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# AN EVALUATION OF THE BLUEPUMP IN KENYA & THE GAMBIA

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# 1 EXECUTIVE SUMMARY

This report presents the results of an evaluation of the Fairwater BluePump, an emerging rural water supply technology in sub-Saharan Africa. Claims about the BluePump's durability and minimal maintenance requirements have provoked significant interest within the rural water sector. This evaluation set out to assess the suitability of the BluePump as a rural water supply technology, taking into account its operational performance, the experiences of water users, the views of local stakeholders, and the broader contextual factors that impinge upon its sustainability.

The assessment took place between February and May 2016 in two BluePump strongholds: Turkana in northern Kenya and The Gambia in West Africa. These settings provide an opportunity to consider the handpump's strengths and weaknesses amidst vastly different socio-economic, hydrogeological, climatic and institutional settings. Data were collected at 300 waterpoints, including 130 BluePump installations. In order to contextualise the relative pros and cons of the BluePump, data were also collected for a variety of competing handpump models.

Similar stories emerge from both Turkana and The Gambia. The BluePump appears to be a more robust technology than its competitors, in that the mean time between breakdowns is greater than other handpumps. Local perceptions add weight to the BluePump's credentials – water users in both settings rate BluePumps as more reliable than other handpump models. Nonetheless, the BluePump is not maintenance free. In total, one in four pumps inspected was not producing water, and breakdowns occur on average about once every three years. The most common mechanical faults in both countries relate to rods, pipes and cylinders. A number of other minor issues were observed, including worn shock absorbers, cracked outflow tubes, pump head corrosion, and damage to the concrete pedestal. The developer continues to modify the design of the BluePump in response to some of these technical issues; however it is too early to appraise the impact of these changes.

The BluePump's main disadvantages are its heaviness and high upfront cost. The difficulty of operation is a widespread complaint, even for the relatively shallow installation depths in The Gambia. Increased reliability also comes at a cost – the BluePump is around 2-3 times more expensive than the India Mark II and Afridev in Kenya. However, the cost difference is less marked with respect to the PB Mark II in The Gambia, and the BluePump is considerably cheaper than the Duba Tropic II in Kenya. The flipside is that the BluePump's annual maintenance costs appear to be substantially lower than other pumps.

Ultimately, the full benefits of a more robust handpump will only translate into long-term sustainability if the technology is coupled with effective maintenance systems. In both settings, a centralized approach to maintenance is adopted, which has the advantage of circumventing spare part supply chain challenges. In Turkana, a well-coordinated and subsidised maintenance service is made available to BluePump users by the Diocese of Lodwar, while in The Gambia, the BluePump distributor Swe-Gam offers repair services on an ad hoc basis. However, in both settings there are communities who are unaware of these services, and many are unable or unwilling to pay for them. Furthermore, the commercial viability and long-term sustainability of Swe-Gam's repair service in The Gambia is highly doubtful. As a result, the average downtime for the BluePump in The Gambia is around 2 to 3 times longer than Mark II handpumps.

Overall, the BluePump holds promise: it is – and can continue to be – a suitable rural water supply technology in different contexts. However, the technology in and of itself is not a panacea for rural water sustainability dilemmas. As with any hardware, the pump inevitably needs maintenance and repairs. This in turn requires effective institutional and business models, and rests upon the willingness and ability of communities to pay for these services.

# 2 INTRODUCTION

Waterpoint sustainability is an enduring challenge in rural sub-Saharan Africa. Handpumps have long been the default technological approach to rural water supply programming, with the Afridev and India Mark II especially predominant. Yet high levels of handpump non-functionality have persisted across the continent for several decades (Arlosoroff et al., 1987; Parry-Jones et. al., 2001; Harvey & Reed, 2004). Most recent estimates suggest one in three handpumps are broken down at any one time (RWSN, 2009). In response, a non-profit organisation known as Fairwater Foundation has developed the 'BluePump', a technology that is purportedly more robust and durable than mainstream handpump models.

Although previous studies have investigated the early stages of the BluePump roll-out in Turkana (McSorley, 2011) and 14 installations in Mozambique (Cornet, 2012), there have been calls for further empirical evidence that sheds light on the performance of the BluePump relative to other handpump technologies. This paucity of information is not unique to the BluePump – despite the dominance of handpump water supplies in rural areas, there have been surprisingly few field evaluations of different technologies in the last two decades. Since the large-scale testing carried out under the auspices of the World Bank in the 1980s (see e.g Reynolds, 1992), only a handful of investigations have attempted to conduct field-based comparisons of performance (Harvey & Drouin, 2006; Coloru et al., 2012; Cornet, 2012; Nampusuor & Mathisen, 2000). Analyses of waterpoint mapping datasets have begun to illuminate functionality rates for different handpump types (Foster, 2013; Fisher et al., 2015), although the limitations of this binary metric are well documented (Carter & Ross, 2016).

In order to appraise the suitability of the BluePump as a rural water supply technology, in February 2016 Oxfam Kenya commissioned an evaluation of BluePump installations in Turkana County. To provide additional insights from a different socio-economic and hydrogeological landscape, a further assessment was carried out in The Gambia in April-May 2016 with the financial support of the University of Technology Sydney. In both countries, the examinations set out to assess the BluePump's operational performance, the experiences of water users, the views of local stakeholders, and the broader contextual factors that impinge upon its sustainability. This report presents the results of this investigation.

# 3 BACKGROUND

## 3.1 The BluePump

The BluePump is a lever-action reciprocating handpump which is promoted as a more durable alternative to mainstream handpump models in rural sub-Saharan Africa. Developed by Fairwater Foundation, the pump has been deployed in numerous countries throughout the African continent.[1] According to the developer, the pump is a low maintenance technology with a range of comparative advantages including lower cost operation, ease of installation, and greater depth range (Van Beers, 2013a, 2013b). The pump has an open top cylinder design which allows for the rods and the cylinder to be removed without the need to pull up the riser pipes. Other highlighted design features include the lack of a rubber seal in the piston; PVC pipes that are resistant to corrosion; heavy duty bearings; a bottom support system that enables cylinder depths up to a recommended 80 meters[2]; and its compatibility with the pedestal of an old India Mark II or Afridev. Since its advent, the design of the BluePump has undergone numerous iterations and improvements. Components that have been modified include the spout, centralisers (Figure 1), rods, cylinder, bearings, handle, and head cover.[3]

**Figure 1 - Evolution of BluePump centralisers**

## 3.2 Study sites

Turkana and The Gambia provide apt contexts within which to examine the strengths and weaknesses of the BluePump. The two regions play host to more BluePump installations than anywhere else, yet they provide contrasting conditions in many respects (Table 1). For a start, The Gambia has annual rainfall that is 3 to 4 times greater than Turkana, and groundwater that is considerably shallower. Deep boreholes are common in Turkana, whereas hand-dug wells are ubiquitous throughout The Gambia. Groundwater quality parameters also vary greatly, with pH levels rarely dropping below 7 in Turkana, compared with the highly aggressive waters found across The Gambia. Handpump maintenance models also differ: while a network of local area handpump mechanics has served communities in Gambia since the mid-1980s, water users in Turkana have long-depended on a centralized maintenance service provided by the Diocese of Lodwar.

One commonality that has allowed the BluePump to become a prominent technology in both Turkana and The Gambia is an informal approach to handpump standardization.

[1] Countries include Kenya, Tanzania, Mozambique, Swaziland, Mali, The Gambia, Burkina Faso, Sierra Leone, South Sudan, Angola, and Niger. For more information, see http://www.fairwater.org/sponsor-a-bluepump
[2] In some circumstances in Turkana, cylinders have been installed at a depth of up to 90m
[3] For more detailed information on the BluePump's evolution, see McSorley et al. 2011

Historically, collective norms rather than policy prescriptions have tended to guide handpump choices. Kenya has ‘de facto’ standardization favouring the India Mark II and Afridev nationally (MacArthur, 2015), although the Duba Tropic 2 is also common in the north of the country. Recommendations in The Gambia have supported the installation of Mark II handpumps (MacArthur, 2015), in particular the German-manufactured PB Mark II.

**Table 1 - Comparison of BluePump study sites**

| | Turkana, Kenya | The Gambia |
|---|---|---|
| Population density (per sq. km) | 6.9[a] | 176.1[b] |
| Predominant livelihood | Pastoral | Agro-pastoral |
| Annual rainfall (mm) | 100-400 | 750-1,500 |
| Avg. SWL for wells and boreholes (m) | 25 | 13 |
| Avg. electrical conductivity (µS/cm) | 1643 | 211 |
| Avg. pH | 7.5 | 5.3 |
| Maintenance providers | Diocese of Lodwar (all handpumps) | Area pump mechanics (Mark IIs), Swe-Gam (BluePump) |
| Handpump technologies | India Mk II, Afridev, Duba Tropic 2, BluePump | India Mk II, PB Mk II, BluePump |
| Handpump standardisation | De facto | Recommendation |

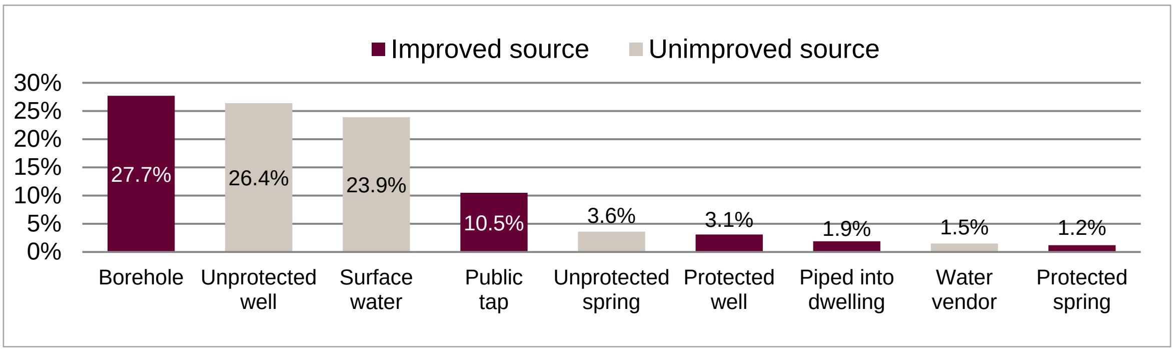
[a] Figure from 2009; [b] Figure from 2013

Note: Rainfall data drawn from Eze & Afolabi (2013) and Opiyo et al. (2015). Average resting water level, electrical conductivity and pH based on data collected during evaluation field work.

