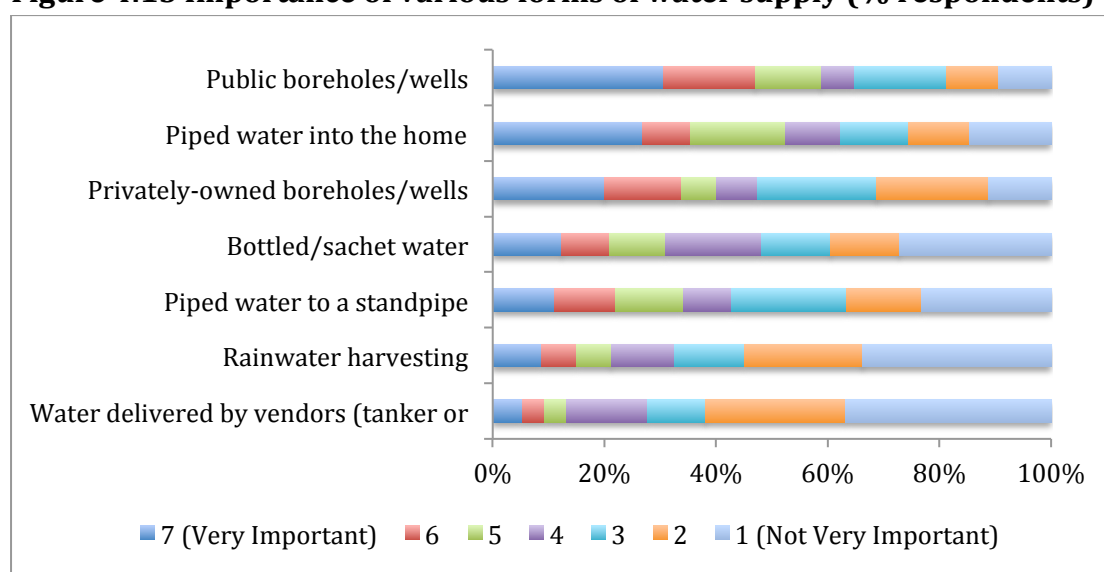
The research sought to explore 5 key themes:

- The perceived importance of different forms of household water supply
- The observed significance of groundwater resources for household water consumption
- The perceived trend in the development of boreholes commissioned directly by households
- The perceived risks and opportunities this offers
- The procedures in place for managing and monitoring groundwater resource use.

⁶The Rural Water Supply Network (RWSN) is a free to join global network of more than 10,000 professionals and practitioners working to raise standards of knowledge and evidence, technical and professional competence, practice and policy in rural water supply. It is supported financially by the African Development Bank, IRC, Skat Foundation, Swiss Agency for Development and Cooperation, UNICEF, WaterAid and World Bank Group.

The findings of the survey are informative, indicating the important role that privately-commissioned boreholes now play in domestic water supply across much of Africa (Figure 4.15). This is particularly so in non-rural areas, where it is almost as significant a source as public piped water supplies. The survey emphasises the strong preference of households for having access to their own borehole and demonstrates the rising trend anticipated in the number of households accessing water through their own boreholes.

