STOP THE ROT

Report I: Handpump reliance, functionality and technical failure

ACTION RESEARCH ON HANDPUMP COMPONENT QUALITY AND CORROSION IN SUB-SAHARAN AFRICA

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Cover Photo: Broken Afridev Pump Hook (*source*: Larry Bentley).

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ABBREVIATIONS AND ACRONYMS

BIS	Bureau of Indian Standards
CBM	Community-based Management
GI	Galvanised Iron
HPB	Handpump Borehole
IWMI	International Water Management Institute
JMP	Joint Monitoring Programme
MDG	Millennium Development Goals
MVWS	Multi-village Water Schemes
NGO	Non-governmental Organisation
RWSN	Rural Water Supply Network
SS	Stainless Steel
SSA	Sub-Saharan Africa
UNICEF	United Nations Children's Fund
UPVC	Unplasticised Polyvinyl Chloride
WASH	Water, Sanitation and Hygiene
WHO	World Health Organization
WPDx	Water Point Data Exchange

MAP SHOWING COUNTRY NAMES AND LOCATIONS

SUMMARY

In January 2021, *Ask for Water* GmbH and Skat Foundation, under the Rural Water Supply Network (RWSN), launched a 15-month initiative called 'Stop the Rot'. It set out to document the scale and extent of rapid handpump corrosion and the use of poor-quality handpump components in sub-Saharan Africa (SSA) and to bring about actions to address these problems. These two interlinked issues contribute to poor handpump performance, rapid handpump failure and poor water quality, all of which can result in abandonment of the handpump sources and thus force users to return to using contaminated or distant sources. These issues are recognised as problematic by some water sector practitioners and organisations but have in general been poorly documented.

Handpumps have revolutionised access to safe, reliable water supplies in low-income countries, particularly in rural areas. They provide a viable alternative to contaminated surface water, open wells and unprotected springs. The India Mark II pump and the Afridev pump are the two most common community handpumps in SSA, while the Vergnet pump is most likely the third most common handpump in SSA. The people of Zimbabwe rely on the Bush Pump. Based on analysis of the most recent data published by the World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) through the Joint Monitoring Programme (JMP), it is estimated that almost 200 million people in SSA (18.5% of the total population) rely on about 700,000 handpumps to provide them with their main drinking water supply. Of this, urban reliance is estimated to be 7.3% whereas rural reliance is 25.9%. Reliance is highest in Malawi, South Sudan, Zimbabwe, Guinea and Burkina Faso, ranging from 42% to 61% of the population.

Despite their merits, much criticism has been directed to handpumps. Limited ability to transport large quantities of water, coupled with a lack of storage capacity at the home, means that water from handpumps is usually fetched on a daily basis. Handpumps have also made the headlines: in 2010, only an estimated two out of three handpumps in SSA were working; a decade later it was estimated to have only improved to three out of four. When water services fail, there are negative impacts on health and other human development gains, not to mention the burden on users of finding alternative sources.

Interest in other technologies, particular solar pumps and motorised piped schemes for SSA, is growing. However, the handpump asset base in SSA remains considerable and makes a significant contribution to safe and reliable water supplies. An estimated 23% of the SSA population (about 230 million people) still rely on unsafe and distant water sources and many could benefit from a handpump. Moreover, not all hydrogeological settings can support abstraction rates that are much higher than that of a handpump; motorised schemes may consequently be even more challenging to maintain than handpumps. To avoid backsliding in terms of drinking water access, handpumps should be considered alongside alternatives.

There is ongoing interest in water point functionality, with a number of national estimates available that are based on different methods of collection and calculation. Despite the headline figures of non-functionality, there is need for caution in undertaking cross-country benchmarking. The headlines generated by the commonly used binary indicator (functional/non-functional) have stimulated interest and studies on handpump management and maintenance. However, functionality estimates do provide information on how handpumps are actually performing, or why sources are failing.

Tested ways of measuring performance include assessing a sample of sources and using a tiered approach that considers yield, reliability and water quality. In a sample from Ethiopia, for example, although 82% of pumps were working, and thus considered functional, only 59% provided sufficient yield and only 45% were also reliable. Grading water point sources in terms of water availability and other sub-categories is another means of measuring performance. In a sample from within Sierra Leone, 56% of water points were found to be functional, with 17% functioning poorly and in need of repairs or replacement of parts, and 27% of water points were without water and categorised as having a problem with either the pump or the well.

A handpump breaks down for a very specific technical reason (such as the breakage of the chain or an O-ring failing) whereas its repair depends on the ability of the community to raise funds, organise a mechanic and source spare parts. In turn, these depend on other factors within the locality and country.

Particular cause for concern is the sizeable drop in functionality in the first one to two years after installation, which is a common occurrence. This represents a premature technical failure, as even the fastest wearing parts in a handpump should last for the first year. Premature failure means that something went wrong with the engineering – such as the borehole siting, design and/or construction, pump quality or installation, or the pump use – or that there was vandalism or theft. Alternatively, the installation may have been rejected by the users from the outset (e.g. due to the handpump location, or the appearance or taste of the water).

There is a perception among sector stakeholders that handpumps, alongside community management, have not been performing as well as they should have, but to date there is no conclusive evidence or consensus as to which factors are most important for good performance. While there have been many studies into the causes of non-functionality, this report finds that engineering and hardware issues – handpump hardware issues in particular – have not been sufficiently considered in the literature. Based on anecdotal evidence shared by practitioners and some limited studies, premature handpump failure has continued to occur since the 1980s, with rapid corrosion and the installation of poor-quality handpump components among the key causes. However, these issues are not prominent in the global discourse on achieving universal access to safe water. Policy dialogue and political action to tackle these issues is lacking. Notable exceptions include Uganda, where the government has taken measures to militate rapid handpump corrosion.

Rigorous examination of the quality of handpump hardware is not within the scope of assessment tools used today. Removal of the handpump from the ground and its inspection, alongside follow-up of user perceptions of water quality (taste and appearance), would provide useful insights into component quality, rapid corrosion and whether a handpump has actually reached the end of its service life. Not doing so has significantly compounded our understanding of the extent of the problem.

This ongoing lack of emphasis on the physical condition of handpumps may be due to the shift of focus away from infrastructure towards service delivery in the rural water supply sector. With a few exceptions, handpump hardware quality seems to be largely taken for granted.

Reports II and III of the Stop the Rot initiative consolidate evidence of rapid handpump corrosion and poor handpump component quality in SSA. Meanwhile this report closes by urging stakeholders to come together and explore another question: 'Handpump functionality is not binary: so, what are the implications for programmes, projects, services, monitoring and assessments?'

INTRODUCTION

In January 2021, *Ask for Water* GmbH and Skat Foundation, under the Rural Water Supply Network (RWSN),[1] launched a 15-month initiative to document the scale and extent of rapid handpump corrosion and the use of poor-quality handpump components in sub-Saharan Africa (SSA) and to bring about actions to address these problems. These two interlinked issues contribute to poor handpump performance, rapid handpump failure and poor water quality, all of which can ultimately lead to abandonment of the handpump sources, thus forcing users to return to contaminated or distant water supplies. This initiative is referred to as 'Stop the Rot'.

This is the first of a set of three reports produced by the initiative. It estimates the reliance on handpumps in SSA,[2] reviews the literature on handpump functionality and performance, and synthesises information on handpump technical quality from various studies and assessments. The second report examines handpump corrosion in detail, with an overview of what is known and what has been done to address the issue in specific SSA countries and by select organisations. The third report reflects on the existing guidance on handpump quality assurance, collates examples of poor-quality components, and examines handpump supply chains through a case study of Zambia.

Based on analysis of the most recent data published by the World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) through the Joint Monitoring Programme (JMP), it is estimated that almost 200 million people in SSA (18.5% of the total population) rely on about 700,000 handpumps to provide them with their main drinking water supply. Handpumps have revolutionised access to safe, reliable water supplies in low-income countries, particularly in rural areas, providing a viable alternative to contaminated surface water and open wells. However, limited ability to transport large quantities of water coupled with a lack of storage capacity at the home means that water from a handpump is usually fetched on a daily basis (Curtis, 1986).

Concerns over low performance, breakdown and abandonment of handpumps have been raised for decades. A breakdown of even a short duration can result in the use of unsafe surface water supplies or require users to spend more time collecting water from a more distant source (Anscombe, 2011; Thibert, 2016). Water service failure impacts negatively on health and can inhibit other human development gains (Hunter et al., 2009; 2010; Baguma et al., 2017). Handpump breakdowns can also lead to overcrowding at neighbouring improved sources and even to conflict (MacDonald et al., 2019).

Water services underperform and fail for a variety of reasons. In the case of handpumps, all components need replacement at some stage, and fast-wearing parts need to be replaced more frequently. The use of substandard components undermines performance. Such components may wear rapidly, break prematurely or cause another component to fail. Furthermore, if components of inappropriate material are installed in 'aggressive' groundwater (i.e. in water that has a low and therefore acidic pH), they will rapidly corrode. All components that are permanently submerged will eventually corrode, but the lifetime of a pump is shortened significantly when galvanised iron (GI) pump rods and riser pipes are installed in water with a pH of less than 6.5. The result is that the water, when pumped after a period of rest, is turbid, reddish in colour, has an unpleasant taste and can stain. In these circumstances, pump performance will diminish quickly and the handpump can fail prematurely.

Water supply practitioners have been concerned with the related challenges of: (i) ensuring the quality of handpump components; and (ii) preventing rapid corrosion of certain components since the 1980s. The consistent quality of handpump components and the use of appropriate materials is underpinned by national and organisational policies and practices. Since the shift away from the centralised, hardware-based water supply projects of the 1980s, the challenges of rapid corrosion and poor-quality components have largely been neglected. Exceptions include efforts in some countries to mitigate rapid corrosion (notably Uganda), interest to understand and/or address the corrosion challenge by select organisations,[3] and attempts to improve quality assurance within the supply chain by some organisations. Reflecting the reduction of interest in handpump technology by international donors from the mid-2000s, the RWSN is

[1] The RWSN developed out of the Handpump Technology Network.
[2] This study includes Sudan within its definition of SSA. Several island states (Cape Verde, Mayotte, Mauritius, Reunion, Seychelles and St. Helena) have not been included due to a lack of data on groundwater point sources.
[3] Namely WaterAid, the British Geological Survey and UNICEF.

no longer involved in handpump quality assurance or design modifications, and international handpump standards committees are no longer active.[4]

Judging from the concerns about rapid handpump corrosion and poor-quality handpump components raised regularly within the online discussions of the RWSN Sustainable Groundwater Development group,[5] these two challenges remain prevalent. However, relatively little academic research on rapid handpump corrosion or handpump component quality means that the extent and scale of these problems is not well documented. Given the ongoing extensive use of handpumps in SSA, and concerns about low functionality, it is perplexing that only a few international development partners (including the UK Foreign, Commonwealth & Development Office and Japan International Cooperation), governments and non-governmental organisations (NGOs) (including WaterAid and Inter Aide) are actively engaging in the related challenges of handpump quality and rapid corrosion. Neither are these topics prominent in global political dialogue.

This initiative sets out to investigate the scale and extent of rapid handpump corrosion in SSA, document handpump quality issues and better understand handpump supply chains, including quality assurance mechanisms. By involving and informing stakeholders in the research from the outset, the initiative has tried to catalyse action at global and national levels to reduce the incidence of rapid handpump corrosion and improve handpump component quality.

The scope of this initiative covers two public domain handpumps that are used extensively in SSA – the India Mark II and the Afridev, which are the community handpumps of choice of governments and development agencies in many SSA countries (MacArthur, 2015). It also incorporates learning from the Bush Pump. Other handpumps in the public domain, propriety pumps, including the Vergnet pump,[6] or locally made handpumps for household use[7] are not covered by this study.

[4] From 2010 to 2017, RWSN efforts with respect to handpump technologies were limited to documentation of the development of low cost handpumps (Baumann, 2011), public domain handpumps (Baumann and Furey, 2013) and research into handpump standardisation (MacArthur, 2015).

[5] https://dgroups.org/rwsn/groundwater_rwsn

[6] Vergnet Hydro (2021) estimates that 110,000 handpumps have been installed, and the Vergnet is most likely the third most common pump in SSA, with distributors in at least 16 SSA countries.

[7] There are also numerous homemade or locally made pumps, such as the pitcher pump (common in Madagascar) and the rope pump, which have been developed for local manufacture. They usually lift water from fairly shallow depths and are designed for use by a single household or a small group of households rather than by a community.

1. HANDPUMPS

1.1 HANDPUMP TYPES

There are many different types of handpump available on the market around the world.[8] This study focuses on two public domain community handpumps – the India Mark II (or variants thereof) and the Afridev. It also incorporates learning from the Bush Pump, which is used almost exclusively in Zimbabwe. Figure 1 shows the pump heads for these three handpumps.

(a) India Mark II
Source: Karl Erpf.

(b) Afridev
Source: Karl Erpf.

(c) Zimbabwe Bush Pump
Source: Peter Morgan.

FIGURE 1 THREE HANDPUMP TYPES INCLUDED IN THIS STUDY

The **India Mark II Pump** is a robust conventional lever action handpump, designed for heavy-duty use, serving communities of 300 persons. The maximum recommended lift is 50 m. It is a public domain pump defined by Skat and RWSN (2007b) and Bureau of Indian Standards (BIS, 2004) specifications. It requires special skills for installation and maintenance and is not considered as suitable to be maintained at village level.

The **Afridev Pump** is a conventional lever action handpump, designed for heavy-duty use, serving communities of up to 300 persons. The maximum recommended lift is 45 m. The Afridev Pump is a public domain pump defined by Skat and RWSN (2007a) specifications. It was designed with community-based maintenance in mind.

The **Bush Pump** is a robust conventional lever action handpump, developed and standardised in Zimbabwe (Government of Zimbabwe, 2013). It is designed for heavy-duty use, serving communities of 300 persons. Three different cylinders are available, with the smallest one extending the range to a maximum recommended lift of 80 m. The Bush Pump requires special skills for installation and maintenance.

Sutton with Butterworth (2021) estimate that 6.2% of the SSA population own a household level improved groundwater supply (i.e. a borehole or protected well), which are generally shared with neighbours. Given that these pumps tend to be used by fewer people than community sources, they do not need to be as robust as community pumps. Some self-supply users will thus use rope pumps or other low-lift pumps, while others will use motorised pumps, relying on solar energy or other sources such as diesel, petrol or the electricity grid.

1.2 A VERY BRIEF HISTORY

The India Mark II was developed and tested in India from the late 1970s as a collaboration that included UNICEF and the Indian private sector. Further development and testing took place within the United Nations Development Programme/World Bank ‘Handpump Project’ as part of the ‘International Drinking Water Decade’ (1981–90) (for more details, see Arlosoroff et al., 1987).

The Afridev was conceived as a deep well pump that was easy to maintain, could potentially be manufactured in countries where industrial resources are limited and in such a way as to minimise corrosion. Its development commenced in Malawi

[8] In June 2021, the RWSN website provided information on 19 main handpump types and listed another 15 (RWSN, n.d.).

in 1981, with a shift in focus to Kenya in 1993. Field-testing was supported by the Swedish International Development Agency.