## 3.2.1 Turkana

Turkana provides a particularly challenging environment for handpumps. Situated in the north of Kenya, the region is characterized by low levels of rainfall and there is a heavy dependence on boreholes fitted with handpumps both for domestic purposes and for watering livestock (Figure 2). Handpump usage levels can be extreme, with many used non-stop throughout daylight hours and often late into the evening. Moreover, pump cylinders often need to be positioned at great depths (e.g. up to 90m) owing to the deep groundwater levels in certain areas. There are two further distinguishing features of the rural water landscape in Turkana. First, in addition to the BluePump, the county plays host to Afridev, India Mark II and Duba Tropic 2 handpumps in roughly equal numbers (RVWSB, 2013). Second, maintenance service provision for handpumps of all kinds is by way of a centralised scheme operated by the Diocese of Lodwar (DoL). As such, unlike many other parts of rural Africa, very few repairs (if any) are carried out by communities or local area mechanics.

**Figure 2 - Access to water sources in Turkana, 2009**




Data source: KNBS (2012)

Oxfam has championed the BluePump in Turkana for almost a decade. Since 2007, more than 100 have been installed across the county. While Oxfam has been responsible for the majority of these, partner NGO Practical Action has also commissioned a number of BluePump installations, while the County Government has more recently requested Oxfam to install several on their behalf. At the outset, full pump sets and spare parts had to be ordered directly from Fairwater Foundation in the Netherlands. More recently, a Nairobi-based distributor known as Techno Relief has begun to supply BluePumps to Turkana, and the East African region more broadly. Techno Relief also provides technical support to BluePump buyers, and offers a 2 year warranty on the hardware. During this time, other sector stakeholders (namely DoL and the Turkana County Government), have continued to install India Mark II and Afridev handpumps (Table 2 and Table 3). The Duba Tropic 2 also continues to be a rural water supply workhorse throughout the region, despite the cessation of new installations in 2006.[4]

**Table 2 - Technical and supply chain details of handpumps installed in Turkana**

| | BluePump | Afridev | India Mark II | Duba Tropic 2 |
|---|---|---|---|---|
| **Technical characteristics** | | | | |
| Operation | Lever | Lever | Lever | Rotary |
| Pumping lift | <80m | <45m | <80m[a] | <100m |
| Open-top cylinder | Yes | Yes | No | Yes |
| Rising main | PVC | PVC | Galvanised iron | Galvanised iron |
| Domain | Private | Public | Public | Private |
| **Supply chain** | | | | |
| Location of manufacturer | Netherlands | India | India | Belgium |
| Location of suppliers | Nairobi | Lodwar, Nairobi | Lodwar, Nairobi | Belgium |
| Buyers | Oxfam, Practical Action | County Government, Diocese of Lodwar | County Government, Diocese of Lodwar | Diocese of Lodwar[b] |

[a] Includes extra deep well model
[b] Although new Duba Tropic 2 pumps are no longer installed, DoL continues to procure spare parts.

[4] DoL have ceased installing new Duba Tropic 2 pumps in favour of solar pump installations, which they consider to be a lower cost option for deep boreholes.

**Table 3 - Handpump decision criteria in Turkana**

| Implementer | BluePump | India Mk II | Afridev |
|---|---|---|---|
| TURKANA COUNTY GOVERNMENT | • Boreholes with frequent handpump breakdowns | • High yield boreholes with installation depth <30m<br>• Boreholes with installation depth 30+m | • All shallow wells<br>• Low yield boreholes with installation depth <30m |
| Oxfam | • All boreholes<br>• All shallow wells | | |
| Diocese of Lodwar | | • Boreholes with installation depth 20+m | • All shallow wells<br>• Boreholes with installation depth <20m |
| PRACTICAL ACTION | • All boreholes<br>• High yield shallow wells | | • Low yield shallow wells |

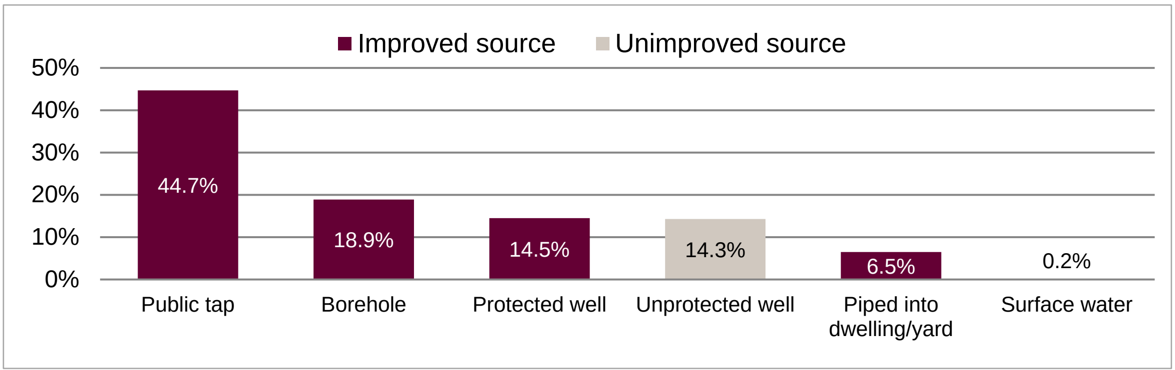
BluePump maintenance in Turkana proceeds along the same lines as other handpump models. DoL provides a repair service for communities across the county, charging a fixed annual fee of 3,500 KSh (US $35)[5] per waterpoint, irrespective of the handpump model. The DoL technicians were initially familiarized with technical aspects of the BluePump by way of training provided to them by the BluePump developer. And although BluePump components can now be ordered through Techno Relief, an initial consignment of parts provided to DoL by Oxfam continues to be drawn upon. Soon after a BluePump is installed, Oxfam 'hands over' the waterpoint to the community, during which water users are made aware of the DoL scheme, and strongly urged to register. In the interim period between installation and hand-over, Oxfam provides a warranty for any faults that might occur.

### 3.2.2 The Gambia

In contrast to Turkana, Gambia is blessed with relatively shallow groundwater, and hand-dug wells are ubiquitous. Significant rural water supply investments were made throughout the 1980s and 1990s, during which time large numbers of German-manufactured PB Mark II handpumps were installed across the country. By the mid-1990s, there were almost 1,500 concrete-lined wells with handpumps (Sonko & Jallow, 2002). Anecdotal evidence suggests various modifications to component selection were initially made, most notably an early shift towards corrosion-resistant materials in response to the highly aggressive groundwater. More recently, an increasing number of cheaper, but lower quality India Mark II pumps have been introduced by implementers. A unique feature of the Gambian rural water landscape is that a substantial proportion of wells are equipped with two handpumps (hereafter called "twin" waterpoints).

[5] An exchange rate of US $1 = 100 Kshs is used throughout this report

**Figure 3 - Access to water sources in rural Gambia, 2013**




Data source: GBOS & ICF International (2014)

Over the last 5 to 10 years, around 125 BluePumps have been installed across The Gambia. Approximately three quarters of these have replaced pre-existing Mark II handpumps. The local supplier Swe-Gam has sold and installed all of these pumps, with funding derived from a variety of philanthropic sources. Although a country-wide network of area pump mechanics provides repair services for Mark II pumps, up until now Swe-Gam has preferred to assume responsibility for the maintenance and repairs of the BluePumps they sell.

**Table 4 - Technical and supply chain details of handpumps installed in The Gambia**

| | BluePump | India Mark II | PB Mark II |
|---|---|---|---|
| **Technical characteristics** | | | |
| Operation | Lever | Lever | Lever |
| Open-top cylinder | Yes | No | No |
| Rising main | PVC | Stainless Steel | Stainless steel |
| Domain | Private | Public | Public |
| **Supply chain** | | | |
| Location of manufacturer | Netherlands | India | Germany |
| Location of suppliers | Serrekunda | Serrekunda | Serrekunda |
| Buyers | Various | Various | Various |

# 4 METHODOLOGY

In order to evaluate the BluePump, this investigation utilizes a mixed-methods approach comprised of three components:

1. **Gambia & Turkana:** Site visits at BluePump installations to collect data on operational performance, maintenance arrangements, water user experiences, and waterpoint characteristics. In order to compare results across handpump types, site visits were also undertaken at Mark II, Afridev and Duba installations (the latter two handpump types were not present in The Gambia). For these "comparator" pumps a convenience-quota sampling method was preferred over a randomized sampling approach due to incomplete information about handpump locations and the lengthy travel times involved. The field work was carried out between February and May 2016.
2. **Turkana only:** Analysis of handpump maintenance and installation records provided by DoL and Oxfam
3. **Turkana only:** Convening a Technology Applicability Framework (TAF) workshop with sector stakeholders to appraise the broader building blocks for sustainability of BluePump installations. This involved stakeholders from local government, maintenance service providers, and implementing organisations. The workshop followed the methodology outlined in Olschewski & Casey (2015).

Across the two study sites, more than 300 waterpoints were visited. Data were collected for 130 BluePumps, 136 Mark IIs, 24 Afridevs, and 13 Dubas.[6] At each site, two questionnaires were administered. The first questionnaire related to the handpump and its history, and was directed to a community member who was knowledgeable in this area. The second questionnaire was designed to elicit user perceptions about the handpump across various dimensions. Additional stroke and leak tests were carried out, as well as inspection of above above-ground components. Where possible, water quality parameters (EC, pH) and static water level were measured using a multiparameter meter (HI98195) and an Aqua Dipper Pro respectively.

**Figure 4 - Water user interviews in Turkana**

[6] Data for the visited waterpoints can be downloaded from the Water Point Data Exchange (WPDx) at https://www.waterpointdata.org

Information at each waterpoint was collected on handpump performance and user satisfaction levels. Operational performance was measured across several indicators, including (i) functionality rate, (ii) number of breakdowns per year, (iii) operational days in the previous 12 months, (iv) flow rate, and (v) prevalence of leaks. Table 5 presents definitions and methods used in the assessments. A handpump was deemed non-functional if it was not producing water for users on the day of inspection. Information relating to the number and duration of breakdowns was based on user recollections. Flow rate was determined by observing the number of seconds an adult female took to fill a 20 litre jerrican. In order to take into account other factors that could influence these performance metrics, data pertaining to cylinder depth, static water level, handpump age, usage levels[7] and maintenance arrangements were also sought. To ascertain water user views on the BluePumps, a series of questions were asked about satisfaction levels with respect to reliability,[8] discharge and ease of use.