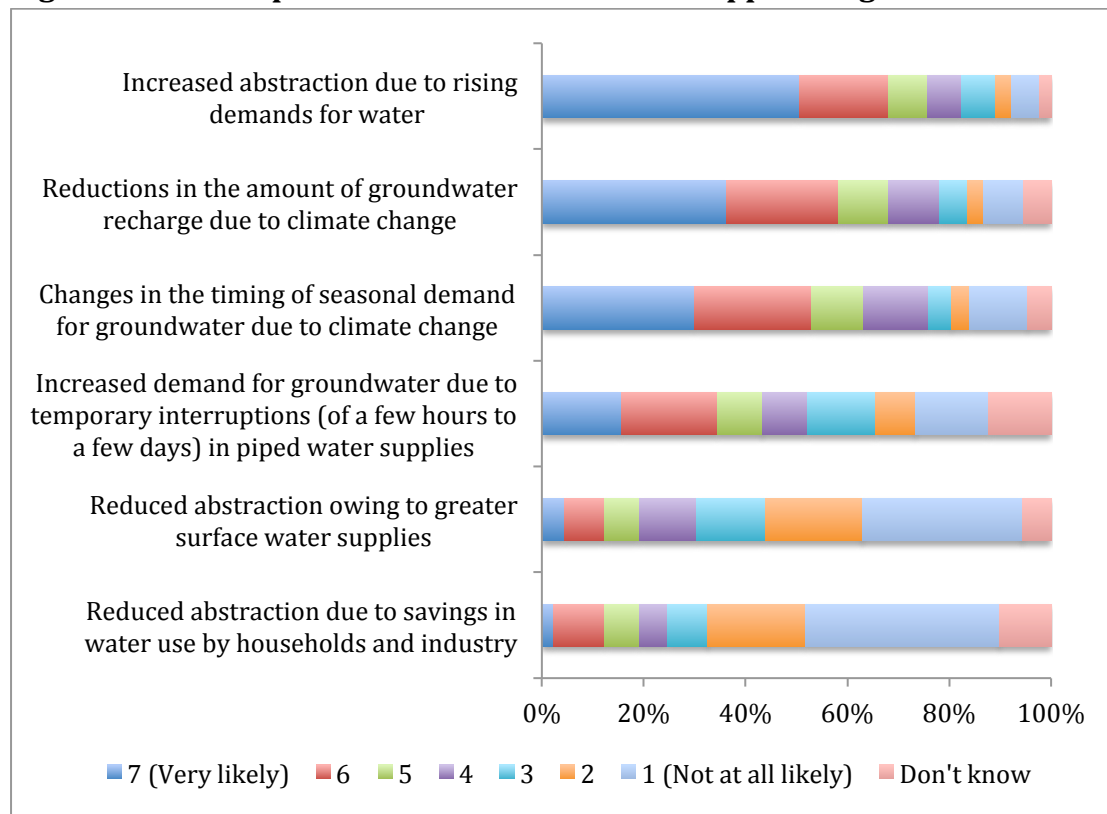
Figure 4.15 Importance of various forms of water supply (% respondents)



It is striking that 76% of urban respondents foresaw an increase in the proportion of households using private boreholes over the next 10 years, compared to 60% of respondents commenting on mixed urban-rural areas. Interestingly, 68% of respondents commenting on rural areas also foresaw an increase in the use of private-boreholes by households in their areas, suggesting that the trend is not solely restricted to urban areas.

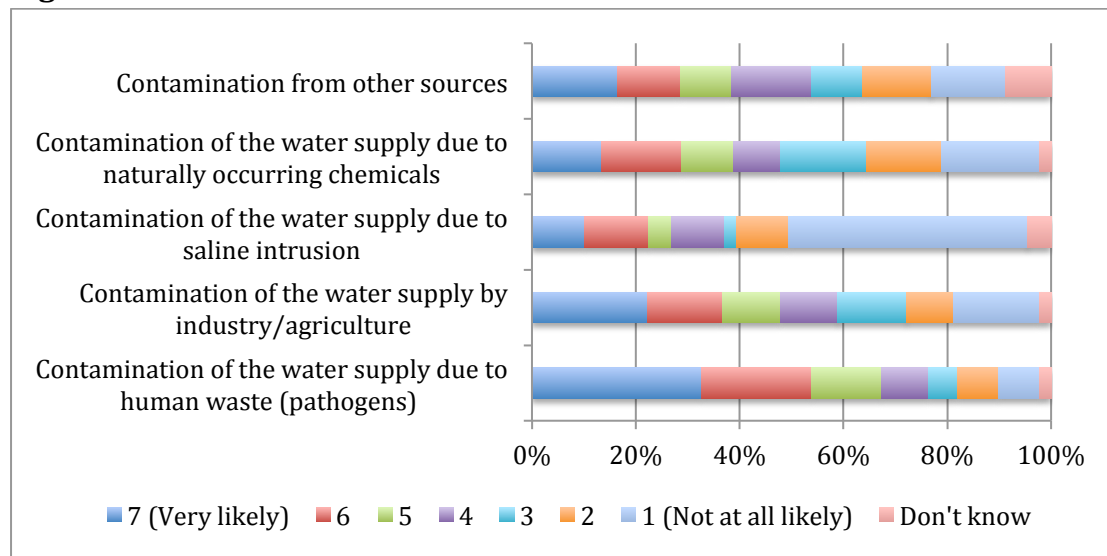
The survey also reinforces the significant role played by groundwater reserves in domestic water supplies, which is linked to the important role played by boreholes in water provision. Significantly, whilst the demand for groundwater is anticipated to rise, the amount of groundwater available is expected to fall. The majority of water professionals report that they have a very strong professional concern for the amount of groundwater available in their area over the coming 10 years. This is partly due to the increased rates of abstraction predicted, and to expected falls in the level of recharge, coupled with changes to the timing of seasonal demands (Figure 4.16).

