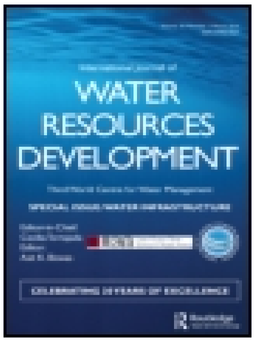

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Functionality of handpump water supplies: a review of data from sub-Saharan Africa and the Asia-Pacific region

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ABSTRACT

Handpumps are heavily relied upon for drinking water in rural areas of low- and middle-income countries, but their operation and maintenance remain problematic. This review presents updated and expanded handpump functionality estimates for 47 countries in sub-Saharan Africa and the Asia-Pacific region. Our results suggest that approximately one in four handpumps in sub-Saharan Africa are non-functional at any point in time, which in 2015 was roughly equivalent to 175,000 inoperative water points. Functionality statistics for Asia-Pacific countries vary widely, but data gaps preclude a robust region-wide estimate. In spite of data inconsistencies and imperfections, the results illustrate the persistent and widespread nature of rural water supply sustainability concerns.

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Rural water supply; handpumps; sub-Saharan Africa; Asia-Pacific; Sustainable Development Goals

Introduction

Non-functional rural water supplies in low- and middle-income countries pose a major obstacle to the Sustainable Development Goal of safe water for all. Premature failure of water services is likely to have significant adverse health implications, and prevent the realization of other human development gains (Baguma et al., 2017; Hunter, Zmirou-Navier, & Hartemann, 2009). As the most widespread rural water supply technology in sub-Saharan Africa and the Asia-Pacific region, handpumps are emblematic of the rural water service sustainability challenge. Macarthur (2015) estimates that 184 million people in rural sub-Saharan Africa depend on handpumps, while they serve in excess of 400 million people in India alone (ORGCCI, 2011).

Advocacy and arguments seeking to characterize the performance of rural water supplies have commonly cited handpump functionality statistics published by the Rural Water Supply Network (2009). These statistics covered 20 countries in sub-Saharan Africa and were drawn from estimates made by various experts. When aggregated, the estimates suggested that 36% of handpumps were non-functional, with country-level rates ranging from 10% to 65%. For almost a decade, these statistics

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have provided an important impetus for the rural water sector's shifting focus away from installation of infrastructure and towards service delivery.

There is an opportunity and a need to refresh these functionality estimates. A recent survey revealed strong demand for updated statistics among sector stakeholders (Furey, 2013). The rationale is threefold. First, the original estimates are outdated. The most recent were published in 2009, and the brief descriptions accompanying the data indicate that some or all of the country-level estimates refer to a period between 2000 and 2005. Since then, there has been an unprecedented surge of new information on handpump functionality, chiefly in the form of water point mapping data sets (Dickinson, Knipschild, & Magara, 2017). Second, the quality and accuracy of the original estimates remain unverifiable, as they were not based on publicly available information sources. Third, the countries included in the estimates were limited to sub-Saharan Africa, even though most handpumps are in Asia (Foster, Shantz, Lala, & Willetts, 2018).

This review provides updated handpump functionality statistics for countries in sub-Saharan Africa and the Asia-Pacific region. In doing so, it complements other recent quantitative assessments of rural water supply functionality. For example, Banks and Furey (2016) provided an important contribution by broadening functionality estimates to other water supply technologies and geographical regions. However, the analysis was confined to 11 countries and included data collected from implementing organizations at the time of installation, and so functionality results were likely biased upwards. Wide-ranging statistics on the operational performance of rural water services have also been compiled by Improve International (2015), Tincani et al. (2015) and Burr et al. (2015). This review builds on these efforts by way of a broader search strategy, the addition of new data that have since been made available, and consolidation of results at a regional level.

Methods

This review aimed to produce the most robust and up-to-date estimates possible for handpump functionality. To do so, we searched, collated and analyzed relevant data from inventories and reports for countries in sub-Saharan Africa and the Asia-Pacific region. Information sources included data sets and documents available online through digital libraries and data portals administered by government ministries and authorities, development partners, and other relevant organizations. A comprehensive list of databases and platforms searched can be found in the online supplemental material (https://doi.org/10.1080/07900627.2018.1543117). Search terms used to locate relevant documents and data were 'hand pump', 'handpump' and 'manual pump' and their non-English equivalents where appropriate. Priority was placed on comprehensive data sets or data points with nationwide coverage, but in their absence, data pertaining to (1) a nationally representative sample, or (2) entire administrative areas at the first or second level (based on the Database of Global Administrative Areas, http://www.gadm.org), were also eligible for inclusion. In light of the fragmented nature of functionality data, the threshold for data representativeness was less stringent than that used by the Joint Monitoring Programme to track progress towards Sustainable Development Goal target 6.1 (WHO/UNICEF, 2018). A data set was only included if it was collected after 2000. For each data source identified, the definition of a non-functional handpump was taken as given, and it was not possible to apply a harmonized definition across all data sources

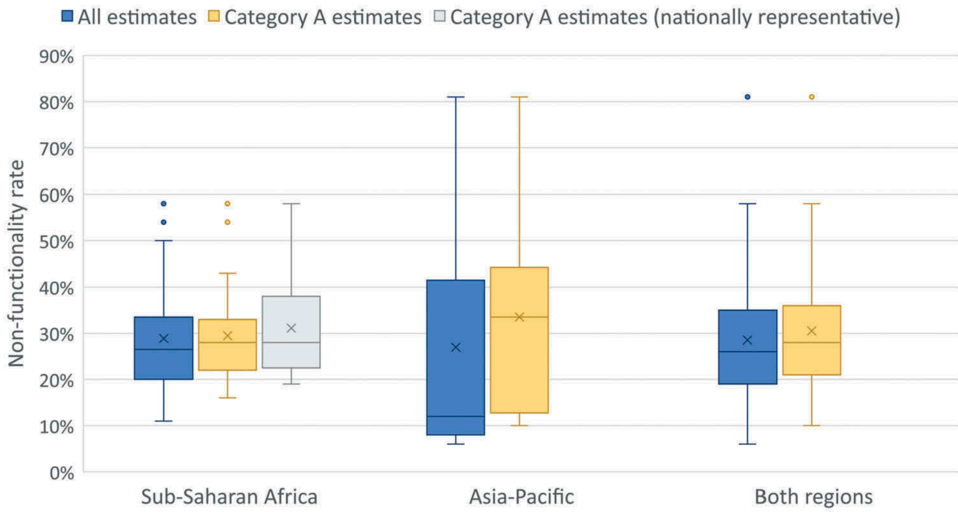

Figure 1. Box-and-whisker plot of country-level estimates of handpump non-functionality.

used. The Water Point Data Exchange (WPDx, 2016) – a platform from which several data sets were extracted – deems a water point to be functional 'if any water is available on the day of the visit, recognizing that it may be a limited flow'. Estimates were classed as Category A where information detailing the data collection methodology was identified, and Category B where it was not. Where available, multiple data sources were aggregated to form a single country-level estimate so long as they had no geographical overlap. A disaggregation of multiple data sources (where data categories differed) can be found in Table A1 in the online supplemental material.