**Table 5 - Performance indicator definitions**

| Indicators | Definition |
|---|---|
| **Functionality** | Handpump deemed non-functional if no water produced at time of visit, or its operation was so impaired such that the community could no longer draw water. |
| **Breakdowns per operational year** | Based on self-reported number of breakdowns in the previous 12 months. Calculated as a weighted average of the number of breakdowns per 365 operational days, adjusted to exclude non-operational days |
| **Operational days per year** | Based on self-reported number of days in the last 12 months for which the handpump was operational. Calculated by summing the duration of all breakdowns in the previous 12 months, and subtracting this number from 365. |
| **Flow rate for female adult (l/min)** | Number of litres produced per minute when handpump operated by an adult female. |
| **Major leak** | Turkana: >2 maximal strokes needed before water produced after leaving handpump idle for 2 mins.<br>Gambia: >5 maximal strokes needed before water produced after leaving handpump idle for 5 mins. |
| **Minor leak** | Turkana: 2 maximal strokes needed before water produced after leaving idle for 2 mins.<br>Gambia: Between 2 and 5 maximal strokes needed before water produced after leaving handpump idle for 5 mins. |

## 4.1 TURKANA

Prior to the commencement of data collection in Turkana, 100 BluePump installations were identified from records kept by Oxfam and Practical Action. Of these, 25 could not be accessed as they were situated in insecure regions. Seventy-five sites were subsequently visited, with 71 BluePump installations confirmed.[9] Data were also collected for 71

[7] As settlements in Turkana are often highly dispersed and migratory, estimating the number of households using the handpump was difficult. Moreover, the livestock population is likely to be a more significant driver of usage in many instances. Thus usage level was classified as either ‘non-stop during the day’ or ‘intermittent use’.

[8] In this context, reliability referred to how frequently (or infrequently) the system broke down.

[9] One site could not be found and three BluePumps had been replaced – one by a solar pump, one by an India Mark II and one by an Afridev.

comparator handpumps, comprised of 34 India Mark IIs, 24 Afridevs and 13 Duba Tropics (Figure 5). Characteristics of waterpoints visited are summarised in Table 6.

**Figure 5 - Waterpoints visited in Turkana**

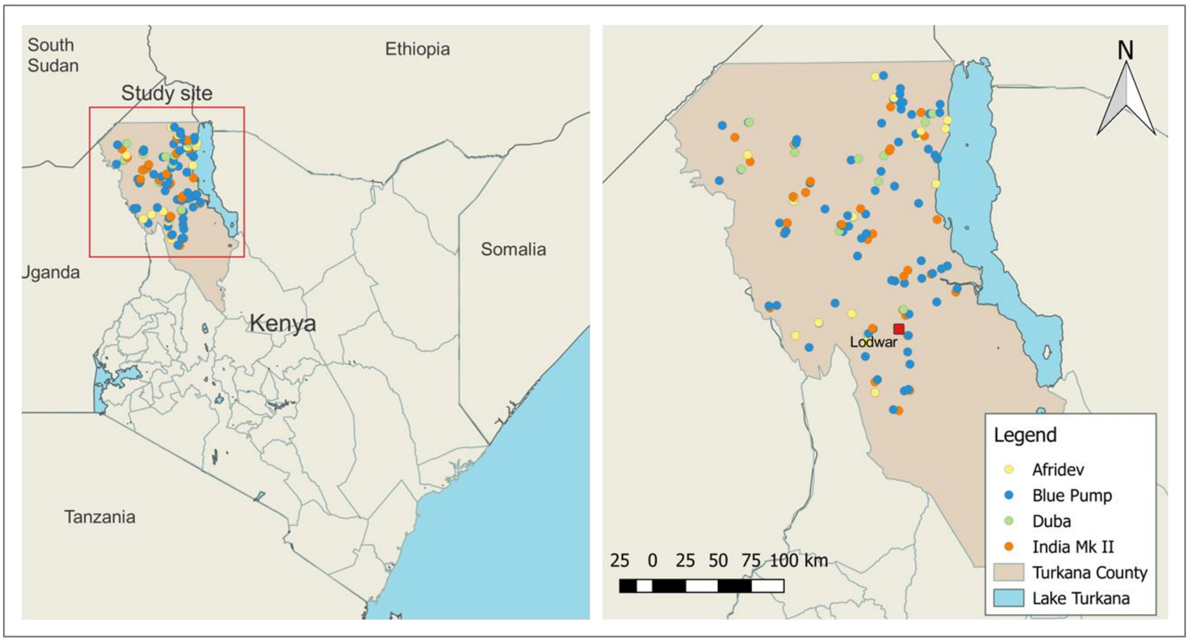



**Table 6 - Mean characteristics of waterpoints visited in Turkana**

| Mean characteristics | BluePump (n=71) | India Mark II (n=34) | Afridev (n=24) | Duba Tropic 2 (n=13) |
|---|---|---|---|---|
| Cylinder depth (m) | 42 | 36 | 12 | 56 |
| Static water level (m) | 27 | 21 | 8 | - |
| Boreholes (%) | 84.5 | 91.4 | 28.0 | 100 |
| Age (years) | 3.6 | 4.6 | 8.6 | 13.2 |
| Distance to spare parts & technicians (km) | 86 | 81 | 97 | 92 |
| Electrical conductivity (μS/cm)[10] | 1897 | 1629 | 922 | 1062 |
| pH | 7.6 | 7.5 | 7.5 | 7.4 |
| DoL subscription (%) | 34 | 41 | 21 | 85 |

Note: Water quality parameters could not be measured for non-functional handpumps

## 4.2 THE GAMBIA

Prior to the commencement of data collection in The Gambia, the locations of 69 possible BluePump installations were identified from the website of Fairwater Foundation. Of these, 52 were located, and an additional 7 were found during the course of the field work. Due to the difficulty in locating Mark IIs that were broadly within the same age cohort as BluePumps, a higher number of these pumps had to be sampled than expected. In total, data were collected for 59 BluePumps and 102 Mark II pumps (Figure 6). Characteristics of waterpoints visited are summarised in Table 7.

[10] This excludes two extreme outlier values.

**Figure 6 - Waterpoints visited in The Gambia**

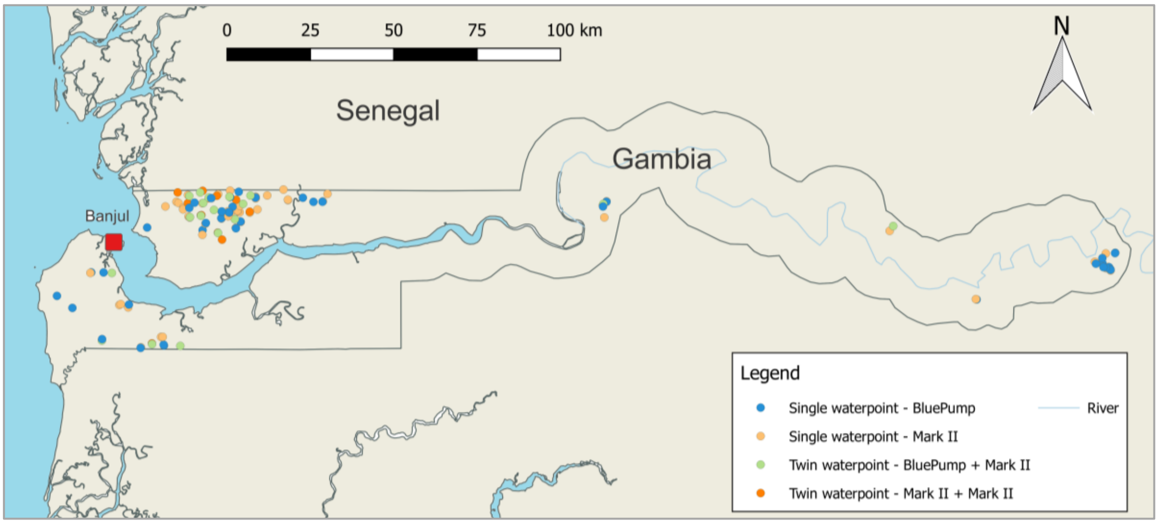



**Table 7 - Mean characteristics of waterpoints visited in The Gambia**

| Mean characteristics | BluePump (n=59) | Mark II by location of manufacture | | |
|---|---|---|---|---|
| | | All (n=102)[a] | Germany (n=80) | India (n=17) |
| Static water level (m) | 13.7 | 13.3 | 13.0 | 15.3 |
| Age (years) | 3.6 | 15.6 | 17.8 | 3.9 |
| Distance to spare parts (km) | 96.0 | 44.3 | 42.9 | 53.9 |
| Distance to technicians (km) | 96.0 | 6.9 | 6.8 | 5.9 |
| Electrical conductivity (µS/cm) | 255 | 237 | 235 | 160 |
| pH | 5.3 | 5.3 | 5.2 | 5.4 |
| Turbidity (NTU) | 1.3 | 1.2 | 1.1 | 1.5 |
| Borehole (%) | 3.4 | 10.8 | 7.5 | 29.4 |
| Twin handpumps (%) | 31 | 44 | 53 | 12 |

Note: Water quality parameters could not be measured for some non-functional handpumps.

[a] The location of manufacture could not be ascertained for 5 Mark II pumps.

# 4.3 LIMITATIONS & CAVEATS

At the outset, when interpreting the results it is important to keep in mind the following limitations and qualifications:

- Data on breakdown frequency and downtime were self-reported by water users, and are therefore susceptible to recall bias.
- Given time constraints, a comprehensive diagnosis of failure modes and technical issues was not possible, particularly for down-the-hole components. Fault identification in Turkana was guided by Oxfam's technician; however work is ongoing to more precisely identify failure modes. As such, it was not always possible to distinguish between borehole failure and handpump failure.
- As the design of the BluePump has evolved over time, certain mechanical faults may no longer be relevant where the component has since been modified.
- Due to time and logistical constraints, a convenience-quota sampling method was preferred over a randomized approach for comparator pumps. This may introduce a degree of sampling bias into the results.

- In Turkana, a number of sites where BluePumps were originally installed have been upgraded to solar pump installations, and these sites were not included in the assessment.
- Functionality rates for older handpump cohorts may be biased upwards by virtue of the “denominator problem” (see Carter & Ross, 2016), as little physical evidence may remain for those handpumps that have been non-functional for many years (thus reducing their likelihood of being included in the sample).
- Handpump performance is likely influenced by a range of factors, not all of which could be measured or controlled for. Hence results may be subject to confounding and omitted variable bias.
- Stroke tests to assess flow rate were carried out by an adult female at each functioning waterpoint, however pumping technique (e.g. stroke length and speed) is a major determinant of output, and these techniques varied from person to person and waterpoint to waterpoint.
- Given the relatively young age of BluePump installations, it is difficult to make definitive statements about full lifecycle costs and lifespans.
- Caution should be taken when interpreting cross-tabulated results disaggregated by key characteristics due to the small sample sizes involved. Likewise, for some waterpoints cylinder depth and age could not be determined. Disaggregated sample sizes less than 3 are not presented, and signified by ‘NS’.
- The social, hydrogeological and institutional characteristics of the study sites – particularly the unique conditions of Turkana – must be taken into account when interpreting results.
- The two study sites represent ‘mature’ BluePump markets, and the results may not be directly transferrable to settings where the BluePump has yet to achieve a critical mass. In particular, the study sites likely have stronger supply chains, greater technical support, and lower upfront prices than regions with fewer BluePumps.