Figure 4.16 Anticipated trends in demand and supplies of groundwater



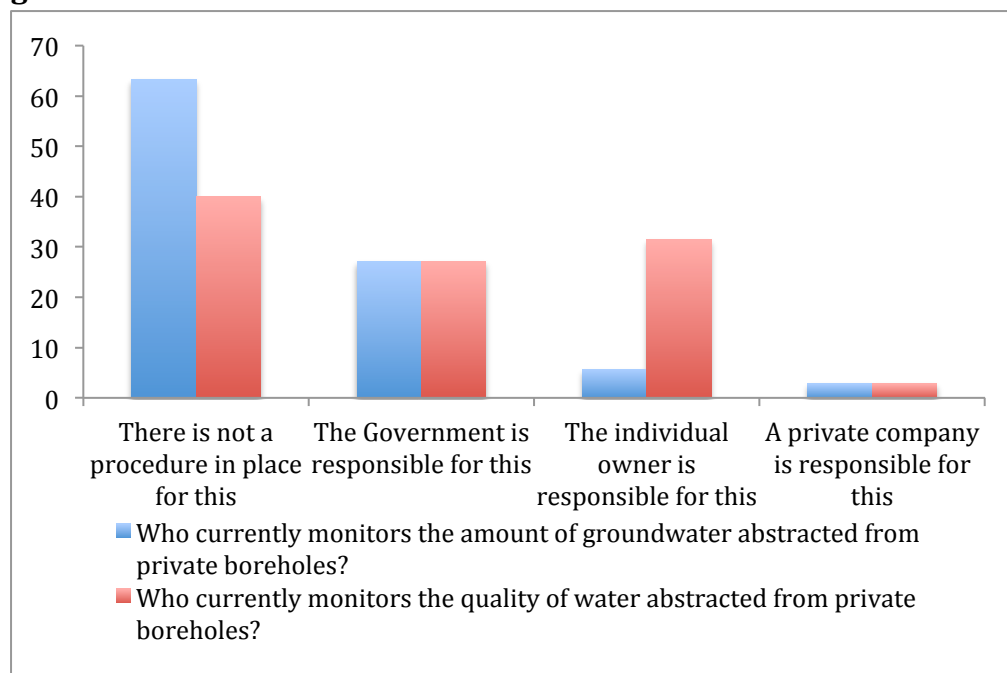
Respondents to the survey express concern regarding the risk of contamination to domestic water supplies. Whilst groundwater supplies are regarded as slightly more at risk than public water supplies, both are regarded as vulnerable. The main concern relates to the risk of pathogenic contamination from human waste, although other risks are also identified. Concerns for the future quality of groundwater supplies are particularly acute, with 86% of respondents expressing their professional concern. In contrast, less than 10% stated that they are not concerned. It is apparent (Figure 4.17) that the strongest risk factor is perceived from human waste (pathogenic) followed by other anthropogenic sources, particularly industry and agriculture. The risk of contamination from naturally occurring chemicals (geogenic) is widely recognised but is seen likely to occur in fewer cases. Contamination from saline intrusion is regarded as least likely, possibly reflecting its geographical determinants.