To present region-wide results, country-level estimates were inputted into box-and-whisker plots. The results are presented for (a) all estimates, (b) Category A estimates, and (c) nationally representative Category A estimates (Figure 1). Results for sub-Saharan Africa were also extrapolated temporally and spatially to produce a region-wide estimate of handpump functionality (as of 2015) in a way that compensated for data gaps and adjusted for variations in the year data were collected. Details on the methodology and assumptions underpinning this region-wide estimate can be found in the online supplemental material. In light of the imperfect data, the aim of the African-wide quantification of non-functionality was to produce a broad-brush 'best estimate', as opposed to a precise computation. A region-wide estimate for the Asia-Pacific region was not possible due to the absence of data for several large countries.

Results and discussion

Handpump functionality data that met the inclusion criteria were identified for 38 countries in sub-Saharan Africa (Table 1) and nine countries in the Asia-Pacific region (Table 2). The results suggest that more than one in four handpumps in sub-Saharan Africa are non-functional at any point in time. The interquartile range for sub-Saharan

Table 1. Handpump functionality statistics for sub-Saharan Africa.

Country	Year(s)	Scope	Handpumps	Non-functional	Data category	Data source(s)
Angola	2015	National	4,389	25%	B	MINEA, 2015
Benin	2016	National[a]	13,003	12%	B	DGE, 2017
Burkina Faso	2017	National	52,596	11%	B	MEA, 2018
Burundi	2012	National	229	58%	A	ABHR, 2013
Cameroon	2011–15	189 of 316 communes	6,899	32%	B	PNDP, 2018[b]
Central African Rep.	2003	National	3,177	25%	B	MEMH, 2005
Chad	2000	National	3,267	16%	B	HCNE, MEE, ONU-DAES, & PNUD, 2003
Congo (Brazzaville)	2008	1 of 10 rural depts	159	50%	B	World Bank, 2011
Dem. Rep. of Congo	2011	National sample	2,214	25%	A	STUDI International, 2015
Côte d'Ivoire	2016	National	22,807	30%	B	Ibrahiman, 2016
Eritrea	2006	National	864	43%	A	WRD, 2007
Ethiopia	2011–14	2 of 9 regions	4,620	33%	A	Assefa, 2013; EMWIE, 2016
Gabon	2012	National	1,158	47%	B	DGEPF, 2013
Ghana	2014	6 of 10 regions[c]	20,365	26%	A	CWSA, 2017
Guinea	2012	National	12,815	18%	B	MEH, 2012
Guinea-Bissau	2016	Sub-national[d]	703	36%	A	UNICEF, 2017
Kenya	2013	9 of 48 counties	2,580	24%	A	AWSB, 2014; FAO, 2013; Foster & Hope, 2016; LVNWSB, 2013; LVSWSB, 2013; NWSB, 2013; RVWSB, 2013; TAWSB, 2013; TWSB, 2013
Liberia	2017	National	12,684	20%	A	NWSHPC, 2017
Madagascar	2018	National[e]	15,068	20%	A	MEAH, 2018
Malawi	2007	National[f]	24,769	22%	B	Baumann & Danert, 2008
Mali	2015–16	5 of 8 regions	19,951	29%	A	DNH & SNV, 2016
Mauritania	2012	1 of 15 regions	71	54%	B	MID, 2012
Mozambique	2011–12	93 of 128 districts	12,180	20%	B	DNA, 2012[g]
Namibia	2000	2 of 14 regions	94	54%	A	LCE, 2002
Niger	2015	National	10,072	15%	B	MHA, 2016
Nigeria	2006	35 of 36 states[h]	25,470	42%	A	JICA, 2014
Rwanda	2008–09	6 of 30 districts	279	16%	A	JICA, 2010b
Senegal	2014	National	2,903	22%	B	PEPAM, 2014
Sierra Leone	2016	National	11,895	25%	A	MOWR, 2017
South Africa	2000	8 of 44 districts	11,735	27%	B	Harvey & Kayaga, 2003
South Sudan	2009	5 of 10 states	4,951	20%	A & B	IOM, 2009a, 2009c, 2009d; WI, UNICEF, & SNV, 2012
Sudan	2009–10	6 of 18 states	7,933	35%	A & B	AfDB, 2016; IOM, 2009b
Swaziland	2013–15	National	801	28%	A	DWA, 2015
Tanzania	2011–13	27 of 31 regions	22,021	33%	A	Ministry of Water, 2014
Togo	2006–7	National	4,550	30%	B	DGEA, 2009

(*Continued*)

Table 1. (Continued).

Country	Year(s)	Scope	Handpumps	Non-functional	Data category	Data source(s)
Uganda	2016	National	58,366	19%	A	MWE, 2017
Zambia	2007	National[i]	25,624	27%	B	MLGH, 2007
Zimbabwe	2014–17	6 of 8 provinces	29,986	28%	A	NACWASH, 2017

[a]A 2014–15 mapping of handpumps in 6 of 11 Departments found a non-functionality rate of 21% (DGE, 2015). [b]Data collated from individual commune development plans. [c]A 2013 service level assessment of 568 handpumps in three districts found a non-functionality rate of 19% (Adank et al., 2014). [d]Data refer to boreholes with handpumps, and data collection is ongoing. [e]A survey of 121 handpumps in 2013 found a non-functionality rate of 29% (Ryan, 2014). [f]A 2015 inventory of handpumps in Chikwawa District found a non-functionality rate of 22% (Water for People, 2015). [g]Data collated from individual district-level reports. [h]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% (Cronk & Bartram, 2017), while a 2015 inventory of 6108 handpumps in 20 local government areas found a non-functionality rate of 29% (UNICEF, 2015). [i] A more recent survey of 300 handpumps across all 10 districts found a non-functionality rate of 29% at baseline in 2012 and 22% at endline in 2016 (JICA, 2017). Water point mapping in eight districts identified 2123 handpumps, of which 16% were non-functional (SNV Zambia, 2014).