# 5 RESULTS FROM TURKANA

## 5.1 OPERATIONAL PERFORMANCE

Based on the sample of handpumps assessed, the BluePump outperformed both the India Mark II and Afridev across measures of functionality, breakdowns per year and operational days per year (Table 8). Nonetheless, this is tempered with the observation that one in three BluePumps was still found to be non-functional. The BluePump appeared to break down less frequently than other pumps across different cylinder depths, ages and usage levels (Table 9). Disaggregated differences in functionality rate and operational days were more mixed. Leak tests revealed only a small fraction of BluePumps had either minor or major leaks (Figure 7).

Acknowledging the small sample involved, the Duba exhibited a superior functionality rate and number of operational days despite breaking down more often, a result which is likely linked to the high proportion of systems which are registered for the DoL maintenance service. Notwithstanding these findings, it should be borne in mind that the DoL ceased installing the Duba pump around a decade ago (due to its prohibitive price point), and it is unclear to what extent the results are influenced by the 'denominator problem' that Carter & Ross (2016) suggest might affect functionality statistics for older waterpoint cohorts.

**Table 8 - Summary of operational performance of sampled handpumps in Turkana**

| | BluePump | India Mk II | Afridev | Duba |
|---|---|---|---|---|
| **All handpumps** | | | | |
| Sample size | 71 | 34 | 24 | 13 |
| Functionality (%) | 67.6 | 61.8 | 41.7 | 76.9 |
| Breakdowns per year | 0.4 | 0.8 | 1.3 | 0.9 |
| Operational days per year | 284 | 255 | 167 | 305 |
| Flow rate for female adult (l/min) | 11.3 | 13.1 | 14.6 | 21.0 |
| | | | | |
| **Handpumps 0-7 years** | | | | |
| Sample size | 66 | 28 | 10 | NS |
| Functionality (%) | 68.2 | 60.7 | 20.0 | NS |
| Breakdowns per year | 0.3 | 0.9 | 2.5 | NS |
| Operational days per year | 285 | 247 | 132 | NS |
| Flow rate for female adult (l/min) | 11.2 | 12.9 | ND | NS |

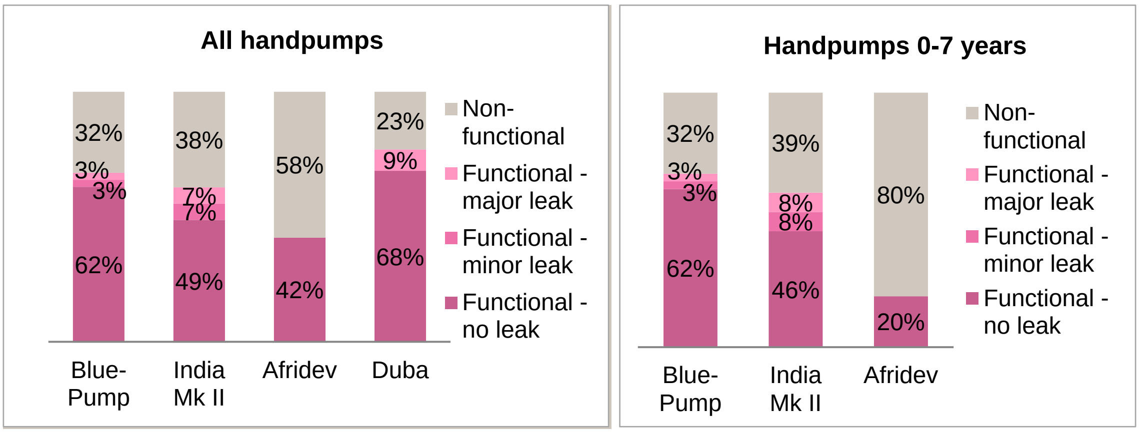
NS = Not shown due to small sample size (n<3); ND = No data

**Table 9 - Operational performance disaggregated by key characteristics in Turkana**

| Indicator | Variable | Category | BluePump | India Mk II | Afridev | Duba |
|---|---|---|---|---|---|---|
| **Functionality (%)** | Cylinder depth | <20m | 57.9 | 25.0 | 33.3 | ND |
| | | 20-40m | 75.0 | 85.7 | NS | NS |
| | | 40+m | 67.7 | 71.4 | ND | 66.7 |
| | Age | 0-3 years | 75.0 | 60.0 | 20.0 | NS |
| | | 4-7 years | 60.0 | 61.5 | 20.0 | NS |
| | | 8+ years | 60.0 | 66.7[a] | 63.6[a] | 81.8 |
| | DoL subscriber | Yes | 76.2 | 83.3 | 75.0 | 81.8 |
| | | No | 65.0 | 52.9 | 40.0 | NS |
| | **Functionality rate – All (%)[b]** | | **67.6** | **61.8** | **41.7** | **76.9** |
| **Breakdowns per year** | Cylinder depth | <20m | 0.2 | NS | 1.7 | ND |
| | | 20-40m | 0.7 | 1.3 | NS | NS |
| | | 40+m | 0.4 | 1.0 | ND | 1.1 |
| | Age | 0-3 years | 0.4 | 0.8 | 3.4 | NS |
| | | 4-7 years | 0.3 | 0.9 | NS | NS |
| | | 8+ years | 1.6 | NS | 0.7 | 0.8 |
| | Usage level | Intermittent | 0.3 | 0.5 | 1.1 | 1.1 |
| | | Non-stop | 0.5 | 0.9 | 5.5 | 0.8 |
| | Used for drinking | No | 0.0 | 0.0 | ND | 1.5 |
| | | Yes | 0.5 | 0.9 | 1.3 | 0.8 |
| | **Avg. breakdowns per year – All[b]** | | **0.4** | **0.8** | **1.3** | **0.9** |
| **Operational days per year** | Cylinder depth | <20m | 240 | 183 | 128 | ND |
| | | 20-40m | 306 | 323 | NS | NS |
| | | 40+m | 283 | 303 | ND | 338 |
| | Age | 0-3 years | 318 | 232 | 192 | NS |
| | | 4-7 years | 248 | 267 | 73 | NS |
| | | 8+ years | 269 | NS | 222 | 305 |
| | DoL subscriber | No | 310 | 322 | 222 | 305 |
| | | Yes | 274 | 210 | 174 | NS |
| | **Avg. operational days per year – All[b]** | | **284** | **255** | **167** | **305** |
| **Flow rate for female adult (l/min)** | Cylinder depth | <20m | 18.6 | NS | NS | ND |
| | | 20-40m | 12.0 | 12.8 | NS | NS |
| | | 40+m | 7.9 | 10.4 | ND | NS |
| | **Avg. flow rate for female adult – All[b]** | | **11.3** | **13.1** | **14.6** | **21.0** |

NS = Not shown due to small sample size (n<3); ND = No data
[a] Further investigation is needed to determine why the older cohort of India Mark II and Afridev handpumps appear to have better functionality rates than the newer cohort. Possible explanations include a 'denominator problem' (see Carter & Ross, 2016) or confounding factors. [b] 'All' results include those handpumps with unknown cylinder depth and/or age.

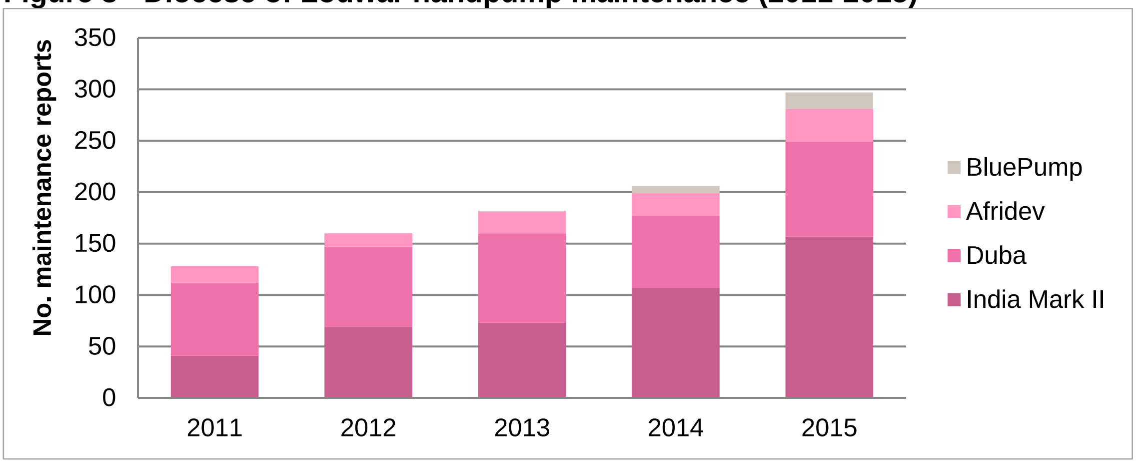
**Figure 7 - Prevalence of leaks in Turkana**




Of the four pump types assessed, the BluePump averaged the lowest volumetric output. On the surface, this seems a less important measure than other operational indicators assessed. However, it warrants mention that DoL, one of the most prominent procurers of handpumps in Turkana, chooses to install the India Mark II over the BluePump in part because of the perceived difference in volumetric output

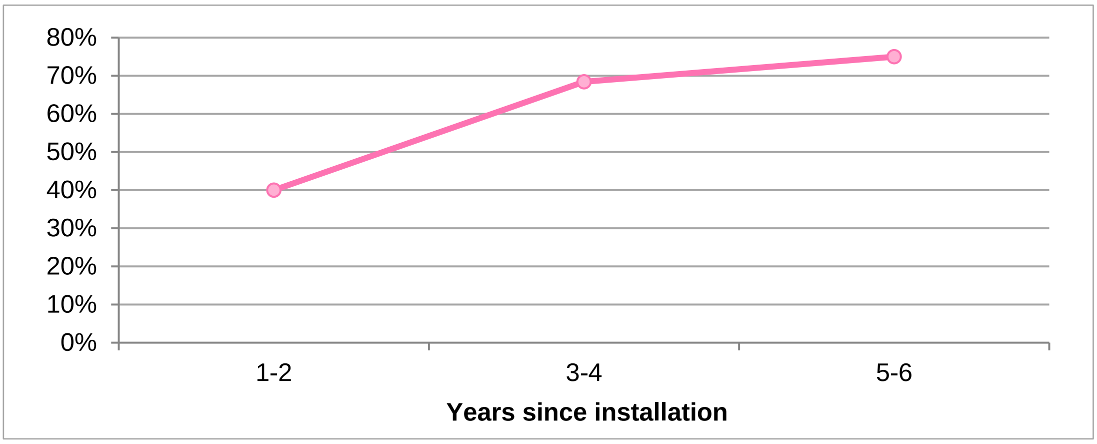
Maintenance data recorded by DoL provide further support for the findings on breakdown frequency. In 2015, 5% of handpump maintenance reports related to BluePump faults, and 2.5% since 2011 (Figure 8). Although the total number of handpumps throughout Turkana is unknown, it is possible that BluePumps now make up around 10-20% of the total stock. This suggests BluePumps are under-represented in the maintenance data, consistent with the observation that they experience fewer breakdowns.