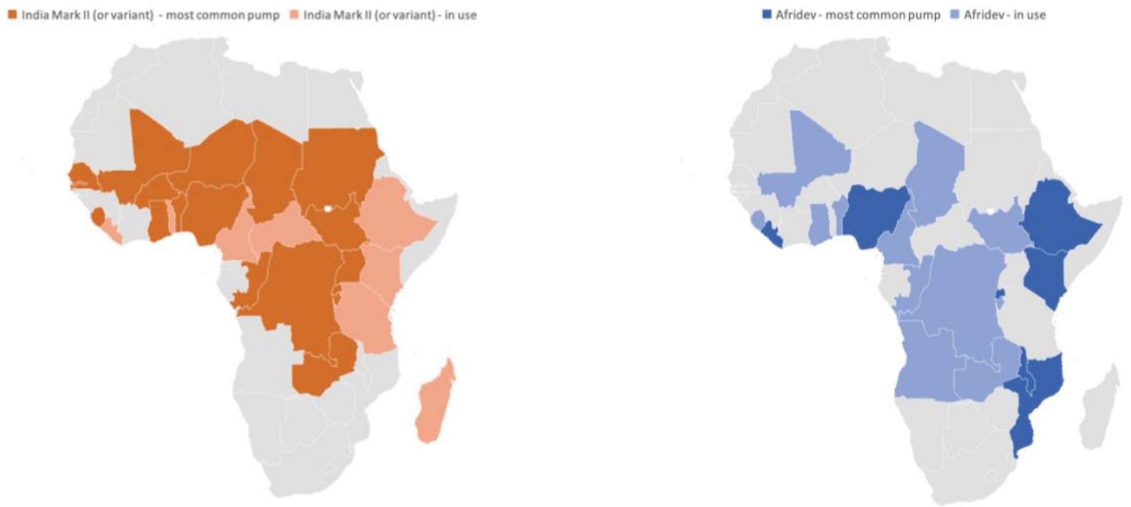
The Bush Pump was first designed in 1933 by Tommy Murgatroyd, a water supply officer working in Plumtree, Matebeleland. The pump is almost unique on the African continent in that it was conceived, designed and wholly manufactured within Zimbabwe. The family of Bush Pumps have a simplicity of design and rugged construction and continue to serve the people of Zimbabwe, almost 90 years after the first pumps were designed and built.

The India Mark II, Afridev and Zimbabwe Bush Pump are all intended as community pumps rather than for individual households and were designed to be robust. For more details on the development of these three handpump types, see Baumann and Furey (2013).

2. USE OF COMMUNITY HANDPUMPS

2.1 COMMUNITY HANDPUMP TYPES IN USE TODAY

According to MacArthur (2015) the India Mark II Pump (or variant) is used in 25 SSA countries and is the most common pump in 17 of them (Figure 2a). The Afridev is used in 21 countries and is the most common pump in four of them (Figure 2b). The next most common community handpump, the Vergnet pump, is used in 18 countries, and is most common in seven of these (MacArthur, 2015). Zimbabwe relies mainly on the Bush Pump.



(a) India Mark II (or variant) prevalence

(b) Afridev prevalence

FIGURE 2 PREVALENCE OF THE INDIA MARK II (OR VARIANT) AND THE AFRIDEV IN SUB-SAHARAN AFRICA

Source: MacArthur, 2015; Tanzania augmented by Mubarak, 2021. Note that Ethiopia and Nigeria were classified by MacArthur as having both the India Mark II and the Afridev as the most common pump.

Other pumps used in a few countries include the Nira, Volanta, Kardia, Mono, Walimi, Duba and SWN-80/81. Rope pumps are also used in some countries but are not as robust and so tend to be used on family wells or for a few households.

2.2 ESTIMATING HANDPUMP RELIANCE AND NUMBERS

This section estimates handpump users and handpump numbers in SSA based on an analysis of data collated by the JMP.

USE OF POINT GROUNDWATER SOURCES

National surveys and censuses regularly collect data on groundwater point sources (i.e. tubewells/boreholes and protected/unprotected wells and springs).[9] These national estimates are collated and compiled by the JMP (WHO and UNICEF, 2021a). Drawing on estimates for each country from the most recent surveys/censuses collated by the JMP, this study estimates that 50% of the total population of SSA[10] – about half a million people – rely on protected or unprotected groundwater point sources for their main drinking supply. Details of the surveys/censuses and population data used are presented in Annex 1.

Figure 3 shows the estimates for all SSA countries. In 23 countries, over 50% of the population depends on point groundwater sources, while in 10 countries, over 65% of the population rely on them – Republic of Congo, Uganda, South Sudan, Malawi, Guinea, Chad, Liberia, Nigeria, Niger and Zimbabwe. For full details, see Annex 1.

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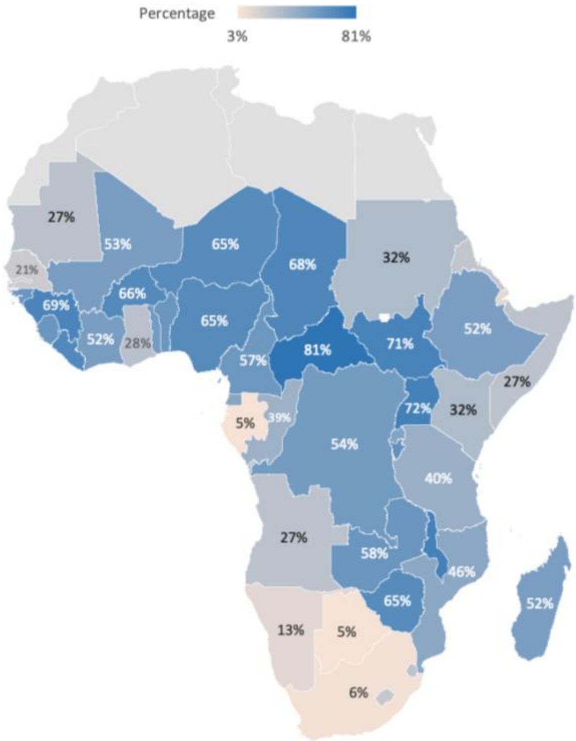
[9] In contrast, it is very difficult to estimate groundwater reliance for individual countries as data on the source of piped water supplies/tap water is not readily available.

[10] This study includes Sudan within its definition of SSA. Several island states (Cape Verde, Mayotte, Mauritius, Reunion, Seychelles and St. Helena) have not been included due to a lack of data on groundwater point sources.



Estimates not detailed on the map:

Benin – 58%
Burundi – 5%
Djibouti – 13%
Eritrea – 25%
Eswatini – 27%
The Gambia – 23%
Lesotho – 23%
Liberia – 67%
Malawi – 72%
Rwanda – 48%
São Tomé and Príncipe – 3%
Sierra Leone – 58%
Togo – 54%

FIGURE 3 PERCENTAGE OF TOTAL POPULATION USING A POINT GROUNDWATER SOURCE (SPRING, WELL OR TUBEWELL) AS THEIR MAIN DRINKING WATER SUPPLY

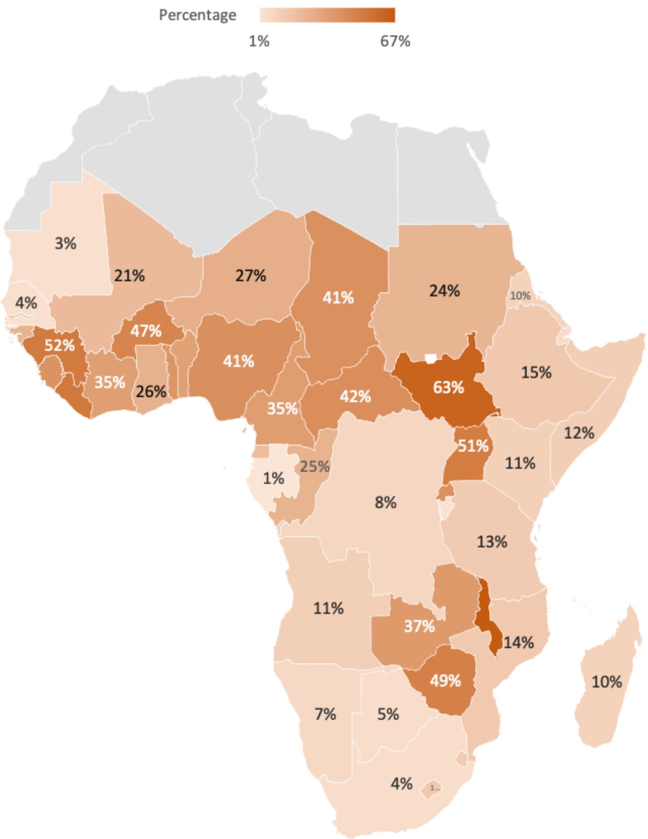
In terms of estimated numbers of people relying on groundwater point sources, the top five countries are Nigeria (131 million), Ethiopia (56 million), the Democratic Republic of the Congo (45 million), Uganda (32 million) and Tanzania (22 million).

USE OF BOREHOLES AND PROTECTED WELLS

Based on further analysis of the JMP estimates (WHO and UNICEF, 2021a), this study estimates that 20.8% of the total population of SSA use a borehole, and 3.8% use a protected well as their main source of drinking water supply, corresponding to 24.6% in total (see Annex 1 for data sources and detailed estimates). These include sources that have been financed by agencies as well as household-financed sources (self-supply). Reliance on boreholes and protected wells differs considerably between countries (Figure 4).

In South Sudan, Malawi, Guinea and Liberia, more than 50% of the population rely on boreholes or protected springs, whereas reliance in Senegal, Gabon, São Tomé and Príncipe and Mauritania is less than 5%. In terms of the highest numbers of people in specific countries, an estimated 83 million in Nigeria, 22 million in Uganda, 15 million in Ethiopia and 11 million in Malawi rely on protected wells or tubewells for their main source of drinking water supply.

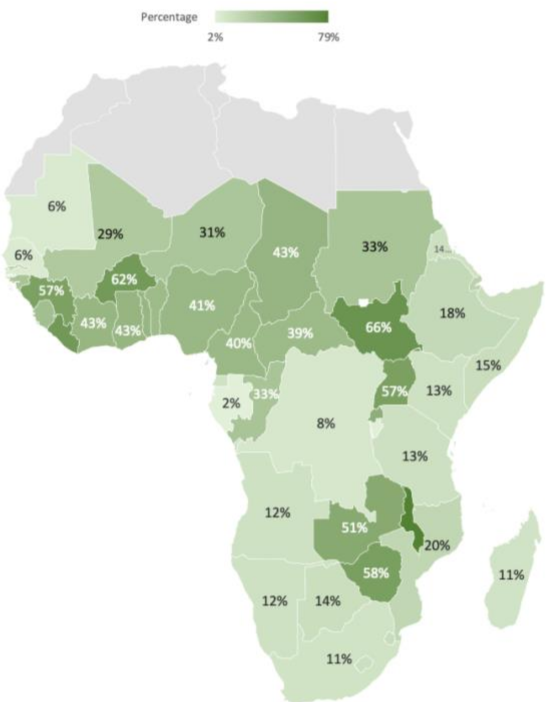
Use of boreholes or protected wells as the main source of drinking water is generally higher in rural than in urban areas (see Figures 5 and 6). In Zimbabwe, Uganda, Malawi, Liberia, Guinea and South Sudan, 55% or more of the rural population rely on boreholes and protected wells.



Estimates not detailed on the map:

Benin – 34%
Burundi – 2%
Djibouti – 5%
Eswatini – 13%
The Gambia – 14%
Lesotho – 14%
Liberia – 53%
Malawi – 65%
Rwanda – 41%
São Tomé and Príncipe – 3%
Sierra Leone – 40%
Togo – 39%

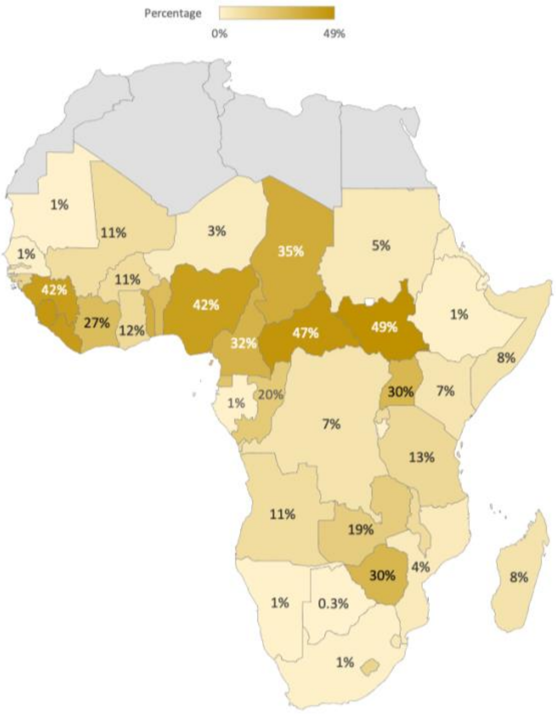
FIGURE 4 PERCENTAGE OF <u>TOTAL</u> POPULATION USING A BOREHOLE OR PROTECTED WELL AS THEIR MAIN DRINKING WATER SUPPLY



Estimates not detailed on the map:

Benin – 39%
Burundi – 3%
Djibouti – 23%
Eritrea – 14%
Eswatini – 16%
The Gambia – 24%
Lesotho – 14%
Liberia – 62%
Malawi – 79%
Rwanda – 47%
São Tomé and Príncipe – 7%
Sierra Leone – 36%
Togo – 42%

FIGURE 5 PERCENTAGE OF <u>RURAL</u> POPULATION USING A BOREHOLE OR PROTECTED WELL AS THEIR MAIN DRINKING WATER SUPPLY



Estimates not detailed on the map:

Benin – 27%
Burundi – 0.2%
Djibouti – 0.2%
Eswatini – 5%
The Gambia – 7%
Lesotho – 15%
Liberia – 43%
Malawi – 12%
Rwanda – 11%
São Tomé and Príncipe – 0.8%
Sierra Leone – 45%
Togo – 34%

FIGURE 6 PERCENTAGE OF URBAN POPULATION USING A BOREHOLE OR PROTECTED WELL AS THEIR MAIN DRINKING WATER SUPPLY

ESTIMATED RELIANCE ON HANDPUMPS IN SUB-SAHARAN AFRICA

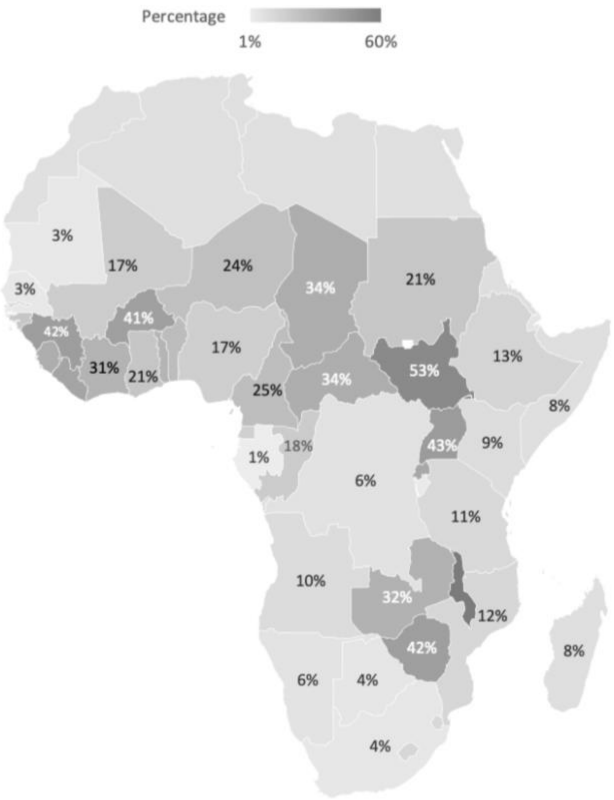
While all boreholes must be installed with a pump, it may not always be a handpump. Protected wells can be installed with a handpump, motorised pump or windlass.[11] Using the preceding estimates for boreholes and protected well reliance, handpump reliance in SSA is estimated below by assuming the following:

- In all SSA countries 90% of urban and rural protected wells are installed with a handpump. This allows for 10% of protected wells to use a motorised lifting device or a windlass. In all SSA countries (apart from Nigeria and Somalia), 50% of urban and 90% of rural boreholes are installed with a handpump. This allows for 50% of urban and 10% of rural boreholes to be motorised.
- For Nigeria, it has been assumed that only 10% of urban boreholes are installed with handpumps and that in rural areas only 70% of boreholes are installed with a handpump. This reflects widespread use of electric submersible pumps at household level in Nigeria.
- In the case of Somalia, it is assumed that there are no handpumps on boreholes (due to the prevalence of very deep groundwater requiring the use of electric submersible pumps), and that handpumps are only installed on protected wells.