Table 2. Handpump functionality statistics for the Asia-Pacific region.

Country	Year(s)	Scope	Handpumps	Non-functional	Data category	Data source(s)
Afghanistan	2013–14	194 of 398 districts	24,504	36%	A	DACAAR, 2014, DACAAR, 2015
Bangladesh	2017	National	1,656,695	9%	B	DPHE, 2017
Cambodia	2008–14	48 of 163 districts	136,722[b]	7%	A & B	Foster et al., 2018; JICA, 2010a; SNV, 2014
India[a]	2013–17	National	5,723,533	6%	A & B	MDWS, 2017; WAMS, 2018
Kiribati	2003	4 of 24 councils	187	81%	A	Loco, Sinclair, Singh, & Mataio, 2015; Loco, Singh, Mataio, Bwatio, & Sinclair, 2015; Loco et al., 2015; Overmars, 2004
Laos	2015	2 of 147 districts	720	35%	A	SNV, 2015
Philippines	2014	6 of 81 provinces	10,743	10%[c]	A	PNWC, 2014
Timor-Leste	2007–8	3 of 13 districts	99	47%	A	Grumbley & Hamel, 2010; Kamtukule, 2008; Willetts, 2012
Vanuatu	2014–16	60 of 66 council areas	245	12%	A	DWR, 2016

[a]In 2009, India's Ministry of Drinking Water and Sanitation reported 4,155,000 handpumps, with 11.8% non-functional (MDWS, 2009). [b]Sample includes privately owned handpumps. [c]Based on operational status of handpumps prior to Typhoon Haiyan.

African countries was 20–34% for all estimates, 22–33% for Category A estimates, and 23–38% for nationally representative Category A estimates. Measures of centrality were consistent across the three data classes analyzed, with medians of 27–28% and means of 29–31%. Spatial and temporal extrapolation of results for sub-Saharan African countries produced a total estimate of 680,000 handpumps across the region in 2015, of which 175,000 (26%) were non-functional (Table A2 in the online supplemental information). Based on recent capital cost benchmarks (Burr & Fonseca, 2013; Burr, Nyarko, Dwumfour-Asare, & Fonseca, 2013), this non-functional cohort likely represents US$ 1.5–2.5 billion in capital investment.

Non-functionality rates in the Asia-Pacific region were more varied: the interquartile range was 8–42% for all estimates and 13–44% for Category A estimates. Measures of centrality were also divergent, with medians of 12% (all estimates) and 34% (Category A estimates) and means of 27% (all estimates) and 34% (Category A estimates). A lack of qualifying data precluded calculation of measures of centrality and variability for nationally representative Category A estimates. Non-functionality rates in India and Bangladesh were notably lower than other Asia-Pacific countries. Even though there were fewer countries in the Asia-Pacific region with available data, the total number of inoperative handpumps in the region far exceeded that of sub-Saharan Africa. Government monitoring data in India and Bangladesh reported more than 450,000 non-functional handpumps in those countries alone.

These updated handpump functionality estimates reaffirm the persistent and widespread nature of rural water supply sustainability concerns. The problems appear ubiquitous in sub-Saharan Africa, where all countries reported a non-functionality rate in excess of 10%. Data from several countries in the Asia-Pacific region (e.g. Afghanistan, Timor-Leste, Laos and Kiribati) show comparatively high non-functionality rates (>25%), as do particular sub-national regions (e.g. Chittagong Hill Tracts in Bangladesh, Andhra Pradesh in India). The handpump functionality issue is therefore of greater geographical breadth than commonly quoted functionality statistics suggest. A corollary is that the adverse human development consequences of handpump failure are also more significant than has previously been supposed.

The issue also has implications for the Sustainable Development Goal target of universal access to safe drinking water, though the ramifications are conceptually different from the earlier Millennium Development Goals framework. Under the Millennium Development Goals, a handpump qualified as an improved water source, and so premature failure could directly undermine progress towards the headline indicator. However, under the Sustainable Development Goals framework a handpump can constitute a limited, basic or safely managed service, depending on its location relative to users. Communal handpumps typically provide only a basic or limited service, and hence an operational failing has no direct effect on the proportion of households using a safely managed service. That said, high failure rates are likely to disrupt the stepwise movement of low-income households up the water service ladder towards the safely managed apex, and result in the diversion of significant amounts of funding towards rehabilitating systems in a state of disrepair.

The imperfect and in some cases approximate nature of the statistics presented must be stressed. First of all, functionality status is a simplistic binary measure of operational performance (Carter & Ross, 2016), and ideally data would allow the benchmarking of more nuanced service level indicators. Handpumps deemed to be functional may still provide a poor service in terms of water quality or quantity, and may experience lengthy repair times when they do break down. Promisingly, there have been important advances towards the establishment of appropriate and consistent service level classifications for handpump supplies (Bonsor, Macdonald, Casey, Carter, & Wilson, 2018) and for rural water services more broadly (World Bank, 2017b). Second, although the estimates are backed by publicly available sources, there are still gaps as to the methodologies used to collect the data, and it is difficult to evaluate the reliability of many estimates. The underlying data undoubtedly contain inaccuracies and inconsistencies stemming from both sampling and non-sampling errors (Cronin & Thompson, 2014; Verplanke & Georgiadou, 2017). Possible sources of bias include varying functionality definitions (Bonsor et al., 2018), underreported non-functionality rates linked to abandoned handpumps that have been forgotten or dismantled (Carter & Ross, 2016), and the season in which data have been collected (Foster, 2013). Moreover, in cases where data cover only a sub-national administrative unit, the functionality statistic is not strictly representative of the national level. For these reasons, the results should be understood as 'best estimates' that in most instances understate the true extent of the problem. Caution should therefore be exercised when interpreting results at both country and region-wide levels.