**Figure 8 - Diocese of Lodwar handpump maintenance (2011-2015)**




It is instructive that the BluePump maintains an edge over the India Mark II for both operational days and functionality rate when handpumps were three years of age or less, but not for those pumps aged between 4 and 7 years. This may point to the limits of durability in the Turkana context – although breakdowns may occur less frequently and further down the track for the BluePump, they do eventually happen. By the end of the fourth year, in excess of 60% of BluePumps had broken at least once (Figure 9). Thus in the long-term, sustainability will ultimately be defined by the presence or absence of effective maintenance systems that users are willing and able to pay for. Indeed, when subject to the same centralised maintenance service operated by DoL, the functionality rates for all three handpumps lay within a band of 75-85%. This compares to 40-65% for those waterpoints not registered for the repair scheme.[11] Another possible contributing factor is the evolution of the BluePump design, with component modifications potentially leading to a difference in operational performance between newer and older BluePump models.

**Figure 9 - Proportion of BluePumps having had at least one breakdown in Turkana**




It is important to note that the DoL maintenance service may obscure the potential benefits of reliability that might materialise in other contexts. Fewer breakdowns may not directly translate into higher functionality rates in Turkana because DoL provides communities with an unlimited number of repairs for a fixed price. In other words, the community pays the same fee irrespective of the number of breakdowns in a given year. This means that users do not bear the actual cost of maintenance and repairs, a situation this is likely to mute the functionality advantage that be might expected to arise from the BluePump's lower breakdown rate.

## 5.2 MAINTENANCE & REPAIRS

Work is still underway to ascertain precise failure modes and root causes of BluePump breakdowns in Turkana. Time constraints did not allow for down-the-hole components to be inspected during the field work, hence Table 10 provides approximate ranges based on 'best guesses' rather than precise figures. Early estimates suggest 20-30% of failures can be attributed to factors other than routine mechanical faults (e.g. dry boreholes, wells silting up, flood damage). The three most common mechanical failure modes appeared to relate to the cylinder (either leaking or clogged with silt), rod breakages and leaking pipes.

[11] The functionality rate of the Afridev was particularly low for those communities not subscribing to the maintenance scheme. As well as more frequent mechanical breakdowns, this may in part be due to the susceptibility of shallow wells to dry up or silt up, and also their tendency to be located beside river beds, thereby offering alternative (unimproved) water sources.

Similar conclusions can be drawn from records kept by DoL and Oxfam. DoL reports reveal 22 BluePump repairs were undertaken between 2011-2016, and Oxfam technician logs document a further 18 repairs carried out between 2009-2016 (excluding 2011, for which there are no longer records). For these 40 repairs, the most common failure modes again pertained to rods, pipes and cylinders (Table 11).

A variety of other above-ground issues were observed on functional BluePumps, including missing or worn shock absorbers; missing or loose anchor bolt nuts; cap damage and corrosion (particularly where the Allen key bolt is inserted); water leaking out of the pump head; concrete pedestal damage; incorrectly installed rod connection plate; and spout corrosion (Figure 10). Some of these issues can be attributed to the handpump itself, whereas others stem from incorrect installation. When interpreting these findings it should also be kept in mind that numerous design modifications have been made over time, and some of the observed problems may be less relevant to current and future BluePump models. Such alterations include changes to the length and diameter of rods; shifting from steel to a stainless steel spout and cap; introduction of double protected rubber stoppers; the addition of an anchor plate; removal of the conical seat rubber; and a redesigned foot valve.

Although the DoL is the sole maintenance provider in Turkana, less than half of communities using a BluePump said they were registered for the service. This may in part reflect the more reliable operation – communities experiencing few or no breakdowns are clearly less likely to subscribe to an annual service. Nonetheless, the majority of communities with a non-functional BluePump were not registered for the scheme, either because they could not raise the required 3,500 KSh (US $35) or because they were unaware of the scheme.

**Table 10 - Possible BluePump fault types and failure modes in Turkana**

| Failure modes | Frequency (% of all breakdowns) |
|---|---|
| **Major – No water produced** | |
| *Mechanical* | **17-20 (68-80%)** |
| Cylinder clogged with silt | 0-3 (0-12%) |
| Leaking pipe | 0-5 (0-20%) |
| Leaking cylinder | 1-4 (0-16%) |
| Dropped rods | 1 (4%) |
| Broken rods | 1-4 (4-16%) |
| T-piece disconnected from pipes | 1 (4%) |
| | |
| *Environmental* | **5-8 (20-32%)** |
| Dry well/borehole | 2-5 (8-20%) |
| Water level dropped below cylinder | 0-1 (0-4%) |
| Rising main filled with sand due to flooding | 0-1 (0-4%) |
| Well/borehole silted up | 2 (8%) |
| Broken handle | 1 (4%) |
| | |
| **Moderate – Significant impairment of normal operation** | |

| | |
|---|---|
| *Mechanical* | |
| Cylinder clogged with silt | 0-1 |
| Leaking cylinder | 1-4 |
| *Structural* | |
| Major damage to concrete pedestal | 2 |
| *Environmental* | |
| Low yield | 3-4 |

### Table 11 - BluePump repairs documented by Diocese of Lodwar & Oxfam in Turkana

| Repairs | DoL maintenance reports (n=22) | Oxfam technician diary (n=18) | Total (% of repairs) |
|---|---|---|---|
| Rods | 9 | 2 | 11 (27.5%) |
| *Disconnected* | 3 | 0 | 3 (7.5%) |
| *Broken* | 6 | 2 | 8 (20%) |
| Cylinder | 3 | 3 | 6 (15%) |
| PVC pipes & sockets | 6 | 0 | 6 (15%) |
| Bearings | 2 | 1 | 3 (7.5%) |
| Flange | 1 | 1 | 2 (5%) |
| Handle | 0 | 1 | 1 (2.5%) |
| Centralisers | 1 | 0 | 1 (2.5%) |
| Spout | 0 | 1 | 1 (2.5%) |
| Fished out pipes & rods | 0 | 1 | 1 (2.5%) |
| Desilt well | 0 | 1 | 1 (2.5%) |
| Not specified | 1 | 8 | 9 (22.5%) |

### Table 12 - Types of handpump problems encountered by Diocese of Lodwar in Turkana

| Problem | BluePump | India Mark II | Afridev | Duba |
|---|---|---|---|---|
| **Mechanical** | **21 (100%)** | **384 (93.0%)** | **81 (90.0%)** | **364 (95.3%)** |
| Rods & centralisers | 10 (47.6%) | 122 (29.5%) | 23 (25.6%) | 37 (9.7%) |
| Riser pipes | 6 (28.6%) | 171 (41.4%) | 24 (26.7%) | 50 (13.1%) |
| Cylinder assembly | 3 (14.3%) | 131 (31.7%) | 59 (65.6%) | 317 (83.0%) |
| Handle assembly (incl. bearings) | 2 (9.5%) | 31 (7.5%) | 25 (27.8%) | 40 (10.5%) |
| Pump head and pedestal | 1 (4.8%) | 36 (8.7%) | 6 (6.7%) | 3 (0.8%) |
| **Environmental** | **1 (4.8%)** | **17 (4.1%)** | **7 (7.8%)** | **18 (4.7%)** |
| Water-related | 1 (4.8%) | 14 (3.4%) | 3 (3.3%) | 12 (3.1%) |
| Silt-related | 0 (0%) | 3 (0.7%) | 4 (4.4%) | 6 (1.6%) |
| **Total reports** | **21[a] (100%)** | **413 (100%)** | **90 (100%)** | **382 (100%)** |

[a] Excludes one report where problem was not specified
Note: Columns may add up to more than 100% as a waterpoint may have multiple faults

**Figure 10 - BluePump wear and tear in Turkana**

Spout & cap corrosion: (i) Namorupus, (ii) Konoo, (iii) Lokichar SW

Damage to concrete pedestal: (i) Lokipetot Arengan, (ii) Karoge, (iii) Riokomor

Leaking pump head: (i) Napelilim, (iii) Nadunga, (iv) Lonyamile

Worn shock absorber

Broken cap at allen key bolt insertion point:
(i) Kaikor, (ii) Lochor Edome, (iii) Karoge

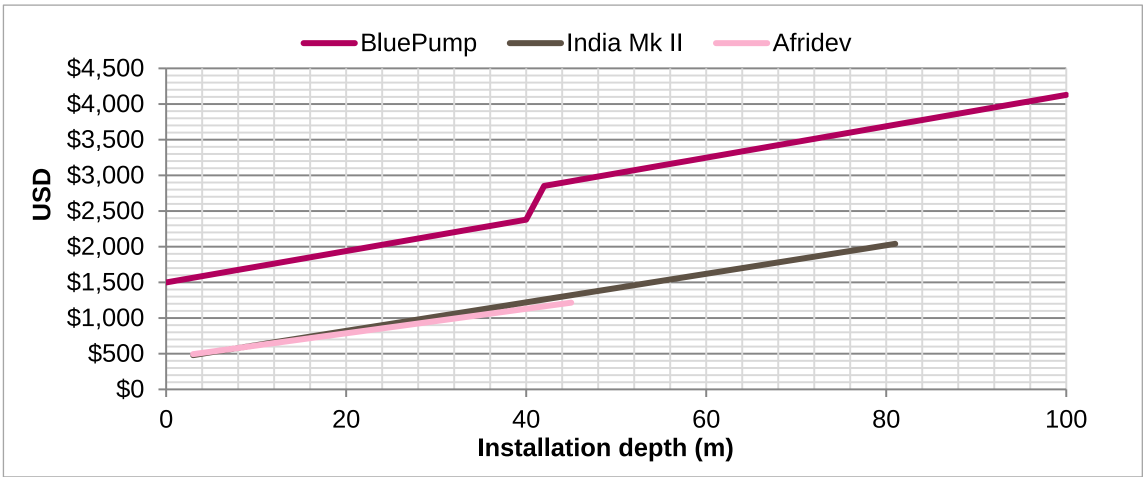
Broken bearing bolt at Kanaodon

## 5.3 FINANCIAL DIMENSIONS

### 5.3.1 Capital costs

The initial cost of a BluePump is higher than both the Afridev and India Mark II. Depending on the installation depth, the price of a full pump set ranges between US $1,500 and $4,000, some 2 to 3 times more expensive than an India Mark II or Afridev of equivalent depth (Figure 11). In contrast, the BluePump is around one third of the cost of a Duba Tropic 2. Thus, although Duba pumps continue to perform well operationally at a range of depths, their price is deemed prohibitive by implementing organisations.