Based on the above assumptions, this study estimates that almost 200 million people in SSA[12] are likely to rely on a handpump for their main drinking water supply, equivalent to 18.5% of the total SSA population (see Annex 1 for details). Figure 7 presents country estimates. The five countries with the highest population percentages relying on handpumps are Malawi (60%), South Sudan (53%), Zimbabwe (42%), Guinea (42%) and Burkina Faso (41%).

[11] A protected well is a dug well that is protected from runoff water by a well lining or casing that is raised above ground level to form a headwall and an apron that diverts spilled water away from the well. A protected well is also covered so that contaminated materials (including bird droppings and small animals) cannot enter the well. Water is delivered through a pump or manual lifting device. Protected wells may be fitted with a range of lifting devices (for example, motorized pumps, handpumps, ropes and windlasses with buckets) but if the well lacks a cover, then it should be classified as an 'unprotected well' (UNICEF and WHO, 2018).

[12] Using a similar methodology – and based on data from the JMP (2013) augmented by data from informants, and assuming that all borehole and protected wells were installed with handpumps – MacArthur (2015) estimated that 184 million people in SSA relied on handpumps to access domestic water supplies.



Estimates not detailed on the map:

Benin – 26%
Burundi –2%
Djibouti – 5%
Eritrea – 9%
Eswatini – 11%
The Gambia – 11%
Lesotho – 12%
Liberia – 39%
Malawi – 60%
Rwanda – 37%
São Tomé and Príncipe – 2%
Sierra Leone – 34%
Togo – 30%

FIGURE 7 ESTIMATED PROPORTION OF TOTAL POPULATION RELYING ON HANDPUMPS FOR THEIR MAIN DRINKING WATER SUPPLY

ESTIMATED NUMBER OF HANDPUMPS IN SUB-SAHARAN AFRICA

In order to estimate the number of handpumps, three national scenarios have been considered whereby, on average, handpumps serve 150, 250,[13] or 400 people. By comparing estimates from this study with the most recent comprehensive estimates on handpump numbers collected by Foster et al. (2019) and others, one of these three scenarios has been selected for each country (Figure 8). Full details of the data and comparisons are set out in Annex 2.

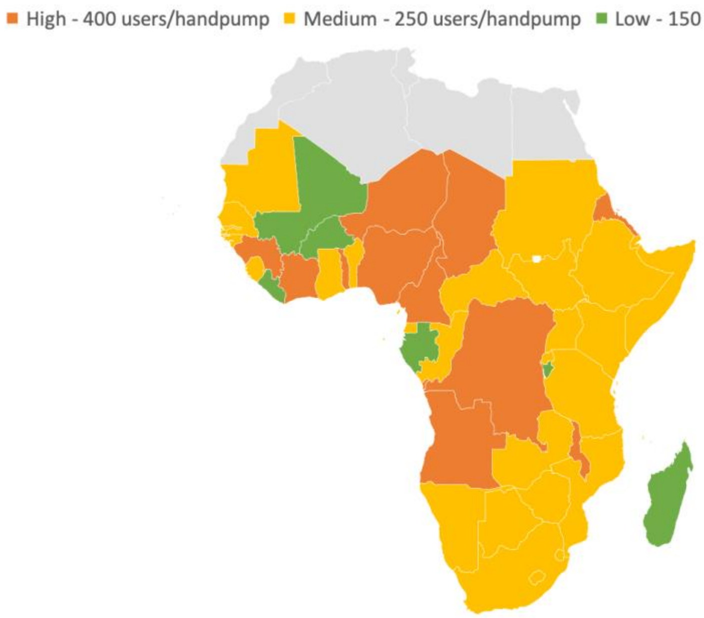
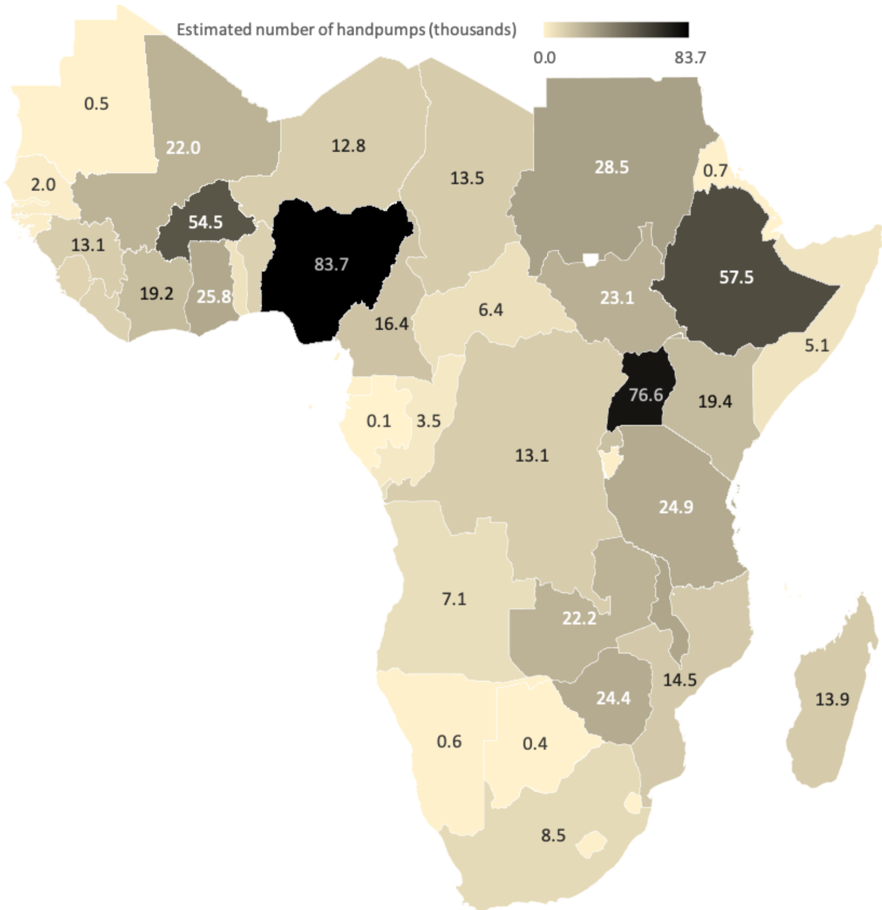


FIGURE 8 ASSUMED SCENARIO FOR NUMBER OF USERS PER HANDPUMP

[13] Deep well handpumps are designed to serve up to 300 people (Baumann, 2000). Organisations involved in rural water supply suggest that community boreholes or wells should supply no more than 250 people (MacDonald et al., 2008). Sutton with Butterworth (2021) note that improved groundwater self-supply sources serve an average of four neighbours.

This study estimates that the number of handpumps used for main drinking water supply in SSA is between 0.5 and 1.3 million. Based on the assumed scenarios for each country in Figure 8, the most likely number of handpumps in use to provide main drinking water supply is 0.7 million. This is in line with previous estimates: Foster et al. (2019) estimated 680,000 handpumps in use in 38 SSA countries; Baumann (2009) estimated that 600,000 to 800,000 handpumps had been installed in the 20 years prior to 2009.

Figure 9 presents estimates for the number of handpumps in the countries covered by this study. Of the 46 countries, there are over 10,000 handpumps in use in 25 of them. There is a large handpump asset base within SSA. For ease of reference, Table 1 summarises the estimates made by this study.



Estimates not detailed on the map:

Benin – 11.9
Burundi – 1.5
Djibouti – 0.18
Eswatini – 0.5
Lesotho – 1.0
Liberia – 11.8
Malawi – 26.6
Rwanda – 17.6
São Tomé and Príncipe – 0.02
Senegal – 2.0
Sierra Leone – 10.6
The Gambia – 1.0
Togo – 5.8

FIGURE 9 ESTIMATED NUMBER OF HANDPUMPS IN USE (THOUSANDS)
Source: Data from Annex 2.

TABLE 1 SUMMARY OF ESTIMATES BY THIS STUDY

Estimate	Urban	Rural	Total
Proportion of population in SSA relying on groundwater point sources as their main drinking water supply	30.8%	62.9%	50%
Proportion of population in SSA using tubewells as their main drinking water supply	15.7%	24.3%	20.8%
Proportion of population in SSA using protected wells as their main drinking water supply	2.9%	4.4%	3.8%
Proportion of population in SSA relying on a handpump as their main drinking water supply	7.3%	25.9%	18.5%

Source: Data from Annex 2.

2.3 HANDPUMP USE IN THE FUTURE

Despite providing the main drinking water source for an estimated 18.5% of the SSA population, attitudes towards handpumps have changed over the years. Some have even stated that they are *no longer relevant* (Furey and Danert, 2022; Schneider, 2021). A case in point is the change of emphasis by the humanitarian organisation World Vision. In the past, World Vision provided about 90% of those they served with a handpump source. In 2021, the organisation announced that in the next five years they will focus primarily on community taps, reducing the provision of boreholes with handpumps to just 3% of their activities (World Vision, 2021). However, with several decades of experience in rural water supplies, Carter (2015) states that for significant numbers of people in rural and poorly served areas the humble handpump will be needed for a while longer – a sentiment echoed by Fallas et al. (2018).

According to the latest JMP report, an estimated 23% of the SSA population (34% rural, 6% urban), equivalent to about 230 million people, still rely on an unimproved source or surface water[14] for their main drinking water supply (WHO and UNICEF, 2021b). Handpumps, whether installed on boreholes or protected wells, would be an option for a considerable proportion of this population, particularly those living in rural areas. Other technologies – including spring protection (with or without a gravity flow piped network), rainwater harvesting and groundwater extraction using submersible, motorised pumps that rely on solar energy, or other sources such as diesel, petrol or the electricity grid – may be viable in certain contexts but are not likely to be applicable ubiquitously.

There is no doubt that water available at the home is preferable to fetching it, and that a tap with a reliable water supply is preferable to using human labour to pump water. This is reflected in the JMP service ladder, which includes 'located on premises' as one of the three criteria for the highest levels of a water supply service – a supply that is 'safely managed'. The other two criteria are 'available when needed' and 'free of faecal and priority contamination'. Despite the fact that community handpumps are only a 'basic' or 'limited' water supply as classified by the JMP, they do play an important role, providing a significant step up from surface water and other unprotected sources.

With drops in the prices of solar technology alongside technical improvements, interest in more use of solar-powered groundwater pumping for domestic water supplies is increasing. UNICEF, the United States Agency for International Development, Water Mission and the International Organisation for Migration all promote solar pumping.[15] UNICEF installed over 800 solar pumping systems for domestic water supplies in SSA in 2019 and 2,015 in 2020 (Ward, 2021). Solar systems are also popular beyond the drinking water sector.[16]

Despite the growing popularity of solar pumps, the extent to which they can and will replace handpumps in the future by providing the basis for standpipes or taps at the home remains unknown. Will solar-pumped, reticulated systems prove to be robust, reliable and easy enough to manage, finance and maintain? Hydrogeological limitations within SSA, alongside likely maintenance challenges and seasonal requirements, mean that these systems are unlikely to become a panacea.

With their relatively low rates of abstraction, handpumps are likely to remain the only alternative for geographic areas in which the groundwater resources can only support low yields. For example, in Northern Ghana, while well-sited boreholes in the crystalline basement can very likely provide a yield of 6 l/min and thus support a handpump, only 30% of boreholes could support moderate yields of 60 l/min, and only about 1% could support yields higher than 300 l/min (Bianchi et al., 2020). Crystalline basement rocks underlie about 34% of Africa's land surface, where approximately half of Africa's rural population lives (MacDonald and Calow, 2009). These circumstances make it difficult for other types of water extraction techniques to be successfully implemented, thereby reinforcing the importance of handpumps.

Studies of the long-term functionality of piped systems in rural areas are sobering. Despite finding over 20 documents praising projects to develop and run gravity-fed systems in Malawi, Kleemeier (2000) found that between three and 26 years after completion, the smallest schemes, as well as the newest ones, were performing well, about half were performing poorly and a third were functioning abysmally. Based on national data sets for handpump and motorised

[14] Unimproved sources include unprotected springs and wells, and surface water.

[15] For more information, see The Solar Hub: https://thesolarhub.org.

[16] The International Water Management Institute (IWMI) has developed a portal to assess land suitability for irrigation by groundwater using solar energy (IWMI, 2021) drawing on modelling work of its potential (Xie et al., 2019). In Senegal's irrigation sector, solar is replacing diesel; while in Kenya, it was estimated that there are about 2,000 solar borehole pumps in use (Hartung and Pluschke, 2018).

schemes in Nigeria, Andres et al. (2018) estimated that handpumps and motorised pumps are initially likely to have a similar rate of failure, but whereas handpump failure probability remains at just under 35%, the equivalent figure for motorised pumps increases to almost 50% after eight to 10 years (Figure 10).

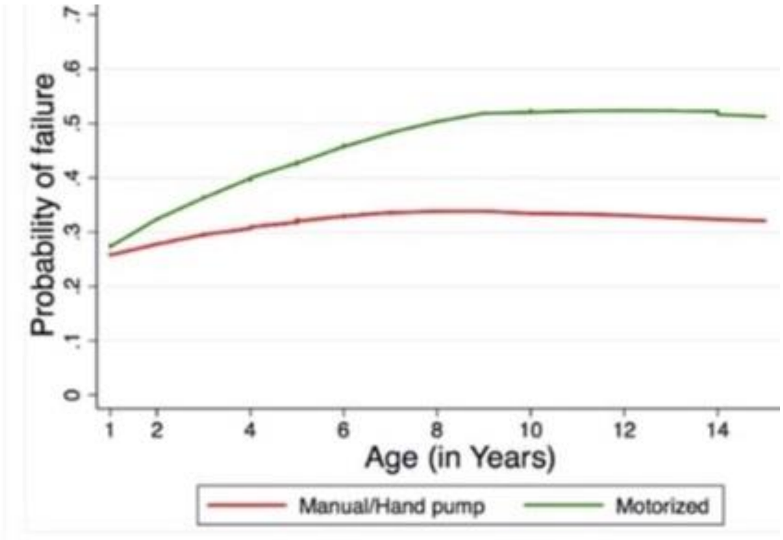


FIGURE 10 PROBABILITY OF WATER POINT AND WATER SCHEME FAILURE BY AGE IN NIGERIA
Source: Andres et al., 2018.

A study of data for over 5,000 individual water points in Ethiopia from January to April 2016, during which the El-Niño drought evolved, found mean functionality was 60% for motorised boreholes and 75% for handpumps (MacAllister et al., 2020). The study recommended that multiple improved sources and a portfolio of technologies that access groundwater be prioritised. Combining this with other data from Ethiopia, it was found that handpump operated boreholes were often the most reliable sources during drought periods (MacDonald et al., 2021).

It is worth noting that the 2016 UNICEF assessment of solar-pumped systems attributed most failures to inadequate borehole construction and improper sizing/design rather than technical limitations inherent in the technology (Bamford and Zadi, 2016). Improving the quality of boreholes has been a longstanding topic for RWSN (Danert et al., 2020), but is beyond the scope of this report.