Data inconsistencies for India are worth singling out, because of both the high number of handpumps and the relatively low non-functionality rate. Data for all but one state were drawn from the ministry's Integrated Management Information System (IMIS), a platform which has previously been described by Wescoat, Fletcher, and Novellino (2016). Three alternative data points suggest that the IMIS understates the true non-functionality rate. First, in 2009 the Ministry of Drinking Water and Sanitation reported a non-functionality rate of 11.8% (MDWS, 2009). Although an eight-year gap separates this figure from current IMIS data, the discrepancy is equivalent to approximately 230,000 non-functional handpumps. Second, a rural water assessment in Bihar reported that 19.5% of handpumps were non-functional in 2012 (Das, Shireesh, Mishra, Bandyopadhyaya, & Samanta, 2013). In comparison, the IMIS suggests that this number is just 1.9%. Third, for three districts in West Bengal and Bihar the IMIS presents lower non-functionality rates than data collected during a water point mapping process in 2015 (Table A3 in the online supplemental information). In light of these conflicts, the estimate for India comes with a great deal of uncertainty.

Functionality data could not be obtained for many countries where handpumps play an important role in supplying water to rural households. It seems at least some of these grapple with operation and maintenance difficulties, including The Gambia (Foster, Willetts, & Mcsorley, 2018), Sri Lanka (Ferdinando, 2011), Somalia (Muthusi, Mahamud, Abdalle, & Gadain, 2007), Tajikistan (Wurzel & Maramov, 2007), and the Solomon Islands (MHMS, 2014). Most notable among the absentees are Asian countries with a considerable number of handpumps, including Nepal, Pakistan, Thailand, Vietnam, Indonesia and China (Table 3). These omissions further undermine the validity of the estimate ranges for the Asia-Pacific region. Moreover, estimates for India and Bangladesh omit private handpumps, which far outnumber communal handpumps. In 2011, more than 29 million households in India had a handpump on their premises (ORGCCI, 2011), and there were

Table 3. Illustrative extent of handpump usage in selected countries with little or no identified functionality data.

Country	Data point illustrating extent of handpump usage
China	19% of population were using a handpump in 2008, equivalent to 250 million people (WHO/UNICEF, 2017)
Indonesia	10% of households were using a handpump in 2009, equivalent to 24 million people (KKRI, 2010)
Nepal	1.2 million handpumps have been installed in the Terai region (SEIU-MWSS, 2016)
Pakistan	29% of population were using a handpump in 2013–14, equivalent to 53 million people (Pakistan Bureau of Statistics, 2016)
Thailand	154,000 handpumps have been installed across the country (Worakul, Painmanakul, and Larbkich, 2015)
Vietnam	97,000 handpumps were supplied across three provinces in 1994–2001 (Ikin and Baumann, 2002)

estimated to be in excess of 10 million privately owned handpumps in Bangladesh (BBS, & UNICEF, 2011).

Studies have identified a strong relationship between handpump age and functionality (Fisher et al., 2015; Foster, 2013; Foster et al., 2018; Jiménez & Pérez-Foguet, 2011), so it is important to note that the estimates presented are not age-standardized in a way that would adjust for handpump age disparities between countries. This issue may also affect the degree to which functionality statistics can be reliably extrapolated over time. On the one hand, non-functionality might rise as a cohort of handpumps grows older; on the other, large deployments of new installations could have a neutralizing effect by lowering the average handpump age. Countries with data sets from two different points in time indicate that changes in national-level functionality rate are typically less than one percentage point per year (Table A4 in the online supplemental material). Applying a one-percentage-point change in non-functionality per year (in either direction) since the time data were collected gives rise to lower and upper bounds for the African-wide non-functionality estimate of 22–29%.

Notwithstanding data quality and coverage issues, outlier countries may provide clues as to what might help improve operational outcomes. For example, in sub-Saharan Africa, Benin and Burkina Faso appear to have above-average functionality rates, and both of these countries have been open to novel management arrangements for handpump operation and maintenance (Foster, 2012; Migan, 2015). Likewise, Guinea performs better than most other countries in sub-Saharan Africa, an outcome that has been attributed to their strict standardization policy (Macarthur, 2015).

Also notable are the relatively low non-functionality rates in parts of South Asia. This warrants further investigation – both to verify these functionality levels and to understand the underlying drivers. Sector-level attributes or service delivery models may play a role, as might higher population densities (and concomitant handpump densities), which boost the viability of technical services and spare-part supply chains. Hydrogeological and technological differences may also explain operational advantages: for example, low-lift suction handpumps are commonplace in Bangladesh, and these tend to be easier and cheaper to repair than the deep-well handpumps prevalent in sub-Saharan Africa, Afghanistan and Timor-Leste (Foster et al., 2018).

The divergent outcomes for the two Pacific Island countries (Vanuatu and Kiribati) are also instructive. While both have faced similar challenges relating to supply of spare parts, Vanuatu enjoys higher rainfall (so handpump usage is probably lower), and from the outset implementing organizations invested in the Nira AF-85 direct action pump, a more expensive handpump technology than the Southern Cross KDC diaphragm pump that was originally rolled out in Kiribati (Mourits & Depledge, 1995). More recently, the Tamana pump has become the dominant handpump in Kiribati, with approximately 1600 installed by 2007 (SOPAC, 2007), and further investigation into its performance could provide useful insights into how a shift in handpump technology can impact functionality at a national level.

Ownership models may also affect estimates. For example, the above-average functionality rate observed in Cambodia may have partly arisen because it is the only country with data that included a substantial proportion of privately owned handpumps. The handpumps clearly denoted as 'communal' had a non-functionality rate of 20%, compared with 5% for handpumps denoted as 'private'. This is consistent with a study from Southern Cambodia that found that privately owned handpumps exhibited better operational performance than communally owned handpumps (Foster et al., 2018).