**Figure 11 - Upfront cost of handpumps by installation depth in Turkana**




Note: BluePump cost calculations assume 26 meters of bottom support once cylinder depth exceeds 40 m (26m is chosen because that is the average difference between the borehole depth and cylinder depth for Oxfam boreholes in Turkana)

The costs associated with borehole/well development and handpump installation are also important considerations. Once factoring these into the cost calculations, a BluePump shallow well installation sums to around 50% more than the equivalent well equipped with an Afridev. For a deep borehole (with installation depth of 50m), the total BluePump installation including drilling costs is about 7% more than the equivalent India Mark II installation (Table 13).

**Table 13 - Indicative capital expenditure requirements for new well/borehole in Turkana**

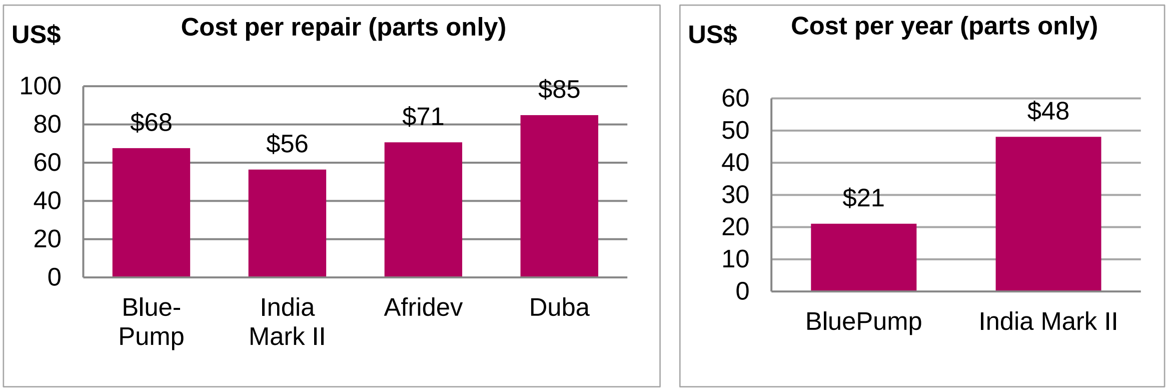
| Cost item | Shallow well, 10m installation depth | | Borehole, 50m installation depth | |
|---|---|---|---|---|
| | BluePump | Afridev | BluePump | India Mk II |
| Handpump | 172,000 KSh ($1,720) | 65,000 KSh ($650) | 303,000 KSh ($3,030) | 144,000 KSh ($1,440) |
| Well/borehole development | 120,000 KSh ($1,200) | 120,000 KSh ($1,200) | 2,000,000 KSh ($20,000) | 2,000,000 KSh ($20,000) |
| Installation | 33,000 KSh ($330) | 33,000 KSh ($330) | 100,000 KSh ($1,000) | 100,000 KSh ($1,000) |
| **Total** | **325,000 KSh ($3,250)** | **218,000 KSh ($2,180)** | **2,403,000 KSh ($24,030)** | **2,244,000 KSh ($22,440)** |

Data sources: Oxfam, Davis & Shirtliff. Note: Cost estimates are rough approximations only.

## 5.3.2 Maintenance costs

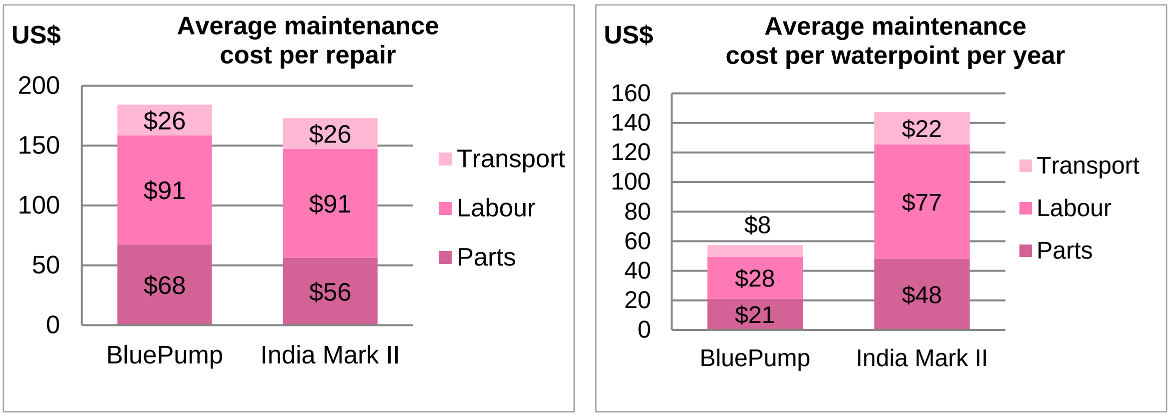
Analysis of handpump maintenance data from the DoL indicates the average cost of BluePump parts per repair is similar to other handpump types (Figure 12). However, once factoring in breakdown frequency, the annual spare part cost burden reduces to less than half that of an India Mark II. Taking into account approximate travel and labour costs incurred by the DoL technicians, and applying average breakdown frequency for handpumps 7 years or under, it is estimated that the annual maintenance expenditure associated with a BluePump is around 5,700 KSh (US $57), some 9,000 (US $90) cheaper than an India Mark II (Figure 13). Given communities pay a flat subscription fee of 3,500 KSh (US $35) irrespective of the handpump type, this suggests annual repair work for a typical India Mark II requires a larger subsidy constituting 76% of the costs incurred, compared to 39% for a BluePump.

**Figure 12 - Cost of parts used per repair & per year in Turkana**




Note: Annualised costs assume breakdown frequency as per results for handpumps 0-7 years of age.

**Figure 13 - Estimated maintenance cost for Diocese of Lodwar maintenance team**




Note: Costs are rough approximations only. Average annual maintenance cost assumes a cost of 200 KSh per litre of fuel.

## 5.4 WATER USER PERCEPTIONS

Water user perceptions largely align with the findings on operational performance (Table 14). Overall, BluePump users are more satisfied with their water supply than users of other handpumps, particularly on the issue of reliability. Conversely, users preferred the alternatives when it came to flow rate and ease of operation. A widespread complaint among water users was that the BluePump is a ‘heavy’ pump that is significantly more difficult to operate, particularly once the cylinder depth exceeds 40 metres. In some instances, this precludes use by young children, and for deeper boreholes requires 3 to 4 women to operate the pump simultaneously. There was little difference between the satisfaction levels expressed by male and female respondents (Table 15). When it came to weighing up these trade-offs, both men and women placed the greatest value on a handpump's reliability, with ease of operation considered the least important of the three attributes (see Box 1)

**Table 14 - Percentage of water users satisfied with water supply in Turkana**

| Handpump type | Overall (%) | Reliability (%) | Flow rate (%) | Ease of operation (%) |
|---|---|---|---|---|
| **All handpumps** | | | | |
| BluePump | 95 | 97 | 69 | 42 |
| India Mk II | 85 | 74 | 73 | 56 |
| Afridev | 88 | 69 | 81 | 73 |
| Duba Tropic | 83 | 92 | 75 | 25 |
| | | | | |
| **Handpumps 0-7 years** | | | | |
| BluePump | 94 | 96 | 71 | 41 |
| India Mk II | 83 | 74 | 68 | 52 |
| Afridev | 88 | 50 | 88 | 75 |

**Table 15 - BluePump satisfaction levels by gender in Turkana**

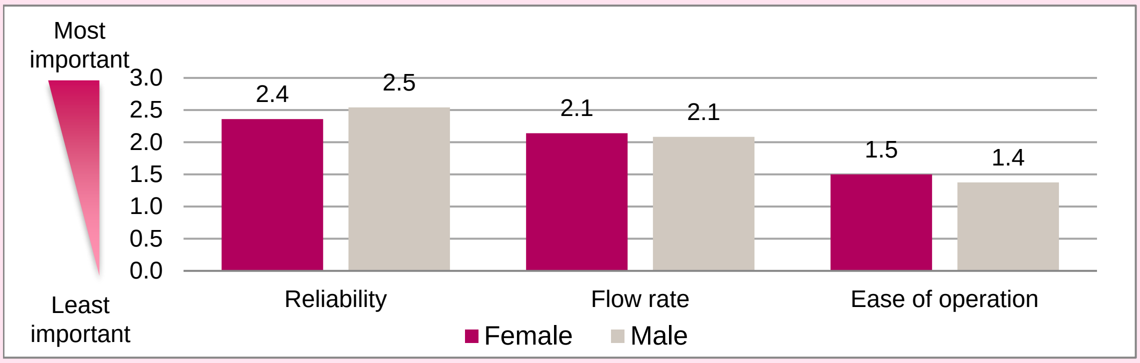
| Respondent | Overall (%) | Reliability (%) | Flow rate (%) | Ease of operation (%) |
|---|---|---|---|---|
| **Female** | 95 | 98 | 68 | 40 |
| **Male** | 93 | 93 | 73 | 50 |

More equivocal trends emerged when directly comparing handpump preferences head-to-head for those respondents who were familiar with more than one type of pump (Figure 14), including those where the two pumps had been fitted to the same well or borehole (Figure 15). The BluePump was perceived to be more reliable than other pumps; however views on flow rate and ease of operation were mixed. Overall, users were split on whether or not they preferred the BluePump over the India Mark II, while the BluePump was generally preferred to the Afridev. Users tended to favour the Duba, which was seen as easier to operate[12] and having a superior flow rate.