3. FUNCTIONALITY AND PERFORMANCE

3.1 HANDPUMP LIFETIME AND MAINTENANCE

If wells and boreholes are properly designed and constructed (including well development) their lifetime should exceed 25 years (Driscoll, 1986). The India Mark II and Afridev handpumps have both been designed so that wearing parts can be replaced; indeed, over a 10-year period every part should be replaced (Arlosoroff et al., 1987). This assumes that preventative maintenance is undertaken, with fast-wearing parts replaced more regularly. Baumann (2006) estimates that without preventative maintenance, handpumps only last around five years. If a key component fails, a handpump will no longer be able to function.

3.2 ESTIMATES OF NON-FUNCTIONALITY AND DATA SOURCES

The WHO's Minimum Evaluation Procedures (WHO, 1985) drew attention to collecting information on whether a water source was functioning or not at the time of evaluation. This binary indicator provides data on a snapshot in time and has become the standard across many countries. It tends to be reported as a percentage for a nation or region.

High levels of non-functionality of handpumps have persisted since the 1970s, despite changes in management approaches in the intervening decades (Bonsor et al., 2018). In 2009, the RWSN published estimates indicating that, on average, one in three handpumps in 20 countries in SSA was not working at any given time, with non-functionality rates for specific countries ranging from 10% to 65% (RWSN, 2009). The data was based on educated guesses by professionals familiar with the locale between 2000 to 2005. The most recent comprehensive data of handpump functionality rates for 38 countries in SSA was published in 2019. They estimate that on average one in four handpumps was not working at any point in time, ranging from 11% in Burkina Faso to 30% in Togo and Côte d'Ivoire (Foster et al., 2019). The data, collected in 2015, is reproduced in Annex 3. Subsequent national studies indicate more than 38% of improved water points are non-functional in Nigeria (Andres et al., 2018), 29% of Afridev handpump boreholes (HPBs) are non-functional in Malawi (Truslove et al., 2019) and 29% of handpumps are non-functional in Tanzania (Joseph et al., 2019).

As well as national statistics presented in the aforementioned studies, a number of online platforms enable the collection and sharing of water point data for multiple countries. This includes the Water Point Data Exchange (WPDx)[17] and mWater.[18] WPDx includes a status indicator set as either functional or non-functional while mWater has standard indicators and allows users to add their own. Water point mapping software developed by the Akvo Foundation has also been used to collate functionality data, such as for the Sierra Leone WASH data portal and data for Ethiopia (MacAllister et al., 2020). However, not all national statistics, nor such platforms, contain comprehensive data.

Comparing non-functionality estimates may appear simple. However, meaningful comparisons and benchmarking of national estimates across countries cannot feasibly be made (Harvey and Reed, 2006; Banks and Furey, 2016; Bonsor et al., 2018). Foster et al. (2019) note that the information presented is a broad-brush 'best-estimate' rather than a precise computation, and there is actually no sector-wide definition of borehole functionality. National monitoring statistics may not reflect unreliable or contaminated sources that may have been abandoned (Martinez-Santos, 2017; Mannix et al., 2018). The use of the ratio 'functional : total' can be misleading, as the denominator may, or may not, leave out abandoned systems completely. Carter and Ross (2016) argue that the binary indicator is crude and they criticise it for its reliance on the judgement of the monitors, not considering seasonal differences, only providing a snapshot and not providing contextual information on the reasons for breakdown, as well as repairs.

3.3 DEFINING FUNCTIONALITY

The usefulness of binary (functional/not functional) indicator is increasingly being called into question. Carter and Ross (2016) further argue that functionality is not a good proxy for sustainability, because sustainability has a time dimension whereas functionality does not. While a handpump may be broken down at the time of spot check, this does not necessarily mean that it lacks an effective maintenance system. Alternatively, a functioning handpump at time of spot

[17] https://www.waterpointdata.org
[18] https://www.mwater.co

check may actually have considerable downtime throughout the year. Duti (2012) and Adank et al. (2014) demonstrate that functionality is also not a good indicator of service level.

Some published national statistics include a third category, for example 'partially-functional' in Ghana (Adank et al., 2014), 'bad condition' in Nigeria (Andres et al., 2018) and 'partial functionality' in a national study for Malawi (Truslove et al., 2019). The WASH Data Portal (n.d.) for Sierra Leone uses four categories of 'broken down' and categorises functionality as 'and in use', 'but not in use' or 'but damaged'.

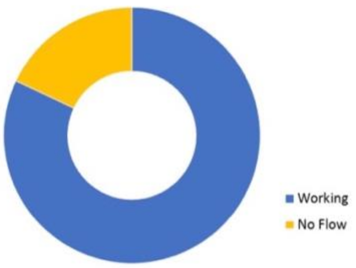
While the binary functionality indicator can generate alarming headline figures, it is not always the ideal starting point to determine how handpumps are actually performing, or why sources are failing. Indicators that are more nuanced are emerging. A review of 111 studies from published and grey literature (Wilson et al., 2016) found six main categories used to define functionality: not defined (by default working or not working); defined binary; multi-categories; tiered definition; sustainability assessment; and design yield. An example of a tiered approach and grading is described below.

3.4 A TIERED APPROACH THAT CONSIDERS PERFORMANCE

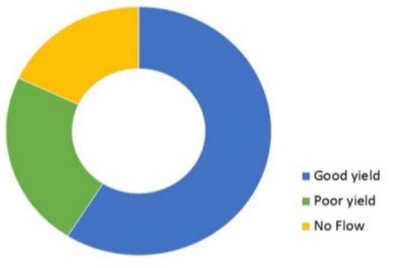
Bonsor et al. (2018) advocate for a tiered approach to defining and measuring functionality and for making a clear distinction between: (i) functionality as a snapshot (as discussed above); and (ii) functionality performance in terms of yield, reliability and water quality.

A tiered approach was applied to 200 handpump-equipped borehole supplies in Ethiopia, Malawi and Uganda (Kebede et al., 2017; Mwathunga et al., 2017; Owor et al., 2017). Figure 11 shows the nuances that can be measured using this approach in comparison to the binary method. A binary approach would indicate that 82% are working, whereas the tiered approach shows that only 59% actually provide sufficient yield and only 45% are also reliable. Given that a tiered approach requires more time and resources than the binary approach, Fallas et al. (2018) recommend that a sample be assessed for different levels of performance, with good sampling design.

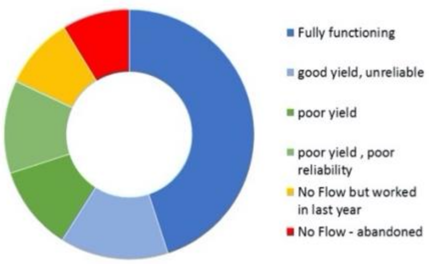
Using another similarly nuanced approach, Adank et al. (2016) measured the service characteristics of reliability, quality, quantity and accessibility (including travel and queuing time) in 16 towns in Ethiopia. They found that while access to water services was high at 82%, only 9% of households received services that fully met national standards.



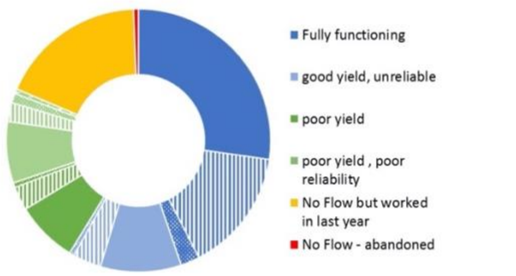
(a) Basic functionality – functionality assessed as working or not working.



(b) Functionality assessed as working with sufficient yield (10 l/min).



(c) Functionality performance – sufficient yield (>10 l/min) and reliability (<30 days downtime in the last year).



(d) Functionality performance, including water quality. Failure to meet WHO inorganic water quality parameters denoted by stipple overlay; failure to meet WHO Thermotolerant Coliforms standards denoted by line overlay; failure to meet both denoted by dashed overlay.

FIGURE 11 FUNCTIONALITY AND PERFORMANCE OF HANDPUMP-EQUIPPED BOREHOLES IN ETHIOPIA
Source: Kebede et al., 2017.

3.5 A graded approach for maintenance and rehabilitation

The development organisation Inter Aide has developed an approach of grading point water sources to 'provide clear and comprehensive information to diagnose and help decision-making on actions and priorities to increase sustainable access' (Inter Aide, 2021). The approach, which has to date been used in Ethiopia and Sierra Leone, grades water supplies according to their status, each with actions for maintenance, rehabilitation or repair (Table 2).

TABLE 2 GRADING OF WATER SUPPLY BASED ON STATUS

Water supply	Grade	Status	Action required
Water	A	**Functional** water point	⇨ Yearly preventive maintenance by a Pump Technician
	B	**Pump functions poorly** some parts need to be changed	⇨ Pump Technician intervention to diagnose the pump and replace the defective parts
No water	C	**Problem linked with the pump** needs to be repaired or fully replaced	⇨ Pump Technician intervention to evaluate if the pump has to be fully replaced or if it can be repaired
	D	**Problem linked with the well** needs to be rehabilitated	⇨ Intervention of a qualified operator to rehabilitate the well
	E	**Problem linked with the well** Rehabilitation is not feasible	⇨ Need to build a new well or to find alternative solution (household water treatment)
No diagnosis	X	Diagnosis not yet performed	⇨ Pump Technician intervention to perform a diagnosis

Source: Inter Aide, 2021.

In a survey of 1,642 water points undertaken in Bombali District, Sierra Leone, it was found that 56% were functional, with 17% functioning poorly and in need of some parts to be changed (grade B); of those with no water, 20% were linked to problems with the pump and 7% to problems with the well (graded D and E) (Inter Aide, 2021).

4. CAUSES OF POOR FUNCTIONALITY

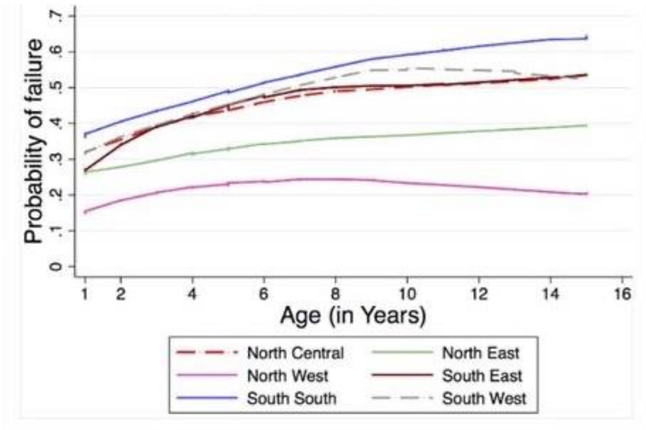
4.1 A MULTITUDE OF REASONS

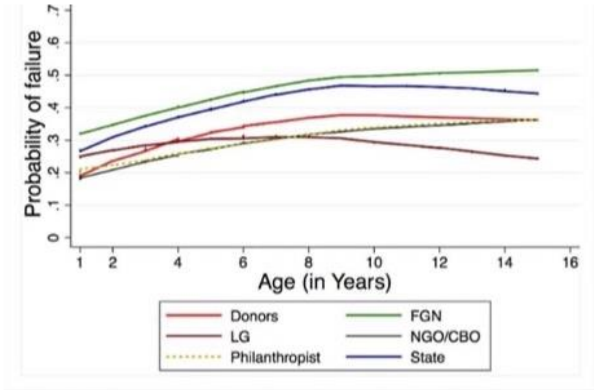
The causes of good or poor handpump functionality are numerous. Different factors and critical issues that have been attributed to, or found to contribute to, water point failure include the existence of a committee at village level, spare parts, collection of money for maintenance by the community, trained handpump mechanic/caretaker, and seasonality of supply, among others (detailed in Annex 4). Reflecting on the 1980s, as it became widely recognised that many rural water supplies in developing countries were failing, Whittington et al. (2009: 697–8) noted that 'engineers blamed poor-quality construction, anthropologists described a lack of community participation, political scientists reported rent-seeking and poor governance structures and economists complained of poor pricing and tariff design'.

Studies have revealed correlation but not causation. To date, no 'magic formula' for ensuring high functionality rates of handpumps has been found. This is hardly surprising given that each handpump, community and wider context is unique. A handpump breaks down for a very specific technical reasons (such as the breakage of the chain or an O-ring failing), whereas its repair depends on the ability of the community to raise funds, organise a mechanic and source spare parts. In turn, these depend on other factors within the locality and wider country, as illustrated in the points and associated studies below:

- Drawing on the largest multi-country data set available at the time, Foster (2013) used logistic regression analysis to identify technical, institutional, financial and environmental predicators of handpump functionality in Liberia, Sierra Leone and Uganda. While there were patterns within the respective countries, only three risk factors were significantly associated with non-functionality across all three countries. These were system age, distance from district/county capital and absence of user fee collection.
- A nationwide study in Nigeria found that geo-political zones and hydrogeology had the biggest impact on functionality and that the age of installation had a significant effect, as shown in Figure 12 (Andres et al., 2018).
- Analysing water point data[19] from Liberia, Malawi, Sierra Leone and Tanzania, Tincani et al. (2015) also concluded that functionality falls as system age rises.
- Franceys and Pezon (2010) contend that a lack of long-term sustainability planning when new assets are being developed leads to risks of them falling into disrepair soon after installation, before requiring subsequent rehabilitation to bring them back into operation.
- The relationship between system age and functionality as found by Foster (2013) and Tincani et al. (2015) was not found in the greater Afram Plains region of Ghana (Fisher et al., 2015), nor in a smaller study in Sierra Leone (Bourgois et al., 2010).
- A 30-year retrospective study of handpumps on the south coast of Kenya suggested that water point failure risks are higher and lifespans are shorter when the water supplied is more saline, the static water level is deeper and groundwater is pumped from an unconsolidated sand aquifer (Foster et al., 2018).

[19] Data covers boreholes but also includes, for Sierra Leone, a significant number of hand-dug wells; the Tanzania data contains a significant number of tap stands associated with piped schemes.





Note: CBO = community-based organization; FGN = Federal Government of Nigeria; LG = local government; NGO = non-governmental organization.

(a) Failure curve by political zone

(b) Failure curve by promoter type

FIGURE 12 PROBABILITY OF WATER POINT FAILURE BY SYSTEM AGE IN NIGERIA
Source: Andres et al., 2018.

- In most SSA countries, community-based management (CBM) has been the dominant management model for community handpump supplies since the late 1980s (Briscoe and de Ferranti, 1998). With CBM, the community has the responsibility of maintaining and operating the service, relying primarily on voluntarism for labour. The model has been criticised (Whittington et al., 2009; RWSN, 2010; Chowns, 2015; Whaley et al., 2019) and improvements in community management itself, or post-construction support, called for (Lockwood et al., 2003; Hutchings et al., 2015; Whaley and Cleaver, 2017). Alternative service delivery models for rural handpump supplies are emerging, including those in which a subsidised service provider maintains a number of handpumps within a particular geographic area, charging communities a fee (Goodall and Katuli, 2016).
- Factors may reinforce or undermine each other. In the Ugandan sample from Foster (2013), handpumps exhibited a functionality rate of 91.7% when committees had regular meetings, had been trained, had women in key positions, collected revenue and ensured that there is regular servicing. Researching in Ghana, Fisher et al. (2015) found a predicted 97% functionality rate when all management determinants were in place. However, it is likely to be difficult for a community to raise funds and keep motivated if a pump breaks down soon after installation or if it continues to break down frequently.

Determining the underlying cause of poor handpump performance or failure is complex. Bonsor et al. (2015) note the absence of a systematic evidence base or analysis of water supply failures and illustrate that while there may be apparent technical reasons for a pump failing, these are in fact caused by primary and secondary causes (Figure 13).

Godfrey et al. (2014) combine weighted indicators for social, technical and financial aspects into a sustainability indictor- However, it is worth noting that there are interlinkages between the different factors that affect failure. Consequently, such an indicator would be highly subjective.