Understanding functionality rate disparities between countries is complicated by the multifarious, multilayered and interconnected nature of the factors that influence rural water service outcomes (Bonsor et al., 2015; Cronk & Bartram, 2017; Foster, 2013; Walters & Javernick-Will, 2015; Whaley & Cleaver, 2017). There is no silver bullet to resolve the myriad socio-political, financial, technical and environmental difficulties, but in recent years substantial work has gone into identifying the foundations needed to achieve sustainable services. It is widely acknowledged that communities require external support to manage their water supply (Harvey & Reed, 2004; IRC, 2012). More broadly, improving the status quo requires strengthening of multiple institutional tiers (national sector, service authorities, service providers) as well as cross-cutting efforts relating to institutional capacity, financing, asset management, water resources management, and monitoring and regulation (World Bank, 2017a).

The persistence of high non-functionality rates raises the question of whether handpumps are still an appropriate technology for rural water supplies in low- and middle-income countries. Handpumps clearly have some disadvantages compared with more advanced water supply systems, such as the effort needed to pump water manually and the inability to incorporate a distribution system to allow for more convenient access points. These limitations may undermine users' willingness to maintain their system over time. The push towards safely managed water services – a definition that is premised upon an on-plot supply – may also shift policy-makers away from communal handpumps. Increasing population densities and the declining price of solar-powered pumps loom as other trends that could shift technology preferences in the coming years. India, for example, is actively moving away from the handpump option in favour of piped schemes (MDWS, 2013).

There are, however, a number of reasons why handpumps will continue to play a central role in securing safe water services for low-income households for many years to come. First, in many cases they remain a less expensive option than small piped schemes (Burr & Fonseca, 2013), particularly in sparsely populated areas in rural sub-Saharan Africa. Even where small distribution systems are established, handpumps may need to be retained as a back-up in the event of service disruptions brought about by power cuts, fuel shortages, or consecutive days of overcast skies. Second, the millions of handpumps still in operation across Asia and Africa dictate that even with a shift in preferred technologies they will persist for some time. Hence, strengthening handpump operation and maintenance systems will have to remain a key priority for policy-makers and practitioners. Third, in Asia the majority of handpumps are privately owned, so consumer preferences may shape technology transitions as much as government policies. Finally, the best available data show that more sophisticated water supply systems are encumbered with similar functionality problems (Banks & Furey, 2016). This foretells that a shift in technologies will be no panacea for sustainability dilemmas: hardware changes will neither obviate the socio-political systems within which water supplies are situated, nor displace the need for the institutional and financial building blocks to ensure that services continue indefinitely.

Conclusion

This review has presented updated and expanded functionality statistics for handpump water supplies in sub-Saharan Africa and the Asia-Pacific region. Approximately one in four handpumps are non-functional in sub-Saharan Africa at any point in time, which in 2015 was broadly equivalent to 175,000 water points in a state of disrepair. Country-level estimates for the Asia-Pacific region vary widely, with South Asian countries reporting comparatively low non-functionality rates. All told, there appear to be at least 600,000 non-functional handpumps across low- and middle-income countries. In light of data gaps, inconsistencies and imperfections, the results should be considered 'best estimates' only, but they do demonstrate the widespread and persistent nature of the rural water supply sustainability challenge. A better understanding of the true situation requires governments and development partners to improve monitoring systems and make data more widely available, along with clear explanations of data collection methodologies. The aim of the article is to provide a reference point that spurs further action and elevates the importance of a situation that adversely impacts the health and welfare of tens of millions of people. To improve the sustainability of handpumped water supplies, efforts are needed to ensure high-quality implementation, bolster service delivery models and strengthen sector capacity and the enabling environment more broadly.

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References

ABHR. (2013). *INEA Atlas 2012: Taux de Couverture en Eau Potable Burundi Millieu Rural*. Bujumbara: Author.

Adank, M., Kumasi, T. C., Chimbar, T. L., Atengdem, J., Agbemor, B. D., Dickinson, N., & Abbey, E. (2014). The state of handpump water services in Ghana: Findings from three districts. In *Proceedings of the 37th WEDC International Conference - Sustainable water and sanitation services for all in a fast changing world*. Hanoi: WEDC.

AfDB. (2016). *Sudan: Darfur infrastructure development report*. Abidjan: Author.

Assefa, M. (2013). Strategies to reduce the non-functionality of water supply schemes in Kedida Gamella Woreda, Ethiopia. In *Proceedings of the 36th WEDC International Conference: Delivering Water, Sanitation and Hygiene Services in an Uncertain Environment*. Nakuru: WEDC.

AWSB. (2014). *GOK/UNICEF WASH Programme: Kiambu County*. Nairobi: Author.

Baguma, A., Bizoza, A., Carter, R., Cavill, S., Foster, S., Foster, T., … Simons, A. (2017). *Groundwater and poverty in sub-Saharan Africa* (UPGro Working Paper). St. Gallen: Skat Foundation.

Banks, B., & Furey, S. (2016). What's working, where, and for how long: A 2016 water point update. In *Paper presented at the 7th Rural Water Supply Network Forum*. Abidjan: Rural Water Supply Network. Retrieved from http://www.rural-water-supply.net/_ressources/documents/default/1-787-2-1502962732.pdf

Baumann, E., & Danert, K. (2008). *Operation and maintenance of rural water supplies in Malawi: Study findings*. Lilongwe: Skat.

BBS, & UNICEF. (2011). *Bangladesh National Drinking Water Quality Survey of 2009*. Dhaka: Author.

Bonsor, H., Macdonald, A., Casey, V., Carter, R., & Wilson, P. (2018). Need for a standard approach to assessing the functionality of community water supplies. *Hydrogeology Journal*. doi:10.1007/s10040-017-1711-0

Bonsor, H., Oates, N., Chilton, P. J., Carter, R. C., Casey, V., MacDonald, A. M., … Bennie, M. (2015). A hidden crisis: Strengthening the evidence base on the current failures of rural groundwater supplies. In *Proceedings of the 38th WEDC international conference - Water, Sanitation and Hygiene Services Beyond 2015: Improving access and sustainability*. Loughborough: WEDC.

Burr, P., & Fonseca, C. (2013). *Applying a life-cycle costs approach to water: Costs and service levels in rural and small town areas in Andhra Pradesh (India), Burkina Faso, Ghana and Mozambique*. The Hague: IRC.

Burr, P., Nyarko, K., Dwumfour-Asare, B., & Fonseca, C. (2013). *WASHCost Sierra Leone Project: Institutional Cost Mapping related to rural and peri-urban WASH service delivery in Sierra Leone*. The Hague: IRC.