Figure 4.17 Perceived likelihood of different contamination sources



A key finding of the survey is the limited governance arrangements for privately-commissioned boreholes and groundwater supplies (Fig 4.18). Most respondents report that government authorities do not have a good knowledge of the number of private boreholes sunk in their area. The majority also report that there is no procedure in place for monitoring the amount of groundwater abstracted from these boreholes.

Figure 4.18 Responsibility for monitoring the quality and quantity of the groundwater resource



Similarly, two-fifths of respondents reported that there was no procedure in place to monitor the quality of water sourced from privately-commissioned

boreholes and almost a third reported suggesting this was the responsibility of the borehole owner. Less than a third of respondents reported that government authorities were responsible for monitoring the quality and the quantity of water abstracted from such boreholes in their areas.

According to the majority of survey respondents, the skills and expertise to drill domestic boreholes are generally available, although this is often not regulated by the state. However, almost a third felt strongly that the necessary skills and expertise is not available. Respondents also suggested that although households would often choose to use contractors that were not certified by government authorities, contractors could normally be trusted to do a good job. However, the quality of the work undertaken by contractors for households is rarely subject to any quality checks by government authorities.

From the survey returns it is apparent that in many parts of Africa, boreholes that are privately-commissioned by households are becoming an important means of augmenting (and potentially supplanting) publicly provided water supplies. Around half of the survey's respondents reported that they felt that privately-commissioned boreholes, operated by individual households or community groups, could form a part of their city, town or municipality's water supply system in the future.

5. Conclusions

Water security is one of the most pressing risks facing the world. Even as we move closer to meeting the Sustainable Development Goal of securing access to water for all, rising populations, ecosystem pressures, and changes in climate are heightening levels of insecurity. Our work has illustrated that one of the means that households are using to overcome their sense of water insecurity is to invest in their own borehole for domestic water consumption. This is most clearly apparent in our survey of households in Lagos, where two-thirds of respondents report using their own private borehole at least once a day. Less than a quarter of respondents reported that they had no access to a private borehole. Similar trends are reported across Africa by professionals working in the water supply sector, suggesting that this is not an isolated example.

The factor underpinning this proliferation of boreholes is firmly identified as a failure of government to otherwise provide water to households, either in terms of their failure to connect households to a public supply, or their failure to ensure a guaranteed supply of water through the public supply. Whilst this is undoubtedly a factor, other drivers identified include the falling costs (and expertise required) of drilling boreholes and a widening of the pool of expertise

available; ease of access to groundwater in particular hydrogeological environments; a permissive institutional environment and the assets available to households (in the form of incomes, access to credit and possessed property rights). It is the intersection of these forces that determines the propensity for borehole development in any given location.

One (often unremarked) side-effect of the proliferation of boreholes and the weak oversight of the construction process is the associated rise in the number of abandoned boreholes. These tend to remain uncapped and offer a potential source of contamination of subsurface resources. The scale of this issue is suggested by anecdotal reports by the Lagos State Water Commission suggesting that the number of abandoned boreholes is around double the number of functional boreholes in the State.

Whilst a proliferation of borehole development is reported in urban, rural and mixed urban-rural areas, the scale of the development is much more significant in urban areas. In some urban areas, such as in Lagos, privately-commissioned domestic boreholes are now so ubiquitous that it is not overstating the case to suggest that they now form a key part of the domestic water supply infrastructure for the city. Indeed, in Lagos, it would appear that the data suggests that private domestic boreholes now supply a greater proportion of the population than is reached by the public water supply.

The proliferation of privately-commissioned domestic boreholes by households is a reported source of professional concern to many water professionals. In the survey they highlighted concerns both with the potential for contamination of the groundwater resource and the risks of over-abstraction. The experiential knowledge of the drilling community supports the fears of the professionals, reporting falling water tables and, in Lagos, localised contamination of the aquifers tapped by household boreholes. These concerns do not seem to be shared by households themselves. Households generally perceive the groundwater resource to be 'inexhaustible', although they do recognise that water table levels are falling, and have few fears of its contamination. Generally, groundwater drawn from a borehole is regarded as safe to drink, whilst that from a shallow well is less trusted. Trust in the quality of groundwater tends to reflect the extent of control over a source (with ones own source more trusted than a shared source) and taste.