Although handpump technical quality (i.e. rapid corrosion and poor-quality components) is likely to contribute towards non-functional handpumps, this aspect is conspicuously absent from many of the above-mentioned studies. Bonsor et al. (2015: 4) suggest that it may have simply been overlooked: ‘supply failure in this region [of Uganda] has traditionally been attributed to inadequacies in community management’.

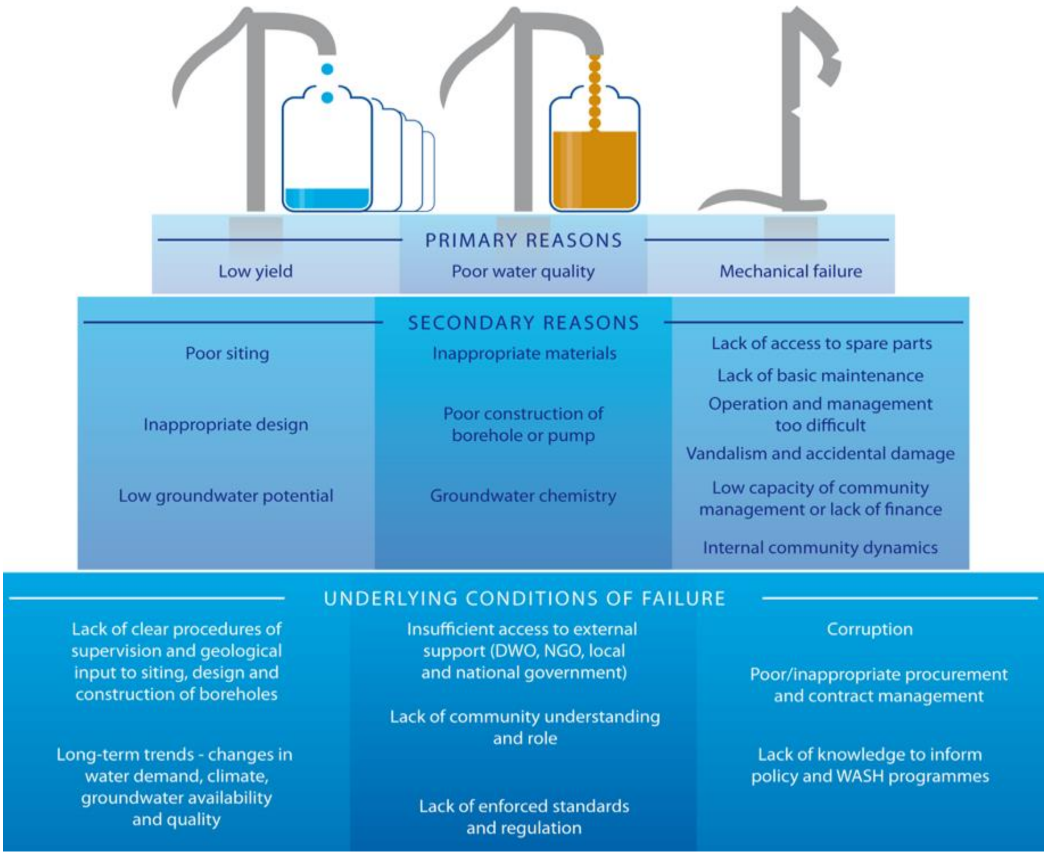


FIGURE 13 PRIMARY REASONS, SECONDARY REASONS AND UNDERLYING CAUSES OF HANDPUMP AND BOREHOLE UNDERPERFORMANCE
Source: Bonsor et al., 2015.

4.2 PREMATURE FAILURE

From an engineering perspective, cause for concern is the sizeable drop in functionality in the first one to two years after installation, as even the most fast-wearing parts in a handpump should last for the first year:

- A total of 15–30% of water points failed in the first one to two years in Liberia, Sierra Leone, Malawi and Tanzania (Tincani et al., 2015). However, Joseph et al. (2019) found that in Tanzania, fewer than 10% of groundwater pumped sources failed in the first year.
- Analysing data for over 80,000 water points[20] in Nigeria, Andres et al. (2018) found that 15–30% were likely to fail in the first year.

Failure within the first year or two is a premature failure, and arguably a technical quality failure, whereby something went wrong with the borehole siting, design, construction, the quality of the handpump components/installation or its suitability for the environmental conditions. The latter includes the use of GI pipes in water with low pH (< 6.5), as the pipes will rapidly corrode. Rejection by users from the outset, vandalism or theft, or overuse of the source (e.g. by a high numbers of users) could also contribute towards premature failure.

Carter and Ross (2016) demonstrate that reducing high rates of early post-construction breakdown and total downtime would greatly improve handpump service performance. Determining what specific factors are causing early breakdown is extremely important.

[20] Includes data on springs, boreholes and hand-dug wells, and is thus broader than handpumps, although the majority of the data relates to boreholes and hand-dug wells.

5. TECHNICAL QUALITY FAILURES

5.1 WATER SECTOR FRAMEWORKS AND TOOLS

Visual inspections of handpumps, such as within rehabilitation campaigns, can provide useful data on handpump technical quality. Removal of below ground parts can provide information about the state of the components, including handpump corrosion. In addition, users can be asked to share their experiences of handpump performance, breakdowns and perceptions of water quality. For example, data on appearance (reddish colour) and taste (metallic or bitter), particularly upon pumping after a period of non-use (e.g. overnight), are indicative of handpump corrosion. Turbid water may indicate siltation of the borehole.

A light-touch review of four frameworks and tools used over the last 15 years to assess water supply programmes and investigate sustainability reveals that some of the early UNICEF sustainability assessments/checks did generate information on technical quality failure, including poor-quality components or handpump corrosion, from visual inspection and user perceptions. However, more recent assessments have not included inspection of the below ground pump components and data on user perceptions of water quality are either not collected or only analysed superficially.

In contrast, an analytical framework for rural water sustainability developed a decade previously by Sara and Katz (1998) does include indicators on the physical condition of the water system. Applying this framework, they found that construction quality was strongly correlated with water system sustainability.

Physical audits (also sometimes known as technical audits) explicitly focus on technical quality issues. The physical audits undertaken in 2013 and 2014 in Burkina Faso (CABINET NTU INTERNATIONAL A/S, 2013; 2014) clearly capture handpump corrosion problems. These reports remained in-country and were obtained by the author thanks to her work in Burkina Faso. There may be other physical audit reports available for other countries, but they are difficult to obtain. Despite attempts, the author was not able to secure such reports for any other country.[21]

Similarly, while Harvey and Reed (2004) highlight the importance of examining signs of incrustation or corrosion in borehole rehabilitation assessments, the reports do not seem to be available in the public domain.

The UNICEF sustainability checks were introduced in 2008 and have been undertaken in 30 countries. They are based on an assessment framework from which countries define their own scope and indicators. While sustainability checks may include factors that influence future sustainability, they generally do not cover handpump technical quality (UNICEF, 2017). Exceptions to this include assessments undertaken in Malawi, which included a technical analysis covering water quality issues (e.g. abandonment due to salt, sediments and/or iron rich) and mechanical issues (Anscombe, 2011; 2013), as summarised in Box 1. In addition, handpump corrosion in Zambia was documented by UNICEF sustainability checks in 2013 (Republic of Zambia and UNICEF, 2013).

[21] As part of the study, the author contacted several donor agencies that have implemented rural water supply programmes in SSA by email regarding physical audit reports or other pertinent information with respect to handpump programmes. Responses included: a lack of bilateral WASH funding, hence there is no information; and the move towards piped systems in the country of work means that handpumps are no longer politically interesting. Two did not respond at all. One agency responded with considerable interest, leading to extensive dialogue and exchange, while another responded that they had asked for information internally, but none was found.

BOX 1 FINDINGS OF UNICEF ASSESSMENTS IN MALAWI – AFRIDEV PUMP

In 2011 and 2012, 102 and 128 of over 2,000 boreholes and handpumps constructed in the previous four to five years with UNICEF support were assessed. In the 2011 study, 95% were functioning and used for all domestic water; 3% were permanently out of action and beyond repair; 4% were working but not used for drinking water (due to high levels of salt or iron). The functionality and use figure for the 2012 study was 94%. Critical handpump component issues found by the 2011 study, whereby handpumps were removed, were:

- Use of sawn riser pipes, including second-hand components with 'waisted' double sockets (can cause rods to catch)
- Abnormal wear of rod centralisers and riser pipes (could be caused by the installation of second-hand items and/or by bent borehole)
- Risers not pushed sufficiently together (can lead to pipe dislocation), or not connected properly
- Incorrect position of plunger in cylinder during installation (causing the plunger to knock on the foot valve and resulting in damage to both)
- Missing outer riser pipe centralisers (leads to pipe and rod flexing, vibration and premature failure)

Substandard handpump brands and components were not found to be significant. Technical problems beyond the handpump itself related to excessive siltation and blocking of the pump cylinder (underpinned by difficult local hydrogeology) and very narrow drilling diameter coupled with the wrong drilling technique. It was estimated that a further 5% of functional boreholes also have a latent siltation problem that may cause premature failure in the future. Low yield (frequently related to shallow drilling depth) was found in 21% of cases. The assessment reports that in addition to the approximately 2,000 boreholes in operation, an additional 550 were abandoned dry or with low yield.

Source: Anscombe, 2011; 2013.

UNICEF sustainability checks for Ethiopia undertaken in 15 *woredas*[22] in 2018 and 2019 found that the water schemes providing water of acceptable taste, colour and smell as per users' perception was between 44% and 79%, varying with location, season and scheme type (Table 3). No further information on the specific user perceptions of taste is provided in the summary document available in the public domain (UNICEF, 2020) to be able to ascertain whether handpump corrosion could be the cause of unacceptable taste.

Sustainability checks undertaken for Mozambique between 2007 and 2013 do not include specific sub-indicators that would reveal corrosion or poor component quality – 'technical indicators' relate to the knowledge of the water committee, availability of local mechanics with capacity and equipment, repairs undertaken within 24 hours and spare parts availability (Godfrey et al., 2014).

The lack of inclusion of handpump technical quality or corrosion in recent assessment tools may contribute to the discrepancy between the prominence of this issue between some practitioners (who generally rely on their own anecdotal evidence) and its relative absence elsewhere.

TABLE 3 EXTRACT FROM WATER SERVICE LEVELS OF IMPROVED WATER SOURCES FOR 15 *WOREDAS* IN ETHIOPIA

Indicator	Sub-indicator	Scheme type*		Location		Season	
		MVWS**	Wells	Highland	Lowland	Dry	Wet
Functionality	% of water points functional (providing water at the source when operated) at the time of visit	74%	73%	79%	22%	88%	82%
Quality	% of water schemes providing microbiologically safe water at the point of delivery at the time of visit	16%	29%	21%	11%	70%	34%
	% of water schemes providing water of acceptable taste, colour and smell as per users' perceptions	68%	44%	47%	44%	79%	67%

*Combined results for dry and wet season indicating that indicator criteria were consistently fulfilled during both phases of data collection. For instance, 70% of the water schemes provided microbiologically safe water during the dry season and 34% during the wet season; however, only 16% of the MVWS and 29% of the shallow wells were found to consistently provide safe water during both survey rounds.
**MVWS = multi-village water scheme

Source: UNICEF, 2020.

[22] A *woreda* is a district local authority.

5.2 Studies and anecdotes

Howe and Dixon (1993) state that problems of poor operation and maintenance begin in the project identification, design, siting and construction stages, with donor and host country biases leading to inappropriate projects, unsustainable technologies and shoddy construction.

Since the 1980s water supply practitioners have been discussing the challenges of: (i) ensuring the quality of handpump components; and (ii) preventing rapid corrosion of certain handpump components by avoiding the installation of GI pipes in water with low pH (< 6.5) (Arlosoroff et al., 1987; Langenegger, 1989; Harvey and Reed, 2004; Casey et al., 2016; RWSN, 2020). Concerns about these issues feature regularly in the RWSN's online discussion group for Sustainable Groundwater Development.[23] Practitioners also share stories of poor technical quality of drilling, borehole design, construction and development contributing to poor outcomes, including abandonment of the supply (e.g. Lane, 2021).

Drawing on limited studies and anecdotal evidence, handpump corrosion and/or substandard quality pump components has been cited as taking place within 20 countries[24] in SSA (Furey, 2014; Nekasa et al., 2015; Danert, 2019; Lapworth et al., 2020). Of the respondents of the 2013 RWSN handpump survey, 66% had received complaints about the quality of the handpumps from the users and 54% regarding the quality or availability of handpump spare parts (Furey, 2013). Of the respondents of the 2021 RWSN handpump survey, 69% of handpump buyers have received feedback or complaints from users about the pump quality and concerns were raised about the quality and durability of specific handpump parts for a number of countries (Furey and Danert, 2022). The survey also found that there are varying levels of awareness and understanding of government regulations and of the activity of regulators responsible for enforcing product and hardware standards, even within the same country.

As noted in Section 4, despite a recognition that handpumps suffer from high rates of premature failure, and that concerns and experiences of poor handpump quality and rapid corrosion are commonplace, there is relatively little literature on handpump technical quality or corrosion. This section presents examples that have been documented from Burkina Faso, Ethiopia, Malawi, Sierra Leone, South Africa and Uganda. These are summarised below:

Burkina Faso: Danert (2019) drew on physical audits that showed considerable corrosion of handpumps. Further, by testing a (non-representative) sample of 'stainless steel' components, it was found that many handpumps were not in accordance with technical specifications.

Ethiopia: Deneke and Hawassa (2008a; 2008b) found that poor water point siting, design and construction contributed to supply failure.

Malawi: An assessment of borehole and handpump flaws for 141 HPBs undertaken as part of a borehole rehabilitation programme (Anscombe, 2004) found that 41% of those that were not able to be rehabilitated could be traced back to inadequate siting[25] and 51% to poor drilling and development procedures,[26] whereas only 8% could be attributed to post-construction errors or user/maintenance crew negligence. Subsequent assessments of handpump functionality and performance in Malawi were undertaken as part of the sustainability checks (see Box 1). The main problems found were in relation to installation and borehole siting, design and completion, whereas substandard handpump brands and components were not found to be significant.

Mannix et al. (2018) found that poorly functioning boreholes fitted with handpumps in Southern Malawi was most commonly caused by: (i) poor water resource (quantity and quality); and (ii) sub-standard borehole construction. Of the surveyed water points, 24% showed problems caused by poor handpump operation, maintenance and management. Based on an evaluation of all rural water points installed in 25 out of 28 districts, Truslove et al. (2019) contend that 'poor standards of water supply infrastructure installed to increase coverage during the MDG [Millennium Development Goals] period have left rural populations in low-income regions with—or vulnerable to—the burden of maintaining the supply at the local level'. They further note that 'the partial functionality and non-functionality of boreholes installed towards

[23] https://dgroups.org/rwsn/groundwater_rwsn

[24] Burkina Faso, Cameroon, Chad, Central African Republic, Democratic Republic of the Congo, Ethiopia, Ghana, Kenya, Malawi, Mali, Niger, Nigeria, Mozambique, Senegal, Sierra Leone, South Sudan, Sudan, Uganda, Zambia and Zimbabwe. More widely – India, Pakistan and Bolivia.

[25] Poor siting can result in a borehole with inadequate yield, unpalatable quality or inappropriate position, which can all prompt failure by more frequent breakdowns and/or community discontent (Anscombe, 2004).

[26] Poor drilling construction and development can result in inadequate yield or enable excessive quantities of silt to pass through the screens into the borehole.

the end of the MDG period point to a risk of poorly designed sub-standard installations that have contributed to a reduced service and abandonment of assets'.