Burr, P., Ross, I., Zaman, R., Mujica, A., Tincani, L., White, Z., … Evans, B. (2015). *Improving value for money and sustainability in WASH programmes: Regional assessment of the operational sustainability of water and sanitation services in South Asia*. Oxford: Oxford Policy Management.

Carter, R. C., & Ross, I. (2016). Beyond "functionality" of handpump-supplied rural water services in developing countries. *Waterlines*, *35*(1), 94–110. doi:10.3362/1756-3488.2016.008

Cronin, A. A., & Thompson, N. (2014). Data and monitoring in the Indian rural water and sanitation sector – A review of current status and proposed ways forward. *Journal of Water, Sanitation and Hygiene for Development*, *4*(4), 590. doi:10.2166/washdev.2014.018

Cronk, R., & Bartram, J. (2017). Factors influencing water system functionality in Nigeria and Tanzania: A regression and Bayesian Network Analysis. *Environmental Science and Technology*, *51*(19), 11336–11345. doi:10.1021/acs.est.7b03287

CWSA. (2017). *CWSA Water Atlas of rural and small towns water services in Ghana*. Retrieved January 17, 2018, from https://cwsawateratlas.org/data/

DACAAR. (2014). *National study on water point functionality in Afghanistan*. Kabul: Author.

DACAAR. (2015). *WPDx data export - Afghanistan - DACAAR*. Retrieved January 17, 2018, from https://www.waterpointdata.org/data-sources/dacaar

Das, V. M., Shireesh, Mishra, B. L., Bandyopadhyaya, V., & Samanta, D. (2013). *Assessment of rural drinking water supply services*. Patna. Retrieved from http://mdws.gov.in/sites/default/files/Sector_Assessment_Study_0.pdf

DGE. (2015). *Water point data files – Benin*. Retrieved October 31, 2018, from https://wash-alliance.org/wp-content/uploads/sites/29/2015/11/

DGE. (2017). *Situation des points d'eau au 31 Decembre 2016*. Cotonou: Direction Générale de l'Eau. Retrieved from http://eaubenin.bj/site/index.php/taux_desserte_eau_potable/

DGEA. (2009). *Étude De Faisabilité Des Forages Manuels Au Togo: Identification Des Zones Potentiellement Favorables*. Lome: Author.

DGEPF. (2013). *Tableu de Bord Social: Situation 2006-2012*. Libreville: Author.

Dickinson, N., Knipschild, F., & Magara, P. (2017). *Harnessing water point data to improve drinking water services*. The Hague: WASHNote.

DNA. (2012). *Programa Nacional de Abastecimento de Água e Saneamento Rural: Inquérito de Base 2011-12 Estudo Institucional*. Maputo: Author.

DNH, & SNV. (2016). *Capitalisation de l'expérience de la DNH et de la SNV sur l'inventaire national des points d'eau modernes au Mali a l'aide des outils Akvo*. Bamako: Author.

DPHE. (2017). *DPHE Circlewise water source status and coverage June 2017*. Dhaka. Retrieved from http://www.dphe.gov.bd/download/Status%20of%20Water%20Points/June%202017.pdf

DWA. (2015). *Swaziland National Water Point Inventory | WPDx*. Retrieved January 17, 2018, from https://www.waterpointdata.org/node/215/download

DWR. (2016). *Vanuatu national water supply data*. Port Vila: Author.

EMWIE. (2016). *WPDx data export | Ethiopia ministry of water irrigation and electricity*. Retrieved January 17, 2018, from https://www.waterpointdata.org/node/209/download

FAO. (2013). *Disaster risk reduction: WIMS inventory*. Retrieved January 18, 2018, from http://www.fao.org/disasterriskreduction/wims/inventory/en/

Ferdinando, D. (2011). Accelerated groundwater development for rural water supplies in Sri Lanka. In *Paper presented at the 6th Rural Water Supply Network Forum*. Kampala: Rural Water Supply Network.

Fisher, M. B., Shields, K. F., Chan, T. U., Christenson, E., Cronk, R. D., Leker, H., … Bartram, J. (2015). Understanding handpump sustainability: Determinants of rural water source functionality in the Greater Afram Plains region of Ghana. *Water Resources Research*, *51*(10), 8431–8449. doi:10.1002/2014WR016770

Foster, T. (2012). *Private sector provision of rural water services: A desk study for Water for People*. Colorado: Water for People.

Foster, T. (2013). Predictors of sustainability for community-managed handpumps in sub-saharan Africa: Evidence from Liberia, Sierra Leone, and Uganda. *Environmental Science and Technology*, *47*(21), 12037–12046. doi:10.1021/es402086n

Foster, T., & Hope, R. (2016). A multi-decadal and social-ecological systems analysis of community waterpoint payment behaviours in rural Kenya. *Journal of Rural Studies*, *47*, 85–96. doi:10.1016/j.jrurstud.2016.07.026

Foster, T., Shantz, A., Lala, S., & Willetts, J. (2018). Factors associated with operational sustainability of rural water supplies in Cambodia. *Environmental Science: Water Research & Technology, 4*, 1577–1588. doi:10.1039/C8EW00087E

Foster, T., Willetts, J., & Mcsorley, B. (2018). Comparative performance evaluation of handpump water-supply technologies in Kenya and The Gambia. *Hydrogeology Journal*. doi:10.1007/s10040-018-1865-4

Furey, S. G. (2013). *RWSN handpump survey 2013: Summary of findings*. St. Gallen. Retrieved from http://www.rural-water-supply.net/en/resources/details/576

Grumbley, A., & Hamel, S. (2010). Accountability and sustainability of rural water supply and sanitation infrastructure in Timor-Leste. In *Paper presented at the IRC symposium 2010: Pumps, pipes and promises*. The Hague: IRC.