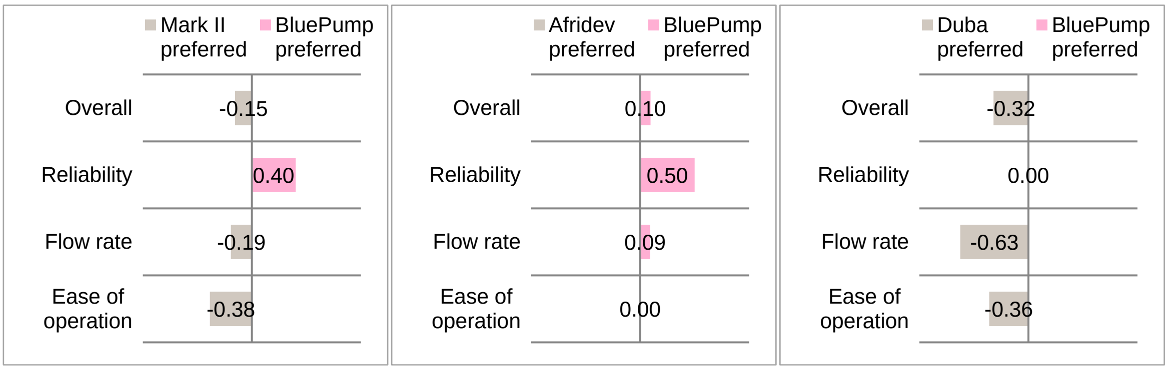
[12] In contrast to lever action handpumps, the Duba Tropic 2 is commonly operated by two people simultaneously.

**Box 1. How do handpump users in Turkana rank the relative importance of different water supply attributes?**

Handpump users in Turkana were asked to rank the relative importance of three key attributes as they pertained to their waterpoint: reliability, flow rate and ease operation. Reliability emerged as the most highly valued attribute for both female and male respondents, followed by flow rate. Ease of operation was considered the least important characteristic.

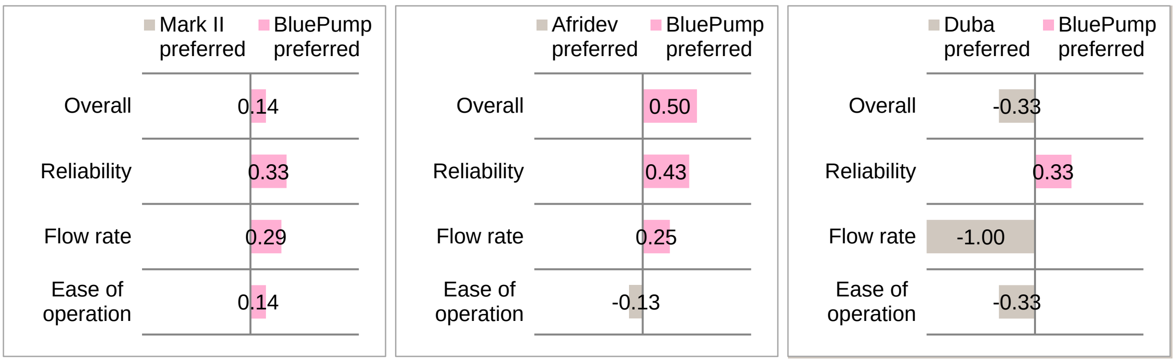



## Figure 14 - Direct head-to-head handpump preferences of water users in Turkana




Note: These head-to-head preferences were only elicited from users who had used both types of handpumps. Note: A score of -1 was assigned to a preference for the Mark II/Afridev/Duba, +1 was assigned to a preference for the BluePump, and zero if performance was considered to be equal.

## Figure 15 - Direct head-to-head preferences for handpumps on same well/borehole




Note: These head-to-head preferences were only elicited from users who had used both types of handpumps on the same well or borehole. A score of -1 was assigned to a preference for the Mark II/Afridev/Duba, +1 was assigned to a preference for the BluePump, and zero if performance was considered to be equal.

# 5.5 TECHNOLOGY APPLICABILITY FRAMEWORK ASSESSMENT

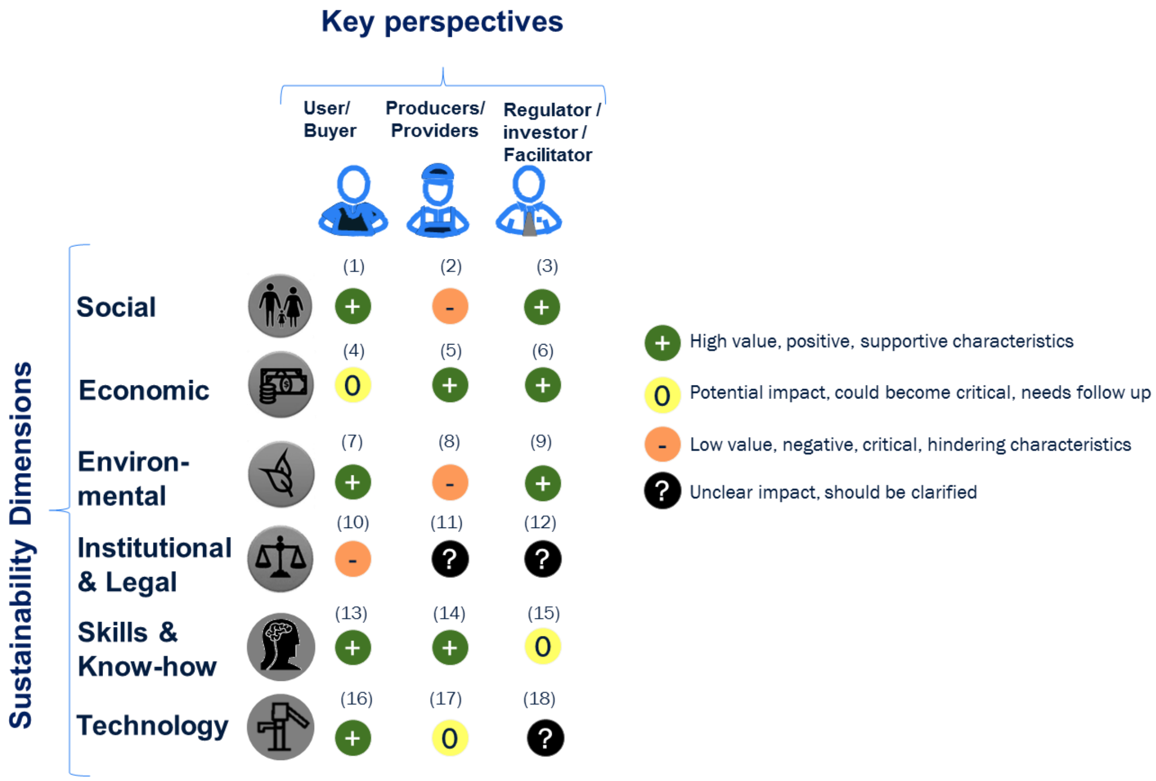
To assess the broader factors that impinge upon the suitability and sustainability of the BluePump in Turkana, stakeholders from local government, NGOs and service providers were convened at a workshop to apply the Technology Applicability Framework (TAF). The perspectives of users, service providers and investors were considered across six key sustainability dimensions: social, economic, environmental, institutional, skills and know-how, and technological. Further information on the TAF is outlined in Olschewski & Casey (2015).

Overall, the 17 attendees concluded that some key building blocks are already in place, while other areas require further strengthening (Figure 16), bearing in mind there was not always full agreement among attendees. As with any focus group of this nature, the discussions were influenced by a diversity of interests, perspectives and knowledge domains. Of the numerous issues debated, workshop participants identified several critical dimensions:

- **Social:** Overall, participants believed there was demand from water users for the BluePump due to its durability. However, it should be noted that very few water users interviewed during the field work felt their community had a choice as to which technology was installed. From the buyers' perspective, many participants agreed that the manufacturer and/or supplier needed to invest more in marketing and promotion at the local level so stakeholders knew how they could procure new pumps and access technical support. Although there is a Nairobi-based supplier (Techno Relief) who is able to deliver pumps to Lodwar and provide technical support, discussions revealed that two of the major handpump installers (County Government & Diocese of Lodwar) were unaware of this possibility.
- **Economic:** It was widely assumed that ongoing BluePump maintenance costs would require some form of subsidy in addition to user contributions. This was not necessarily seen as a problem as compared to other handpumps, as the centralised maintenance scheme operated by the Diocese of Lodwar has long offered a subsidised tariff (currently $35 per waterpoint per year), irrespective of the handpump type. Water users generally view this as a fair and reasonable price, although in reality not all communities are willing and able to pay the annual subscription fee. Participants did, however, note capital costs as a disadvantage of the BluePump vis-à-vis the India Mark II and Afridev (but not the Duba).
- **Skills and knowledge:** There was a consensus that the BluePump was not conducive to community-level maintenance arrangements in Turkana. Reliance instead is placed on the Diocese of Lodwar technicians, who have previously been trained on BluePump repairs and installation by Fairwater Foundation, and are now well versed on BluePump maintenance. It is again important to note that this observation is not specific to the BluePump: no other handpump in Turkana is currently maintained at the community-level due to supply chain constraints and the absence of trained and tooled local pump mechanics.

- **Technical:** Participants believed water users were satisfied with the BluePump, though were aware that many find the pump heavy and difficult to use. The question of whether a viable spare part supply chain exists generated substantial debate. Despite the existence of a Nairobi-based supplier who could deliver BluePump parts to Turkana, several attendees were of the view that in effect there was no viable supply chain because few were aware of this option. It warrants mention that up until this point the supply chain issue has had little bearing on the sustainability of the BluePump. As the sole maintenance provider in Turkana, the Diocese of Lodwar continues to draw on a large consignment of parts originally provided to them by Oxfam (in contrast, the Diocese of Lodwar purchases India Mark II and Afridev parts from Nairobi-based suppliers).

**Figure 16 - TAF traffic light matrix for BluePumps in Turkana**



# 6 RESULTS FROM THE GAMBIA

## 6.1 OPERATIONAL PERFORMANCE

Given the relatively old age of the PB Mark II installations in The Gambia, the comparative analysis of operational performance is most relevant for those handpumps aged 7 years or less (Table 16). For this cohort, functionality rates for the BluePump were marginally higher than Mark IIs on the whole, but lower than PB Mark IIs. The disparity in breakdown frequency was more striking and consistent, with Mark IIs seemingly breaking down 4 to 6 times more often. This advantage held across different groundwater depths, ages and usage levels (Table 17).