South Africa: Poorly constructed boreholes contribute to poor performance of relatively newly constructed piped schemes (Rietveld et al., 2009).

Sierra Leone: Bourgois et al. (2010) found that 26% of all identified systems and 45% of functioning systems (boreholes and hand-dug wells) in three districts dry out for part of the year and thus only provide water seasonally. The study also found evidence that older water points functioned better than newer ones. Quality of construction is considered as one reason for this: on the day of the survey, 73% of the 22-year-old systems were working, as opposed to 40% of the one-year-old systems. Seasonality issues in wells are also noted by Inter Aide (2021).

Uganda: In a study of 37 failed water points in two districts, Bonsor et al. (2015) identified poor siting and construction of supplies as the most significant contributory factors to water point failures in the pilot study area. Corrosion of GI handpump components was also significant, having led or contributed to mechanical and/or water quality failure symptoms in almost all water points examined. Poor construction quality (e.g. repairs involving re-threading and shortened pipes where damaged sections were removed, or completely removing damaged pipes) was found to have further reduced borehole performance in most cases.

Casey et al. (2016) investigated the role of handpump corrosion in contributing to high rates of iron in Uganda, including practical work to develop simple guidelines to diagnose whether iron in pumped water is the result of corrosion or caused by geogenic iron (i.e. iron contained naturally within the geology). Liddle and Fenner (2018) specifically examined the quality of work conducted during drilling/installation and raised concerns about the prolific use of turnkey contracts that are paid via lump sum no-water-no-payment terms, the exclusion of qualified consultants for siting and supervision, low contract prices, procurement delays and bribes, and the use of low-quality and/or hydrogeologically inappropriate materials and borehole designs.

In 2016, the Government of Uganda issued a directive banning the use of GI pipes for handpump installations.

5.3 Forensic analysis: Ethiopia, Malawi and Uganda

As part of a larger project entitled 'Hidden Crisis',[27] research was undertaken to ascertain the physical factors that contribute to rural water supply functionality performance in Ethiopia, Malawi and Uganda. The studies comprised the physical deconstruction and forensic analysis of up to 50 water points. While they provide useful technical insights, the authors caution there are other factors that drive functionality that also need to be considered.

Handpumps with different types of functionalities and performance were selected in different locations within each of the three countries. Groundwater resources characteristics (aquifer transmissivity and depth to groundwater), water quality (microbiology and inorganic chemical), yields and water point construction and condition were examined for each source. In all three countries, handpump components were found to have variable material competency, either due to corrosion or manufacturing variability. The results that specifically relate to handpumps are summarised in Table 4. This research incentivised the Government of Uganda to prohibit the continued use of galvanised steel components, recommending that they be replaced.

The studies found other issues relating to wider construction quality. More than 20% of HPBs in Ethiopia had a depth to groundwater greater than 30 m below ground level and thus beyond the optimum for ensuring good working conditions. In Malawi, 15% of the sites were assessed to have transmissivity below that which should meet the demand of a community water supply (>1.5m^2/d). In the case of Uganda, the figure was 30%. Of the four that remained unacceptable, one contained GI risers that had fallen into the borehole, one had water that still tasted of iron (source unknown), one could not be assessed and one had turbid water. In conclusion, the high levels of iron found previously were due to corrosion of unsuitable handpump components.

[27] https://upgro.org/consortium/hidden-crisis2/

TABLE 4 SELECT RESULTS FROM FORENSIC WATER POINT SURVEYS OF 50 HPBS IN ETHIOPIA, MALAWI AND UGANDA

Country	Condition
Ethiopia	▪ 71% of HPBs (out of 45) demonstrated corrosion and general damage* of handpump components ▪ Over 30% of GI rising mains corroded; 50% of GI pump rods corroded ▪ Variability of ±15% in the thickness of the rising main sections in India Mark II GI and Afridev (unplasticised polyvinyl chloride, uPVC) ▪ Over 60% of India Mark II had a rising main thickness below the specifications (3.25 mm ±0.2mm) ▪ Over 55% of GI pipes measured had a galvanised thickness below the specifications (70–80 µm)
Malawi	▪ 81% of HPBs (out of 49) demonstrated corrosion and general damage of handpump components ▪ GI Pumps rods were significantly affected by corrosion, with over 50% in poor condition ▪ Damage to rising main sections (mostly uPVC) was found in 80% of HPBs ▪ Variation: around 20% handpumps surveyed had rising main thickness below the Afridev specifications and a further 20% had rising main thickness greater than the specifications
Uganda	▪ 78% of HPBs (out of 50) demonstrated corrosion and general damage of handpump components ▪ Rising mains and pump rods were shown to be significantly affected by corrosion, with over 60% in poor condition ▪ Significant variation (±75%) in the thickness of the rising main section ▪ Around 65% of India Mark II had a rising main thickness below the specifications (3.25 mm ±0.2mm) ▪ Over 90% of measured GI components had a galvanised thickness below the specifications (70–80 µm)

* Damage was defined to include evidence of significant wear, for example bent, cracked or worn components.

Source: Kebede et al., 2019; Mwathunga et al., 2019; Owor et al., 2019.

6. CONCLUSIONS

This study estimates that 700,000 handpumps are used by almost 200 million people in SSA (18.5% of the total population) to provide them with their main source of drinking water. A further 23% of the population (about 230 million people) are estimated to rely on unimproved water supplies or surface water. Many of them, particularly those living in rural areas, could benefit from a handpump or other groundwater pump in the future.

Despite growing interest in more sophisticated technologies, particularly in solar-driven pumps and motorised piped supplies more generally, handpumps will continue to be important for the foreseeable future. This is likely to be the case in rural areas with dispersed populations, as well as hydrogeological settings where abstraction rates cannot supply much more than that of a handpump. New technologies for water supply services are emerging, but are unlikely to offer a panacea, and there is evidence that motorised and piped systems may actually face even greater maintenance challenges in SSA than 'the humble handpump'.

There is a perception that handpumps, alongside community management, have not been performing as well as they should have, but to date there is no conclusive evidence or consensus as to which factors are most important for good performance. While there have been many studies into the causes of non-functionality, this report finds that hardware issues – and handpump hardware issues in particular – have been not been sufficiently considered in the literature.

The fact that handpumps are failing prematurely, alongside related anecdotal evidence and limited research, indicates that technical quality issues (poor-quality components and rapid corrosion) are contributing to handpump failure and underperformance. Evaluations, post-construction monitoring, physical audits, third-party monitoring and reports from rehabilitation campaigns could shed light on such challenges if hardware quality was fully embedded in their scope, and if such reports were placed in the public domain. However, hardware quality issues and handpump corrosion are poorly documented and not given appropriate attention within the global water, sanitation and hygiene (WASH) sector.

Binary data on handpumps as functional/non-functional does not provide sufficient information to diagnose specific, or even widespread, underlying problems. Understanding more about poor handpump performance, as well as the reasons for breakdown, is essential if SSA countries are to capably tackle these widespread, underlying and oftentimes ongoing problems.

The fact that recent assessments of sustainability generally do not fully consider technical hardware quality, or examine user perceptions of water quality in detail, may partly explain the discrepancy between concerns about hardware and corrosion that are expressed by practitioners, and the absence of these topics in broader policy discussions.

Perhaps, over the years, handpump hardware quality has simply become taken for granted. Alternatively, the current lack of emphasis on the physical condition of handpump technology or technical quality may be a reflection of the shift away from infrastructure towards other concerns such as service delivery, including improving community management. The relative declining interest in handpumps may be further exacerbating the situation. The extent and scale of handpump component quality problems or rapid handpump corrosion in SSA are simply not known. Arguably, this is the outcome of a vicious cycle – the subject is marginal in the global policy arena, and so the generation of evidence is limited; with a lack of evidence, the subject remains marginal in the global policy arena.

Reports II and III of the Stop the Rot initiative consolidate evidence of rapid handpump corrosion and poor handpump component quality in SSA (Danert, 2022a; 2022b). Meanwhile this report closes by urging stakeholders to come together and explore another question: given that handpump functionality is not binary, what are the implications for programmes, projects, services, monitoring and assessments?

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ANNEX 1 DATA SOURCES, ASSUMPTIONS AND ESTIMATES

TABLE A1.1 SURVEY/S USED FOR ANALYSIS

Country	Survey/s used for analysis		Year
Angola	IIMS	Inquérito de Indicadores Múltiplos e de Saúde	2016
Benin	DHS	Demographic and Health Survey	2018
Botswana	MTHS	Multi-Topic Household Survey	2016
Burkina Faso	MIS & PMA	Malaria Indicator Survey Performance Monitoring for Action	2017
Burundi	DHS	Demographic and Health Survey	2017
Cameroon	DHS	Demographic and Health Survey	2019
Central African Republic	MICS	Multiple Indicator Cluster Survey	2019
Chad	MICS	Multiple Indicator Cluster Survey	2019
Comoros	DHS-MICS	Enquête Démographique et de Santé et à Indicateurs Multiples	2012
Congo, Dem. Rep. of	MICS	Multiple Indicator Cluster Survey	2018
Congo, Rep. of	MICS	Multiple Indicator Cluster Survey	2015
Côte d'Ivoire	PMA	Performance Monitoring for Action	2018
Djibouti	EDAM	Enquête Djiboutienne auprès des Ménages	2017
Equatorial Guinea	EDSGE	Encuesta Demográfica y de Salud	2011
Eritrea	PHS	Population and health survey	2010
Eswatini	SHIMS	Swaziland HIV Incidence Measurement Survey	2017
Ethiopia	PMA	Performance Monitoring for Action	2018
Gabon	DHS	Demographic and Health Survey	2012
The Gambia	MICS	Multiple Indicator Cluster Survey	2018
Ghana	MIS	Malaria Indicator Survey	2019
Guinea	MICS	Multiple Indicator Cluster Survey	2019
Guinea-Bissau	MICS	Multiple Indicator Cluster Survey	2021
Kenya	CEN	Census	2019
Lesotho	MICS	Multiple Indicator Cluster Survey	2018
Liberia	MIS	Malaria Indicator Survey	2016
Madagascar	MICS	Multiple Indicator Cluster Survey	2018
Malawi	MIS	Multiple Indicator Cluster Survey	2017
Mali	DHS	Demographic and Health Survey	2018
Mauritania	MICS	Multiple Indicator Cluster Survey	2015
Mozambique	MIS	Multiple Indicator Cluster Survey	2018
Namibia	FIS	Financial Inclusion Survey	2017
Niger	PMA	Performance Monitoring for Action	2017
Nigeria	GHS & NORM	General Household Survey National Outcome Routine Mappin	2019
Rwanda	LFS	Labour Force Survey	2017
São Tomé and Príncipe	MIS	Multiple Indicator Cluster Survey	2019
Senegal	DHS	Demographic and Health Survey	2019
Sierra Leone	DHS	Demographic and Health Survey	2019
Somalia	SHDS	Somalia Health and Demographic Survey	2019
South Africa	DHS	Demographic and Health Survey	2016
South Sudan	MIS	Multiple Indicator Cluster Survey	2017
Sudan	MICS	Multiple Indicator Cluster Survey	2010
Tanzania	MIS & THIS	Multiple Indicator Cluster Survey Tanzania HIV Impact Survey	2017
Togo	MICS & MIS	Multiple Indicator Cluster Survey Malaria Indicator Survey	2017
Uganda	MIS	Multiple Indicator Cluster Survey	2019
Zambia	DHS	Demographic and Health Survey	2018
Zimbabwe	MICS	Multiple Indicator Cluster Survey	2019

Note: The most recent survey/census with comprehensive data for each country is used. If there are two surveys available in the same year, averages have been used.
Source: WHO and UNICEF, 2021a.

TABLE A1.2 POPULATION DATA

Country	Year	Population (thousands)	Proportion of the population that is urban (rounded to 3 decimal places)	Urban population (thousands)	Rural population (thousands)
Angola	2016	28,842	0.641	18,502	10,340
Benin	2018	11,485	0.473	5,434	6,051
Botswana	2016	2,160	0.679	1,467	693
Burkina Faso	2017	19,193	0.294	5,635	13,558
Burundi	2017	10,827	0.127	1,376	9,451
Cameroon	2019	25,876	0.570	14,741	11,135
Central African Republic	2019	4,745	0.418	1,982	2,763
Chad	2019	15,947	0.233	3,712	12,235
Comoros	2012	724	0.281	204	520
Congo, Dem. Rep. of	2018	84,068	0.445	37,377	46,691
Congo, Rep. of	2015	4,856	0.655	3,183	1,673
Côte d'Ivoire	2018	25,069	0.508	12,730	12,339
Djibouti	2017	944	0.776	733	211
Equatorial Guinea	2011	987	0.675	666	321
Eritrea	2010	3,170	0.352	1,115	2,055
Eswatini	2017	1,125	0.236	266	859
Ethiopia	2018	109,224	0.208	22,678	86,546
Gabon	2012	1,750	0.866	1,516	234
The Gambia	2018	2,280	0.613	1,397	883
Ghana	2019	30,418	0.567	17,249	13,169
Guinea	2019	12,414	0.361	4,487	7,928
Guinea-Bissau	2021	1,921	0.438	841	1,080
Kenya	2019	52,574	0.275	14,462	38,112
Lesotho	2018	2,108	0.282	594	1,515
Liberia	2016	4,587	0.503	2,305	2,282
Madagascar	2018	26,262	0.372	9,767	16,495
Malawi	2017	17,670	0.167	2,953	14,717
Mali	2018	19,078	0.424	8,081	10,997
Mauritania	2015	4,046	0.511	2,067	1,979
Mozambique	2018	29,496	0.360	10,615	18,881
Namibia	2017	2,403	0.490	1,177	1,225
Niger	2017	21,602	0.163	3,532	18,070
Nigeria	2019	200,964	0.512	102,807	98,157
Rwanda	2017	11,981	0.171	2,052	9,929
São Tomé and Príncipe	2019	215	0.736	158	57
Senegal	2019	16,296	0.477	7,766	8,531
Sierra Leone	2019	7,813	0.425	3,319	4,494
Somalia	2019	15,443	0.456	7,035	8,408
South Africa	2016	56,208	0.653	36,727	19,481
South Sudan	2017	10,911	0.193	2,111	8,800
Sudan	2010	34,545	0.331	11,431	23,114
Tanzania	2017	54,660	0.331	18,067	36,593
Togo	2017	7,698	0.412	3,169	4,530
Uganda	2019	44,270	0.244	10,785	33,485
Zambia	2018	17,352	0.435	7,552	9,800
Zimbabwe	2019	14,645	0.322	4,717	9,928
Total estimated population		**1,070,855**		**430,537**	**640,318**

Note: The most recent survey/census with comprehensive data for each country is used with population estimates for that year.
Source: WHO and UNICEF, 2021a.