Harvey, P. A., & Kayaga, S. (2003). *Sustainable handpump projects in Africa: Report on fieldwork in South Africa, May 23 – June 6, 2003*. Loughborough: WEDC.
Harvey, P. A., & Reed, R. (2004). *Rural water supply in Africa: Building blocks for sustainability*. Loughborough: WEDC.
HCNE, MEE, ONU-DAES, & PNUD. (2003). *Schéma Directeur de l'Eau et de l'Assainissement du Tchad*. N'Djamena: Author.
Hunter, P. R., Zmirou-Navier, D., & Hartemann, P. (2009). Estimating the impact on health of poor reliability of drinking water interventions in developing countries. *Science of the Total Environment*, *407*(8), 2621–2624.
Ibrahiman, B. (2016). Eau potable en Côte D'Ivoire: Le sous-secteur de l'hydraulique rurale. In *Paper presented at the 7th Rural Water Supply Network Forum*. Abidjan: Rural Water Supply Network.
Ikin, D., & Baumann, E. (2002). *Appraisal and impact assessment of IDE Vietnam Hand Pump Program*. St. Gallen: Skat & SDC.
Improve International. (2015). *Statistics on water point failures*. Retrieved from https://improveinternational.wordpress.com/handy-resources/sad-stats/
IOM. (2009a). *State report Northern Bahr el Ghazal: Village assessments and returnee monitoring*. Geneva: Author.
IOM. (2009b). *State report Southern Kordofan: Village assessments and returnee monitoring*. Geneva: Author.
IOM. (2009c). *State report Unity: Village assessments and returnee monitoring*. Geneva: Author.
IOM. (2009d). *State report Warrap: Village assessments and returnee monitoring*. Geneva: Author.
IRC. (2012). *Direct support post-construction to rural water service providers*. The Hague: Author.
JICA. (2010a). *Survey on the water supply sector in the Kingdom of Cambodia*. Phnom Penh: Author.
JICA. (2010b). *The study on improvement of rural water supply in the Eastern Province in the Republic of Rwanda*. Kigali: Author.
JICA. (2014). *The project for review and update of Nigeria National Water Resources Master Plan: Volume 2, summary report*. Abuja: Author.
JICA. (2017). *The project for support in national roll-out of sustainable operation and maintenance programme (SOMAP 3) in the Republic of Zambia: Project completion report*. Lusaka: Author.
Jiménez, A., & Pérez-Foguet, A. (2011). The relationship between technology and functionality of rural water points: Evidence from Tanzania. *Water Science and Technology*, *63*(5), 948–955.
Kamtukule, G. (2008). *Covalima district rural water supply management study*. Melbourne: Oxfam.
KKRI. (2010). *Profil Kesehatan Indonesia Tahun 2009*. Jakarta: Author.
LCE. (2002). *Regional rural water supply development plan for the Kavango Region*. Windhoek: Ministry of Agriculture, Water and Rural Development.
Loco, A., Sinclair, P., Singh, A., & Mataio, M. (2015). *KIRIWATSAN Water Resources Assessment Maiana Island, Kiribati*. Suva: Secretariat of the Pacific Community.
Loco, A., Singh, A., Mataio, M., Bwatio, E., & Sinclair, P. (2015). *KIRIWATSAN Water Resources Assessment Abaiang Island, Kiribati*. Suva: Secretariat of the Pacific Community.
LVNWSB. (2013). *Water point mapping report: Busia County*. Kakamega: Author.
LVSWSB. (2013). *Water point mapping: Kisumu*. Kisumu: Author.
Macarthur, J. (2015). *Handpump Standardisation in Sub-Saharan Africa: Seeking a Champion*. St. Gallen: Rural Water Supply Network.
MDWS. (2009). *Rural water supply sector: Background paper*. Delhi: Author.
MDWS. (2013). *National rural drinking water programme: Movements towards ensuring people's Drinking Water Security in Rural India*. Delhi: Ministry for Drinking Water & Sanitation.
MDWS. (2017). *National Rural Drinking Water Programme (NRDWP)*. Retrieved December 12, 2017, from http://indiawater.gov.in/imisreports/Reports/BasicInformation/Rpt_RWS_NoOfHandPump_S.aspx?Rep=0&RP=Y
MEA. (2018). *Inventaire National des Ouvrages d'Approvisionnement en Eau Potable de 2017*. Ouagadougou: Author. Retrieved from http://www.eauburkina.org/index.php/resultats-ino
MEAH. (2018). *Suivi Eau & Assainissement à Madagascar – Indicateurs eaux*. Antananarivo: Author. Retrieved from http://bdeah-sesam.mg