In testing e. coli in water, 52% of the sources were classed as safe to drink, 16% as intermediate risk, 3% as high risk, and 29% as very high risk, according to WHO guidelines. Our results demonstrate that whilst water drawn from boreholes tends to be more likely to be safe to drink than that drawn from shallow wells, this is not always the case. The perceptions of households of the

quality of their water source is complex. Some 70% of sources that failed the WHO drinking water quality standards are perceived to be 'good quality' by users. Given the low incidences of household water treatment practices this may be a cause for concern. However, there is also evidence that water drawn from hand-dug wells is less often used for drinking purposes, which may demonstrate an appreciation by households of the risks involved and the relative quality of this water compared to that available from boreholes.

This raises the question as to where households get their information from. From the community discussions it is clear that the main sources of information are from family and respected members of the community. Traditional media sources do not have a strong reach, and tend not to cover the topic of groundwater quality or quantity. Many respondents were well informed regarding the risks of water borne diseases, with health visitors and health campaigns playing an important role in spreading this message. There was also good awareness of the importance of the siting of a borehole, although this knowledge often seemed to be held in the abstract rather than forming a strong guide to practical action.

The lack of a wider discourse around the development of groundwater supplies, particularly through the commissioning of household boreholes, is significant given the weak groundwater governance arrangements identified across the RIGSS project. In the pilot studies, the survey of households in Lagos and the survey of water supply professionals there was a strong message that there is very little monitoring or management of the development of domestic boreholes by households, nor of the implications of this for the groundwater resource. In terms of water quantities, there seems to be very little by of monitoring or management procedures in place, raising questions as to the vulnerability of supplies to increasing levels of abstraction. Whilst the quality of the water supply emanating from a domestic borehole was widely regarded as the responsibility of the individual borehole owner.

From the finding of the study a number of important conclusions begin to emerge regarding the resilience of communities to future environmental shocks, including some emergent tensions and trade-offs. At the first level, the development of boreholes to access groundwater resources is certainly enhancing the resilience of communities.

In rural communities, particularly those previously reliant on unimproved sources such as rivers, streams and springs, the development of boreholes is providing social, economic and health benefits which better equips households and communities to meet future shocks, especially as such traditional sources

are adversely affected by climate change and its implications (such as increased competition with herders).

In urban communities, where available surface waters tend to be very highly contaminated, domestic boreholes are helping residents to develop water security where public water supplies are unavailable or unreliable. Developing such a distributed system of water supply may make communities more resilient to a range of future shocks, including further failures of municipal supplies which tend to rely on impounded surface waters (as witnessed in Cape Town, South Africa in 2017/2018).

In developing their own supplies, households are demonstrating the role that adaptive behaviours can play in shaping resilience outcomes. As many households report that they willingly share (sometimes without charge) water from their own borehole with other members of the community, this trend is enhancing levels of community resilience at the current time.

However, our results suggest that this enhanced resilience may come at a cost. The first cost is that not all members of the wider community are able to benefit. In particular it appears that the urban poor, who have neither the income, access to credit nor the property rights that would enable investment in a borehole are, potentially, placed at a level of greater vulnerability by the actions of those seeking to reduce their own risks. One element of this may be where the income of the public water supply organisation falls as the proportion of a population paying water tariffs falls. The second cost, is that the unregulated actions of multiple households may be creating the conditions for the contamination of the aquifer on which domestic water supplies now depend. This may take the form of over-abstraction or contamination of the groundwater resource, or, potentially, both. In securing their immediate future households may then be creating the conditions for a future environmental shock and so are transferring risks forwards. Thus, we see a potential transference of risk and vulnerability both temporally and across socio-economic classes, which merits further exploration.

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