TABLE A1.3 GROUNDWATER POINT SOURCES

Country	Proportion of urban pop. relying on groundwater point sources *	Proportion of rural pop. relying on groundwater point sources*	Urban pop. relying on groundwater point sources (Thousands) **	Rural pop. relying on groundwater point sources (Thousands) **	Total pop. relying on groundwater point sources (Thousands) **	% of the total pop. relying on groundwater point Sources**
Angola	17.7%	43.0%	3,280	4,449	7,730	27%
Benin	48.6%	67.0%	2,638	4,052	6,690	58%
Botswana	0.3%	15.7%	4	109	113	5%
Burkina Faso	18.2%	86.0%	1,023	11,663	12,686	66%
Burundi	8.6%	68.1%	119	6,434	6,552	61%
Cameroon	41.0%	77.9%	6,050	8,673	14,723	57%
Central African Republic	66.8%	90.8%	1,323	2,510	3,833	81%
Chad	42.3%	76.5%	1,569	9,354	10,923	68%
Comoros	5.1%	21.3%	10	111	121	17%
Congo, Dem. Rep. of	26.7%	76.1%	9,997	35,529	45,526	54%
Congo, Rep. of	24.9%	65.7%	793	1,100	1,893	39%
Côte d'Ivoire	33.9%	71.0%	4,321	8,763	13,084	52%
Djibouti	0.5%	54.3%	4	115	119	13%
Equatorial Guinea	44.7%	51.9%	298	167	464	47%
Eritrea	3.4%	36.0%	38	740	778	25%
Eswatini	7.8%	32.9%	21	283	303	27%
Ethiopia	5.1%	63.7%	1,165	55,131	56,296	52%
Gabon	2.2%	25.1%	33	59	92	5%
The Gambia	14.9%	37.0%	208	327	535	23%
Ghana	13.7%	47.7%	2,355	6,286	8,641	28%
Guinea	44.6%	83.5%	2,003	6,618	8,621	69%
Guinea-Bissau	35.0%	76.7%	295	829	1,124	58%
Kenya	13.4%	39.0%	1,938	14,864	16,802	32%
Lesotho	5.9%	29.8%	35	451	486	23%
Liberia	58.7%	74.7%	1,352	1,706	3,058	67%
Madagascar	37.6%	60.2%	3,668	9,933	13,601	52%
Malawi	10.2%	84.3%	300	12,399	12,699	72%
Mali	19.7%	76.8%	1,593	8,450	10,043	53%
Mauritania	6.5%	49.4%	134	978	1,112	27%
Mozambique	17.8%	61.3%	1,891	11,575	13,466	46%
Namibia	0.6%	24.4%	7	299	306	13%
Niger	33.9%	71.0%	1,199	12,833	14,032	65%
Nigeria	62.4%	68.4%	64,120	67,167	131,286	65%
Rwanda	13.1%	54.9%	269	5,452	5,721	48%
São Tomé and Príncipe	1.6%	8.4%	2	5	7	3%
Senegal	8.3%	32.6%	642	2,782	3,424	21%
Sierra Leone	54.7%	60.1%	1,815	2,701	4,516	58%
Somalia	10.8%	40.8%	760	3,432	4,191	27%
South Africa	0.4%	16.9%	142	3,301	3,443	6%
South Sudan	57.8%	74.1%	1,220	6,521	7,741	71%
Sudan	5.7%	45.1%	648	10,427	11,075	32%
Tanzania	19.4%	50.5%	3,498	18,478	21,977	40%
Togo	40.4%	64.3%	1,281	2,915	4,195	54%
Uganda	46.4%	79.6%	5,003	26,666	31,669	72%
Zambia	27.2%	81.4%	2,055	7,979	10,033	58%
Zimbabwe	32.1%	80.9%	1,513	8,032	9,545	65%
Total	**30.8%**	**62.9%**	**132,635**	**402,640**	**535,275**	**50%**

Pop. = Population   * Rounded to one decimal place in this table.   ** Note that there will be rounding errors.

Note: Groundwater point sources comprise protected and unprotected wells and springs and tubewells/boreholes.

TABLE A1.4 ESTIMATED BOREHOLE AND TUBEWELL USERS

Country	Proportion of the population (percent)		Population (thousands)		Estimated population (thousands)	
	Using tubewells/boreholes		Using tubewells/boreholes		Relying on handpumps on boreholes	
	Urban	Rural	Urban	Rural	Urban	Rural
Angola	1.4	3.1	256	323	128	291
Benin	22.5	34.5	1,222	2,088	611	1,879
Botswana	0.2	12.4	3	86	1	77
Burkina Faso	7.6	55.0	438	7,670	219	6,903
Burundi	0.0	0.7	0	67	0	60
Cameroon	28.4	34.0	4,186	3,783	2,093	3,405
Central African Republic	25.6	36.4	507	1,005	254	905
Chad	32.4	36.7	1,203	4,493	602	4,044
Comoros	0.8	0.4	2	2	1	2
Congo, Dem. Rep. of	4.2	7.0	1,562	3,266	781	2,940
Congo, Rep. of	16.9	17.9	538	299	269	269
Côte d'Ivoire	2.0	19.4	252	2,392	126	2,153
Djibouti	0.1	17.2	1	36	0	33
Equatorial Guinea	5.5	6.3	37	20	18	18
Eritrea	-	-	-	-	-	-
Eswatini	4.0	12.2	11	104	5	94
Ethiopia	0.1	13.4	29	11,559	14	10,403
Gabon	0.3	1.0	4	2	2	2
The Gambia	4.5	18.8	63	166	31	150
Ghana	8.1	37.9	1,389	4,991	695	4,492
Guinea	30.6	48.1	1,374	3,814	687	3,433
Guinea-Bissau	11.0	23.9	93	259	46	233
Kenya	6.8	11.8	983	4,497	492	4,048
Lesotho	2.8	7.0	16	106	8	95
Liberia	43.0	62.3	992	1,422	496	1,280
Madagascar	5.8	4.3	564	712	282	641
Malawi	6.9	65.8	203	9,685	102	8,717
Mali	10.6	27.6	853	3,036	427	2,732
Mauritania	0.3	3.1	6	61	3	55
Mozambique	3.0	15.9	324	3,005	162	2,704
Namibia	0.1	12.2	1	149	0	134
Niger	2.0	26.2	70	4,729	35	4,256
Nigeria	41.2	38.2	42,340	37,496	4,234	26,247
Rwanda	1.8	4.3	37	430	19	387
São Tomé and Príncipe	0.3	0.2	1	0	0	0
Senegal	0.6	5.8	47	491	24	442
Sierra Leone	12.0	22.6	397	1,018	199	916
Somalia	2.4	2.7	169	223	-	-
South Africa	0.8	10.8	283	2,110	142	1,899
South Sudan	45.6	65.1	963	5,729	481	5,156
Sudan	4.6	30.5	526	7,045	263	6,340
Tanzania	4.0	3.6	727	1,316	363	1,184
Togo	28.4	32.1	901	1,454	450	1,308
Uganda	24.0	51.4	2,585	17,224	1,292	15,501
Zambia	7.1	36.1	540	3,541	270	3,187
Zimbabwe	18.2	38.5	858	3,825	429	3,443
Total	**15.7**	**24.3**	**67,554**	**155,733**	**16,764**	**132,640**

Note: Using the preceding data on borehole and protected well reliance, handpump reliance in SSA is estimated as follows by assuming the following: (i) in all SSA countries (apart from Nigeria and Somalia), 90% of urban and 90% of rural protected wells are installed with a handpump. This allows for 10% of protected wells to use a motorised system or windlass; (ii) In all SSA countries (apart from Nigeria and Somalia), 50% of urban and 90% of rural boreholes are installed with a handpump. This allows for 50% of urban and 10% of rural boreholes to be motorised; (iii) for Nigeria, it has been assumed that only 10% of urban boreholes are installed with handpumps and that in rural areas only 70% of boreholes are installed with a handpump. This reflects widespread use of electric submersible pumps at household level; (iv) in Somalia, it is assumed that there are no handpumps on boreholes (due to the prevalence of very deep groundwater requiring the use of electric submersible pumps), and that handpumps are only installed on protected wells.

TABLE A1.5 ESTIMATED PROTECTED WELL USERS

Country	Proportion of the population (per 100)		Population (thousands)		Estimated population (thousands)	
	Using protected wells		Using protected wells		Relying on handpumps on protected wells	
	Urban	Rural	Urban	Rural	Urban	Rural
Angola	9.4	9.2	1,736	955	1,563	861
Benin	4.9	4.5	268	271	241	158
Botswana	0.1	1.8	1	12	1	632
Burkina Faso	3.6	6.9	210	957	189	75
Burundi	0.2	1.9	2	176	2	675
Cameroon	3.3	6.3	493	703	444	43
Central African Republic	21.0	3.0	416	83	374	226
Chad	2.6	6.1	97	750	87	2,575
Comoros	2.2	9.1	5	47	4	433
Congo, Dem. Rep. of	3.2	1.0	1,212	482	1,091	250
Congo, Rep. of	3.5	15.0	110	251	99	11
Côte d'Ivoire	24.7	23.2	3,144	2,861	2,830	16
Djibouti	0.1	5.7	1	12	1	26
Equatorial Guinea	17.9	5.4	119	17	107	3,734
Eritrea	2.4	13.5	27	277	24	2
Eswatini	1.1	3.4	3	29	3	39
Ethiopia	1.2	4.8	261	4,148	235	617
Gabon	0.3	1.0	4	2	4	628
The Gambia	2.6	4.9	36	43	32	87
Ghana	4.1	5.2	705	686	634	296
Guinea	11.7	8.8	526	698	473	92
Guinea-Bissau	4.0	9.0	34	97	30	-
Kenya	0.0	0.9	6	329	5	993
Lesotho	12.2	6.7	72	102	65	1,696
Liberia	-	-	-	-	-	132
Madagascar	1.9	6.7	185	1,103	167	59
Malawi	4.9	12.8	144	1,885	129	658
Mali	0.2	1.3	14	146	12	3
Mauritania	0.2	3.3	4	65	4	811
Mozambique	1.0	3.9	107	731	96	2,341
Namibia	0.5	0.3	6	3	6	3,822
Niger	1.0	5.0	35	901	31	4
Nigeria	0.7	2.7	742	2,602	668	19
Rwanda	9.5	42.8	196	4,247	176	559
São Tomé and Príncipe	0.9	7.2	1	4	1	947
Senegal	0.2	0.2	14	21	13	79
Sierra Leone	33.1	13.8	1,099	621	989	71
Somalia	5.1	12.5	359	1,052	323	478
South Africa	0.0	0.5	7	88	6	417
South Sudan	3.6	0.9	76	79	68	1,812
Sudan	0.4	2.3	45	531	41	3,212
Tanzania	9.0	9.8	1,626	3,569	1,463	861
Togo	5.6	10.2	177	464	159	1,284
Uganda	5.7	6.0	616	2,014	554	1,743
Zambia	11.8	14.6	894	1,427	805	158
Zimbabwe	11.7	19.5	552	1,937	496	632
Total	**2.9**	**4.4**	**12,521**	**28,070**	**14,747**	**33,732**

Note: The same assumptions as per the note on Table A1.4 have been used.

TABLE A1.6 ESTIMATED HANDPUMP USERS

Country	No. of urban users	No. of rural users	Total no. of users	% Urban	% Rural	% Total
Angola	1,691	1,150	2,841	9%	11%	10%
Benin	852	2,123	2,975	16%	35%	26%
Botswana	2	89	91	0%	13%	4%
Burkina Faso	408	7,764	8,172	7%	56%	41%
Burundi	2	218	221	0%	2%	2%
Cameroon	2,537	4,038	6,574	17%	36%	25%
Central African Republic	628	979	1,608	32%	35%	34%
Chad	689	4,719	5,408	19%	39%	34%
Comoros	5	45	50	2%	9%	7%
Congo, Dem. Rep. of	1,872	3,373	5,245	5%	7%	6%
Congo, Rep. of	368	495	864	12%	30%	18%
Côte d'Ivoire	2,956	4,728	7,684	23%	38%	31%
Djibouti	1	44	45	0%	21%	5%
Equatorial Guinea	126	34	159	19%	11%	16%
Eritrea	24	250	274	2%	12%	9%
Eswatini	8	120	128	3%	14%	11%
Ethiopia	249	14,136	14,386	1%	16%	13%
Gabon	6	4	10	0%	2%	1%
The Gambia	64	189	253	5%	21%	11%
Ghana	1,329	5,110	6,438	8%	39%	21%
Guinea	1,161	4,061	5,222	26%	51%	42%
Guinea-Bissau	77	320	397	9%	30%	21%
Kenya	497	4,343	4,840	3%	11%	9%
Lesotho	73	187	260	12%	12%	12%
Liberia	496	1,280	1,775	22%	56%	39%
Madagascar	449	1,634	2,082	5%	10%	8%
Malawi	231	10,413	10,644	8%	71%	60%
Mali	439	2,864	3,303	5%	26%	17%
Mauritania	7	114	121	0%	6%	3%
Mozambique	258	3,362	3,620	2%	18%	12%
Namibia	6	137	143	1%	11%	6%
Niger	66	5,068	5,134	2%	28%	24%
Nigeria	4,902	28,589	33,490	5%	29%	17%
Rwanda	195	4,209	4,404	10%	42%	37%
São Tomé and Príncipe	2	4	5	1%	7%	2%
Senegal	36	461	497	0%	5%	3%
Sierra Leone	1,188	1,475	2,662	36%	33%	34%
Somalia	323	947	1,270	5%	11%	8%
South Africa	148	1,979	2,126	0%	10%	4%
South Sudan	550	5,227	5,777	26%	59%	53%
Sudan	304	6,818	7,122	3%	29%	21%
Tanzania	1,827	4,396	6,223	10%	12%	11%
Togo	610	1,726	2,335	19%	38%	30%
Uganda	1,847	17,314	19,160	17%	52%	43%
Zambia	1,075	4,472	5,546	14%	46%	32%
Zimbabwe	925	5,186	6,111	20%	52%	42%
Total	**31,503**	**166,192**	**197,695**			
Average				**7.3%**	**26.9%**	**18.5%**

Note: Data calculated from Tables A1.4–A1.5.

ANNEX 2 ESTIMATES OF HANDPUMP NUMBERS

TABLE A2.1 ESTIMATES FOR NUMBER OF HANDPUMPS IN EACH COUNTRY

Country	Estimated number of handpumps for each scenario			Scenario selected	Estimated number of handpumps by this study	Estimates by others			Comments
	Low (150 pph)	Medium (250 pph)	High (400 pph)			Number of handpumps (F*)	Scope of data (F*)	National estimates	
Angola	18,937	11,362	7,101	H	7,101	4,389	National		Either there are as many as 1,000 pph, or estimate reported by F* is questionable. Study assumes 400 pph.
Benin	19,833	11,900	7,437	M	11,900	13,003	National		
Botswana	606	364	227	M	364	-	-		
Burkina Faso	54,482	32,689	20,431	L	54,482	52,596	National	48,800 (Government of Burkina Faso 2016)	Indicates that there are either about 150 people per handpump, or that the data reported by F* contains handpumps that are not in use. Study assumes 400 pph.
Burundi	1,470	882	551	L	1,470	229	National		Indicates that there are either about 150 people per handpump, or that the data reported by F* contains handpumps that are not in use. Study assumes 150 pph.
Cameroon	43,828	26,297	16,436	H	16,436	6,899	189 of 316 communes		Have assumed 400 pph.
Central African Republic	10,717	6,430	4,019	M	6,430	3,177	National		
Chad	36,051	21,631	13,519	H	13,519	3,267	National		Either there are, on average, over 1,400 people per handpump, or data in handpump numbers reported in F* is questionable. Study assumes 150 pph.
Comoros	330	198	124	M	198				
Congo, Dem. Rep. of	34,967	20,980	13,113	H	13,113	2,214	National sample		Either there are as many as 1,900 people per handpump, or data in handpump numbers reported in F*is questionable. Study assumes 400 pph.
Congo, Rep. of	5,758	3,455	2,159	M	3,455	159	1 of 10 rural depts		F* sample too small to compare.
Côte d'Ivoire	51,223	30,734	19,209	H	19,209	22,804	National		Assume 400 people per handpump to bring it in line with F*.
Djibouti	297	178	111	M	178	-			
Equatorial Guinea	1,063	638	398	M	638	-			
Eritrea	1,825	1,095	684	H	684	864	National		Study assumes 400 pph.
Eswatini	853	512	320	M	512	801	National		
Ethiopia	95,903	57,542	35,964	M	57,542	4,620	2 of 9 regions		F* sample too small to compare.
Gabon	68	41	26	L	68	1,158	National		Study assumes 400 pph.
The Gambia	1,685	1,011	632	M	1,011	-			
Ghana	42,923	25,754	16,096	M	25,754	20,365	6 of 10 regions		F* sample covers just over 50% of districts.