MEH. (2012). *Service National des Points d'Eau: Rapport annuel d'activites 2012 bilan des realisations*. Conakry: Author.
MEMH. (2005). *Politique et stratégies nationales en matière d'eau et d'assainissement*. Bangui: Author.
MHA. (2016). *Programme Sectoriel Eau, Hygiène et Assainissement: PROSEHA 2016–2030*. Niamey. Retrieved from https://www.pseau.org/outils/ouvrages/mha_programme_sectoriel_eau_hygiene_et_assainissement_proseha_2016_2030_2016.pdf
MHMS. (2014). *The Solomon Islands Rural Water Supply, Sanitation and Hygiene Policy*. Honiara: Author.
MID. (2012). *Lignes directrices de la Region du Brakna, Mauritanie*. Nouakchott: Author.
Migan, S. A., Tremolet Consulting. (2015). *Benin – Innovative public private partnerships for rural water services sustainability - A case study*. Washington, DC: World Bank.
MINEA. (2015). *Boletim sectorial*. Luanda: Author.
Ministry of Water. (2014). *Water point mapping Tanzania (2014)*. Retrieved January 17, 2018, from http://wpm.maji.go.tz/
MLGH. (2007). *National guidelines for sustainable operation and maintenance of hand pumps in rural areas*. Lusaka: Author.
Mourits, L., & Depledge, D. (1995). *Handpumps in the South Pacific - A review*. Suva: SOPAC.
MOWR. (2017). *Sierra Leone WASH data portal - Water point data*. Retrieved January 18, 2018, from https://washdata-sl.org/water-point-data/
Muthusi, F. M., Mahamud, G., Abdalle, A., & Gadain, H. M. (2007). *Rural water supply assessment*. Nairobi: FAO-SWALIM.
MWE. (2017). *Uganda water supply atlas*. Kampala. Retrieved from https://www.mwe.go.ug/library/water-supply-atlas-2017
NACWASH. (2017). *Rural WASH Information Management System (RWIMS)*. Retrieved January 17, 2018, from http://154.120.240.158/rwims/
NWSB. (2013). *Water point mapping report: Isiolo County*. Isiolo: Author.
NWSHPC. (2017). *Liberia water point data 2017*. Retrieved January 17, 2018, from https://wash-liberia.org/raw-water-point-data/2017-water-point-data/
ORGCCI. (2011). *HH-11: Households classified by source and location of drinking water and availability of electricity and latrine*. Delhi. Retrieved from http://www.censusindia.gov.in/2011census/Hlo-series/HH11.html
Overmars, M. (2004). *Nonouti, Kiribati, water resources assessment*. Suva: SOPAC.
Pakistan Bureau of Statistics. (2016). *Pakistan Social and Living Standards Measurement Survey (PSLM) 2013–14*. Islamabad. Retrieved from http://www.pbs.gov.pk/content/pakistan-social-and-living-standards-measurement-survey-pslm-2013-14-national-provincial
PEPAM. (2014). *8ème revue annuelle sectorielle conjointe 2014. Rapport de présentation*. Dakar: Author.
PNDP. (2018). *Plans communaux de développement*. Retrieved from http://www.pndp.org/plan-communaux-developpement.php?dest=plan&crc=23
PNWC. (2014). *WASH baseline Barangay assessment: Typhoon Haiyan, Philippines*. Manila. Retrieved from http://www.reach-initiative.org/wp-content/uploads/2014/06/WASH_Baseline_Barangay_Assessment_Typhoon_Hayian_Philippines.pdf
Rural Water Supply Network. (2009). *Handpump data, selected countries in Sub-Saharan Africa*. St Gallen. Retrieved from http://www.rural-water-supply.net/_ressources/documents/default/203.pdf
RVWSB. (2013). *Water point mapping report: Turkana County*. Nakuru: Author.
Ryan, P. (2014). *Madagascar WASH Sector Sustainability Check*. Antananarivo: UNICEF.
SEIU-MWSS. (2016). *WASH sector status report*. Kathmandu: Author.
SNV. (2014). *Water point data - Kampot and Tboung Khmum Province*. Phnom Penh: Author.
SNV. (2015). *Technical assessment of rural water supply in Atsaphone and Phin Districts, Savannakhet Province, Lao PDR*. Vientiane: Author.
SNV Zambia. (2014). *SNV-Zambia Data | WPDx*. Retrieved February 12, 2018, from https://www.waterpointdata.org/node/192/download
SOPAC. (2007). *National integrated water resource management diagnostic report: Kiribati*. Suva: Author.

STUDI International. (2015). *Plan National d'Alimentation en Eau Potable et Assainissement en Milieu Rural et Semi-Urban de la RDC a l'Horizon 2015*. Kinshasa: Author.

TAWSB. (2013). *Water point mapping Kajiado County report draft*. Kitui: Author.

Tincani, L., Ross, I., Zaman, R., Burr, P., Mujica, A., & Evans, B. (2015). *Improving value for money and sustainability in WASH programmes: Regional assessment of the operational sustainability of water and sanitation services in Sub-Saharan Africa*. Oxford: Oxford Policy Management.

TWSB. (2013). *Water point mapping report: Embu County*. Nyeri: Author.

UNICEF. (2015). *Sanitation, hygiene and water in Nigeria Project (SHAWN II) - March 2014 to February 2015*. Abuja: Author.

UNICEF. (2017). *UNICEF annual report 2016 – Guinea Bissau*. Bissau: Author.

Verplanke, J., & Georgiadou, Y. (2017). Wicked water points: The quest for an error free national water point database. *ISPRS International Journal of Geo-Information*, *6*(8), 244.

Walters, J. P., & Javernick-Will, A. N. (2015). Long-term functionality of rural water services in developing countries: A system dynamics approach to understanding the dynamic interaction of factors. *Environmental Science & Technology*, *49*(8), 5035–5043. doi:10.1021/es505975h

WAMS. (2018). *District wise scheme wise assets status report*. Retrieved February 15, 2018, from http://mobilewatersoft.com/wams_ap/districtLevelWorkingNotWorkingAssets.jsp

Water for People. (2015). *WPDx - Water for people*. Retrieved February 8, 2018, from https://www.waterpointdata.org/node/67/download

Wescoat, J. L., Fletcher, S., & Novellino, M. (2016). National rural drinking water monitoring: Progress and challenges with India's IMIS database. *Water Policy*, *18*(4), 1015–1032. doi:10.2166/wp.2016.158

Whaley, L., & Cleaver, F. (2017). Can 'functionality' save the community management model of rural water supply? *Water Resources and Rural Development*, *9*, 56–66. doi:10.1016/j.wrr.2017.04.001

WHO/UNICEF. (2017). *Estimates on the use of water, sanitation and hygiene in China*. Geneva: Author.

WHO/UNICEF. (2018). *JMP Methodology: 2017 Update & SDG Baselines*. Geneva: Author.

WI, UNICEF, & SNV. (2012). *Maintenance of Handpumps & Supply Chains for Spare Parts in South Sudan*. Juba: Author.

Willetts, J. (2012). *A service delivery approach for rural water supply in Timor-Leste: Institutional options and strategy*. Sydney: Institute for Sustainable Futures.

Worakul, M., Painmanakul, A., & Larbkich, W. (2015). Groundwater issues and hydrogeological survey of the Mekong River Basin in Thailand. In K. Ha, N. T. M. Ngoc, E. Lee, & R. Jayakumar (Eds.), *Current status and issues of groundwater in the Mekong River Basin* (pp. 85–91). Bangkok: Korea Institute of Geoscience and Mineral Resources,CCOP Technical Secretariat, UNESCO Bangkok Office.

World Bank. (2011). *République de Congo: Revue des Dépenses Publiques du Secteur de l'Eau et de l'Assainissement (2002-2008)*. Washington, DC: Author.

World Bank. (2017a). *Sustainability assessment of rural water service delivery models: Findings of a multi-country review*. Washington, DC: Author.

World Bank. (2017b). *Toward a universal measure of what works on rural water supply*. Washington, DC: Author.

WPDx. (2016). *Water point data exchange - Standardized Hashtags*. Washington, DC. Retrieved from https://www.waterpointdata.org/sites/default/files/page/wpdx_hashtags_0.pdf

WRD. (2007). *Rapid assessment of rural water supply & sanitation in Eritrea*. Asmara: Author.

Wurzel, P., & Maramov, M. (2007). *Water and sanitation evaluation report, Tajikistan*. Dushanbe: UNICEF.