Country	Estimated number of handpumps for each scenario			Scenario selected	Estimated number of handpumps by this study	Estimates by others			Comments
	Low (150 pph)	Medium (250 pph)	High (400 pph)			Number of handpumps (F*)	Scope of data (F*)	National estimates	
Guinea	34,811	20,887	13,054	H	13,054	12,815	National		
Guinea-Bissau	2,645	1,587	19,574	M	1,587	703	Sub-national		F* sample too small to compare.
Kenya	32,268	19,361	12,100	M	19,361	2,508	9 of 48 counties		F* sample too small to compare.
Lesotho	1,735	1,041	651	M	1,041	-			
Liberia	11,836	7,102	4,439	L	11,836	12,684	National		Indicates that there are either about 150 people per handpump, or that the data reported by F* contains handpumps that are not in use. Study assumes 150 pph.
Madagascar	13,882	8,329	5,206	L	13,882	15,068	National		Indicates that there are either about 150 people per handpump, or that the data reported by F* contains handpumps that are not in use. Study assumes 150 pph.
Malawi	70,960	42,576	26,610	H	26,610	24,769	National	23,073 (Truslove et al., 2019)	Study assumes 400 pph to bring it in line with F* and Truslove et al. (2019).
Mali	22,018	13,211	8,257	L	22,018	19,951	5 of 8 regions		Study assumes 150 pph.
Mauritania	805	483	302	M	483	71	1 of 15 regions		F* sample too small to compare.
Mozambique	24,133	14,480	9,050	M	14,480	12,180	93 of 128 districts	11,666 + 154 water points (SINAS, n.d.)	
Namibia	955	573	358	M	573	94	2 of 14 regions		F* sample too small to compare.
Niger	34,226	20,535	12,835	H	12,835	10,072	National		Either there are almost 900 people per handpump, or data in handpump numbers reported in F* is questionable. Study assumes 400 pph.
Nigeria	223,270	133,962	83,726	H	83,726	25,470	35 of 36 states	80,462 boreholes plus 5,920 protected dug wells (Andres et al., 2018)	Either there are as many as 2,300 people per handpump (not realistic), or data in handpump numbers reported in F* is questionable. Study assumes 400 pph, which is in line with Andres et al., 2018).
Rwanda	29,363	17,618	11,011	M	17,618	279	6 of 30 districts		F* sample too small to compare.
São Tomé and Príncipe	36	21	13	M	21	-			
Senegal	3,314	1,989	1,243	M	1,989	2,903	National		
Sierra Leone	17,749	10,650	6,656	M	10,650	11,895	National		
Somalia	8,464	5,079	3,174	M	5,079	-			
South Africa	14,175	8,505	5,316	M	8,505	11,735	8 of 44 districts		F* sample too small to compare.
South Sudan	38,512	23,107	14,442	M	23,107	4,951	5 of 10 states		F* sample too small to compare.

Country	Estimated number of handpumps for each scenario			Scenario selected	Estimated number of handpumps by this study	Estimates by others			Comments
	Low (150 pph)	Medium (250 pph)	High (400 pph)			Number of handpumps (F*)	Scope of data (F*)	National estimates	
Sudan	47,481	28,489	17,805	M	28,489	7,733			
Tanzania	41,485	24,891	15,557	M	24,891	22,021	27 of 31 regions	11,866 (Joseph et al., 2019	
Togo	15,569	9,342	5,838	H	5,838	4,550	National		Study assumes 400 pph to bring data in line with F*.
Uganda	127,736	76,641	47,901	M	76,641	58,366	National		
Zambia	36,975	22,185	13,866	M	22,185	25,642	National	13,242 tubewells (mWater, n.d.) 15,000 handpumps (Sansom, 2009)	
Zimbabwe	40,740	24,444	15,277	M	24,444	29,986	6 of 8 provinces		
Total	1,317,966	790,779	512,819		705,007				

Key:
F* = Foster et al., 2019
pph = people per handpump
H = High scenario
M = Medium scenario
L = Low scenario

ANNEX 3 HANDPUMP FUNCTIONALITY ESTIMATES

TABLE A3.1 HANDPUMP DATA FOR SUB-SAHARAN AFRICA COLLATED BY FOSTER ET AL. (2019)

Country	Year(s)	Scope	Handpumps	Non-functional
Angola	2015	National	4,389	25%
Benin	2016	National[28]	13,003	12%
Burkina Faso	2017	National	52,596	11%
Burundi	2012	National	229	58%
Cameroon	2011–15	189 of 316 communes	6,899	32%
Central African Rep.	2003	National	3,177	25%
Chad	2000	National	3,267	16%
Congo, Dem. Rep. of	2011	National sample	2,214	25%
Congo, Rep. of	2008	1 of 10 rural depts	159	50%
Côte d'Ivoire	2016	National	22,807	30%
Eritrea	2006	National	864	43%
Ethiopia	2010–14	2 of 9 regions	4,620	33%
Gabon	2012	National	1,158	47%
Ghana	2014	6 of 10 regions[29]	32,361	26%
Guinea	2012	National	12,815	18%
Guinea-Bissau	2016	Sub-national[30]	3,190	36%
Kenya	2013	9 of 47 counties	2,580	24%
Liberia	2017	National	12,684	20%
Madagascar	2018	National[31]	15,068	20%
Malawi	2007	National[32]	24,769	22%
Mali	2015–16	5 of 8 regions	19,951	29%
Mauritania	2012	1 of 15 regions	71	54%
Mozambique	2011–12	93 of 128 districts	12,180	20%
Namibia	2000	2 of 14 regions	94	54%
Niger	2015	National	10,072	15%
Nigeria	2006	35 of 36 states[33]	26,423	42%
Rwanda	2008–09	6 of 30 districts	279	16%
Senegal	2014	National	2,903	22%
Sierra Leone	2016	National	11,895	25%
South Africa	2000	8 of 44 districts	34,130	27%
South Sudan	2009–11	5 of 10 states	11,790	20%
Sudan	2009	6 of 18 states	12,058	35%
Swaziland	2013–15	National	801	28%
Tanzania	2011–13	27 of 31 regions	22,021	33%
Togo	2006–7	National	4,550	30%
Uganda	2016	National	58,366	19%
Zambia	2007	National	25,624	27%
Zimbabwe	2014–17	6 of 8 provinces	29,986	28%
				Average: 26%

[28] 2014–15 mapping of handpumps in 6 of 11 departments found a non-functionality rate of 21%.
[29] A 2013 service level assessment of 568 handpumps in three districts found a non-functionality rate of 19%.
[30] Data refer to boreholes with handpumps; data collection is ongoing.
[31] A survey of 121 handpumps in 2013 found a non-functionality rate of 29%.
[32] A 2015 inventory of handpumps in Chikwawa District found a non-functionality rate of 22%.
[33] Data not collected for Borno State due to security concerns. A 2012 inventory of 21,135 handpumps in 661 of 774 local government areas found a non-functionality rate of 36%, while a 2015 inventory of 6,108 handpumps in 20 local government areas found a non-functionality rate of 29%.

ANNEX 4 FACTORS THAT AFFECT HANDPUMP FUNCTIONALITY

TABLE A4.1 COMPILATION OF FACTORS IDENTIFIED THAT AFFECT WATER POINT FUNCTIONALITY FROM SELECT STUDIES ARRANGED BY COUNTRY

Geographical scope (reference)	Factor/critical issue
Chad – Bokoro District (Thibert, 2016)	▪ Poor management
Democratic Republic of the Congo (Koestler et al., 2014)	▪ Access to spare parts
Ghana – Greater Afram Plain (Fisher et al., 2015)	▪ Management ▪ Access to tools and spare parts ▪ Savings ▪ Collection of a tariff ▪ External technical support
Ethiopia (Alexander et al., 2015)	▪ Record-keeping ▪ Regularity of community meetings ▪ Financial audits ▪ Level of monthly fees ▪ A paid caretaker ▪ Water committees with the capacity to perform minor repairs
Liberia, Sierra Leone and Uganda (Foster et al., 2013)	▪ Operational (trained committee, regularity of meetings, number of committee members, regularity of servicing) ▪ Technical (small number of pump types, handpump density) ▪ Institutional (who installed the pump, distance to spare parts supply, trained handpump mechanic) ▪ Financial (revenue collection) ▪ Environmental (seasonality)
Malawi (Anscombe, 2004)	Implementers refer to: ▪ Poor community maintenance ▪ Poor availability of spare parts ▪ Poor-quality pump parts leading to broken (pump) mechanism ▪ Theft and vandalism Anscombe finds: ▪ Poor borehole siting ▪ Poor borehole construction ▪ Post-construction damage
Malawi (Anscombe, 2011)	▪ Low yield ▪ Excessive siltation ▪ Communities not satisfied with water quality ▪ Premature pump wear caused by abnormal use (>100 households) ▪ Pump neglect by non-motivated committees ▪ Poor-quality handpump components ▪ Bent bores combined with off-vertical pedestals ▪ Incorrect installation ▪ Theft of pumps and rods ▪ Incorrect maintenance practices ▪ Non-availability of spares
Malawi (RWSN, 2014)	▪ Inefficiency of user committees ▪ Corruption ▪ Availability of spare parts ▪ Community ownership ▪ Involvement of non-governmental organisations
Malawi – Rhumphi District (Holm et al., 2017)	▪ Community selection of handpump

Malawi (Truslove et al., 2019)	▪ Service provider present ▪ Rehabilitation conducted during life cycle
Malawi (Mannix et al., 2018)	▪ Poor hydrogeological oversight during planning and construction
Morocco (Lynch, 1984)	▪ Maintenance
Mozambique (Jansz, 2001)	▪ Choice of technology
Nigeria – Akwa Ibom State (Ibok and Daniel, 2014)	▪ Lack of maintenance ▪ Lack of community participation ▪ Lack of co-ordination and co-operation among the stakeholders ▪ Political factors ▪ Inefficient monitoring ▪ Poor attitude towards public property
Nigeria (Andres et al., 2018)	▪ Age ▪ Location ▪ Implementing agency ▪ Who maintains (WASHCOM/local mechanics) ▪ Amount of groundwater storage ▪ Groundwater productivity ▪ Groundwater depth ▪ Spares availability
Nigeria and Tanzania (Cronk and Bartram, 2017)	▪ Regularity of fee collection ▪ Management model
Zimbabwe (Mudege, 1993)	▪ Operation and maintenance system in place and carried out
Multiple countries: Liberia, Tanzania, Uganda and Nigeria (Klug et al., 2018)	▪ System type ▪ Age ▪ Management type ▪ Fee collection type
Multiple countries: Benin, Bolivia, Honduras, Indonesia, Pakistan and Uganda (Sara and Katz, 1998)	▪ Demand-responsiveness ▪ Household choice ▪ Training of household members and community organisations ▪ Designated community organisation ▪ Construction quality ▪ Flexible design ▪ Accountability and transparency
Multiple countries: Peru, Bolivia and Ghana (Whittington et al., 2009)	▪ Demand driven ▪ Community management ▪ Access to spare parts ▪ Technical expertise
Africa, Asia and Central America (McPherson and McGarry, 1987)	▪ Non-participation by users

TABLE A4.2 ASSERTIONS ABOUT WHAT AFFECTS HANDPUMP POINT FUNCTIONALITY

Reference	Factor/critical issue
Tincani et al. (2015)	▪ System age
Foster (2013)	▪ Distance from district/county capital
Harvey and Reed (2004) **Carter et al. (1999)** **Carter et al. (2010)**	▪ Cost recovery
Foster (2013)	▪ Well type
Sara and Katz (1998) **Gross et al. (2001)**	▪ Women in key positions
Foster (2013)	▪ Use of national standard pump
Whittington et al. (2009)	▪ Training of committees
Sara and Katz (1998) **Gross et al. (2001)**	▪ Spare parts proximity
Curtis et al. (1993)	▪ Viable spare parts supply chain
Foster (2013)	▪ Rainfall season
Baumann and Furey (2013)	▪ Handpump type
Foster (2013)	▪ Funding organisation
Foster (2013)	▪ Implementing organisation
Foster (2013)	▪ Availability of handpump mechanic
Foster (2013)	▪ Regular servicing
Foster (2013)	▪ Regular water committee meetings
Harvey and Reed (2004) **Gross et al. (2001)**	▪ Perceived benefits of the handpump supplies
Whittington et al. (2009) **Schweitzer and Mihelcic (2012)**	▪ Nature of post-construction support
Lockwood et al. (2003)	▪ Presence of a dynamic leader
Whittington et al. (2009)	▪ Existence of alternative water source
Whittington et al. (2009) **Obiols and Baumann (1998)**	▪ Number of users
Whittington et al. (2009)	▪ Level of ethnic homogeneity
Sara and Katz (1998)	▪ Construction quality
Sara and Katz (1998) **Narayan (1995)**	▪ Level of user participation during implementation
Foster (2013)	▪ Hydrogeological characteristics
Foster (2013)	▪ Broader enabling environment
Janke et al. (2017)	▪ Choice of technology
Baumann (2009)	▪ Ability of users to pay
Lockwood et al. (2003)	▪ Follow-up support

ANNEX 5 MONITORING FRAMEWORKS/TOOLS

TABLE A5.1 ANALYSIS OF RURAL WATER SUPPLY MONITORING FRAMEWORKS/TOOLS AND THEIR CAPTURE OF ISSUES ON CORROSION OR POOR QUALITY HANDPUMPS

Tool (reference)	Scope	Technical (and closely related) aspects covered	Technical quality failure covered as standard?
Sustainability assessment tool (Schweitzer and Mihelcic, 2012)	Eight indicators (activity level, participation, governance, tariff payment, accounting transparency, financial durability, repair service, and system function) each represented with a specific measurement.	Indicator on system function, with measures: ▪ Average hours/day ▪ Average days/week Indicator on repair services, with measures: ▪ Downtime	No – pumps are not taken out of the ground and user experiences of water quality not included.
Sustainability checks (UNICEF, 2017)	Scope is defined in-country. Guidance on scope is in relation to location of the study, WASH components, indicators and underlying factors. Water point functionality, reliability, continuity and seasonality of service as well as factors influencing future sustainability are included as potential focus areas.	Quality of design, construction and quality control is considered as a sustainability factor. Suggested indicator is 'percentage of water points/facilities surveyed where good quality construction is reported by WASH Committee'.	No – pumps are not taken out of the ground and user experiences of water quality not included. Exception is Malawi in 2011 and 2012.
Physical audits (CABINET NTU INTERNATIONAL A/S, 2013; 2014)	Technical aspects of construction quality through visual inspections.	Includes platform and soakaway construction and handpump components. Note, at least in the case of Burkina Faso 2013 and 2014 reports, the borehole itself is not examined, e.g. through use of a borehole camera.	Yes – pumps were taken out of the ground. However, no borehole camera was used to examine borehole technical issues.
Inventory (UNICEF Nigeria) (Daw, 2008)	Handpump sources only: ▪ Sustainability – yield an adequate quantity of water throughout the year (perennial) of acceptable quality (i.e. be potable). ▪ Functionality – sound working condition to deliver water, i.e. in a 'good' physical (mechanical) condition with a proper platform and drain. ▪ Utilisation: 'of use' or be 'utilised' by its users including convenience, preference social norms and cumulative impact.	Issues of mechanics, tools, spare parts and fees for repairs are covered in the 'maintenance assessment', which was undertaken in three of the nine states covered. Water quality problems (found in two villages in Enugu State).	No – pumps are not taken out of the ground and water quality perceptions are not detailed enough to pick up handpump corrosion.