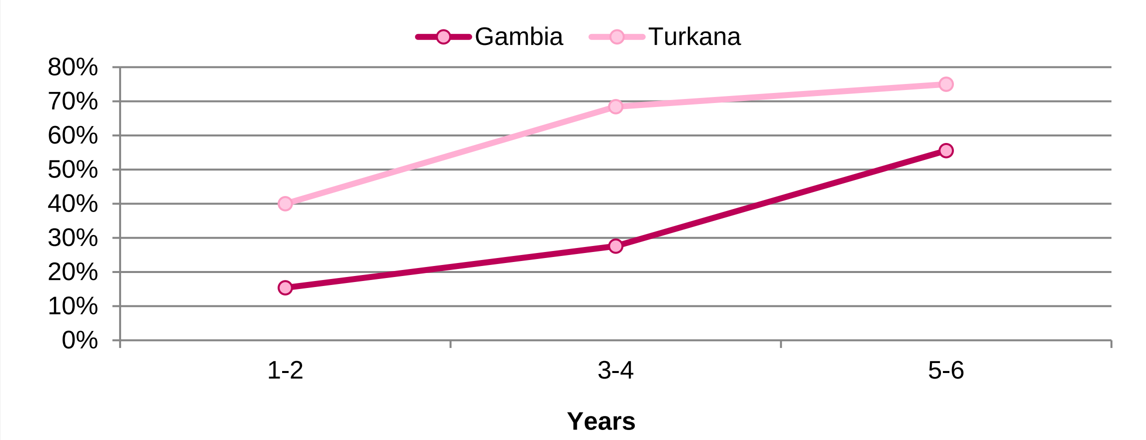
Conversely, average downtime associated with BluePump breakdowns was approximately double the duration for Mark IIs, and little difference was observed in operational days per year. Compared with Turkana, BluePumps in The Gambia tend to operate for a longer period of time before experiencing their first breakdown (Figure 17). Interestingly, leaking systems were far more prevalent in The Gambia than Turkana for both BluePumps and Mark IIs (Figure 18). This may be related to the deeper installation depths in Turkana, meaning equivalent leaks render a handpump unusable (and therefore non-functional) due to the amount of pumping that would be needed to produce water early in the morning.

**Table 16 - Summary of operational performance of sampled handpumps in The Gambia**

| Category | BluePump | Mark II | | |
|---|---|---|---|---|
| | | All | PB Mk II | India Mk II |
| **All handpumps** | | | | |
| Sample size | 59 | 102 | 80 | 17 |
| Functionality (%) | 83.1 | 52.0 | 53.8 | 52.9 |
| Breakdowns per year | 0.2 | 1.7 | 1.9 | 1.6 |
| Operational days per year | 323 | 238 | 226 | 294 |
| Downtime per breakdown (days) | 61 | 23 | 24 | 20 |
| Flow rate for female adult (l/min) | 17.0 | 18.6 | 18.1 | 21.3 |
| | | | | |
| **Handpumps 0-7 years** | | | | |
| Sample size | 55 | 29 | 17 | 11 |
| Functionality (%) | 83.6 | 79.3 | 100.0 | 45.5 |
| Breakdowns per year | 0.2 | 1.1 | 1.0 | 1.4 |
| Operational days per year | 320 | 318 | 328 | 299 |
| Downtime per breakdown (days) | 66 | 34 | 39 | 28 |
| Flow rate for female adult (l/min) | 16.9 | 20.0 | 19.8 | 22.1 |

Note: Downtime per breakdown excludes handpumps that have been non-functional for more than 1 year

### Figure 17 - Proportion of BluePumps having had at least one breakdown in The Gambia



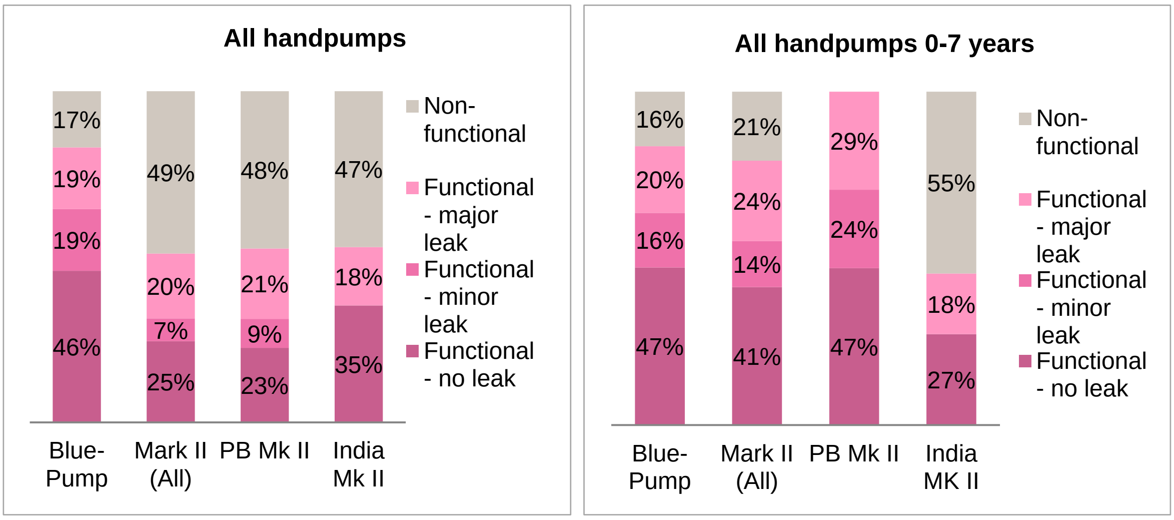

### Table 17 - Operational performance disaggregated by key characteristics in The Gambia

| Performance indicator | Variable | Category | BluePump | Mark II | | |
|---|---|---|---|---|---|---|
| | | | | All | PB Mk II | India Mk II |
| **Functionality (%)** | SWL | <10m | 69.2 | 54.2 | 57.1 | NS |
| | | 10-15m | 90.5 | 55.0 | 56.3 | 50.0 |
| | | 15-20m | 92.9 | 56.0 | 52.4 | 100.0 |
| | | 20-30m | 60.0 | 25.0 | 40.0 | 0.0 |
| | Age | 0-3 years | 92.9 | 73.3 | 100.0 | 50.0 |
| | | 4-7 years | 74.1 | 85.7 | 100.0 | 33.3 |
| | | 8+ years | ND | 46.7 | 45.5 | 100.0 |
| | Spare parts retailer | <50km | 82.1 | 49.4 | 53.6 | 40.0 |
| | | 50+km | 85.0 | 63.2 | 54.5 | 71.4 |
| | Waterpoint configuration | Single | 85.4 | 68.4 | 78.9 | 53.3 |
| | | Twin | 77.8 | 31.1 | 31.0 | NS |
| | **Functionality rate – All (%)[a]** | | **83.1** | **52.0** | **53.8** | **52.9** |
| **Breakdowns per year** | SWL | <10m | 0.0 | 1.0 | 1.0 | 1.0 |
| | | 10-15m | 0.1 | 1.8 | 2.1 | 1.0 |
| | | 15-20m | 0.2 | 2.3 | 2.3 | 2.5 |
| | | 20-30m | 1.7 | 2.7 | NS | 2.1 |
| | Age | 0-3 years | 0.1 | 0.8 | 0.3 | 1.3 |
| | | 4-7 years | 0.4 | 1.6 | 1.5 | 1.8 |
| | | 8+ years | ND | 2.3 | 2.3 | 2.4 |
| | No households | <35 | 0.2 | 1.5 | 1.4 | 1.8 |
| | | 35+ | 0.3 | 2.1 | 2.4 | 0.8 |
| | Use for drinking | Yes | 0.3 | 1.8 | 2.0 | 1.6 |
| | | No | 0.0 | 0.3 | 0.3 | ND |
| | **Avg. breakdowns per year – All[a]** | | **0.2** | **1.7** | **1.9** | **1.6** |
| **Operational days per year** | SWL | <10m | 281 | 284 | 275 | NS |
| | | 10-15m | 329 | 225 | 222 | 213 |
| | | 15-20m | 343 | 217 | 211 | 335 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | 20-30m | 301 | 200 | 142 | 296 |
| | Age | 0-3 years | 348 | 319 | 362 | 282 |
| | | 4-7 years | 291 | 318 | 310 | 346 |
| | | 8+ years | ND | 222 | 219 | 348 |
| | No households | <35 | 326 | 252 | 242 | 306 |
| | | 35+ | 313 | 229 | 220 | 267 |
| | Spare parts retailer | <50km | 314 | 229 | 225 | 271 |
| | | 50+km | 339 | 274 | 234 | 323 |
| | Waterpoint configuration | Single | 339 | 314 | 322 | 310 |
| | | Twin | 286 | 136 | 133 | NS |
| | **Avg. operational days per year – All[a]** | | **323** | **238** | **226** | **294** |
| **Downtime per breakdown (days)** | Spare parts retailer | <50km | 75 | 23 | 25 | 13 |
| | | 50+km | 38 | 24 | 22 | 26 |
| | Waterpoint type | Single | 38 | 19 | 19 | 20 |
| | | Twin | NS | 33 | 33 | ND |
| | **Avg. downtime per breakdown – All[a]** | | **61** | **23** | **24** | **20** |
| **Flow rate for female adult (l/min)** | SWL | <10m | 16.3 | 19.9 | 19.4 | NS |
| | | 10-15m | 16.5 | 18.3 | 17.6 | NS |
| | | 15-20m | 18.3 | 17.7 | 18.2 | NS |
| | | 20-30m | 15.6 | NS | NS | NS |
| | **Avg. flow rate for female adult – All[a]** | | **17.0** | **18.6** | **18.1** | **21.3** |

NS = Not shown due to small sample size (n<3); ND = No data
[a] 'All' results include those handpumps with unknown cylinder depth and/or age.

**Figure 18 - Prevalence of leaks in The Gambia**




## 6.2 MAINTENANCE & REPAIRS

Maintenance records could not be obtained for The Gambia, thus it is more difficult to draw conclusions about failure modes and maintenance costs. Based on inspections during field work and discussions with water users, it would appear that various problems have arisen with rods, pipes and cylinders (Table 18). Likewise, similar above-ground issues were observed with respect to missing or worn shock absorbers, leaking pump heads, concrete pedestal damage, and spout corrosion (Figure 19). Notably, operational problems relating to seasonal groundwater availability and silt were far less common than in Turkana.

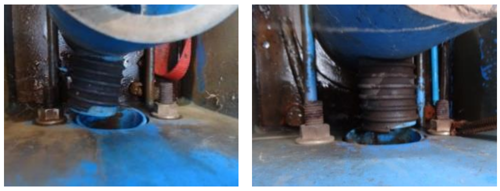
**Table 18 - Possible BluePump fault types and failure modes in The Gambia**

| Failure modes | Frequency | |
|---|---|---|
| | Possible fault (observed Apr-May 2016) | Possible cause of previous breakdown (self-reported by users) |
| **Major – No water produced** | | |
| *Mechanical* | **9** | |
| Leaking cylinder/pipe/conical seat | 4 | 4 |
| Broken rods | 2-3 | 3 |
| | | |
| *Environmental* | **1** | |
| Water level dropped below cylinder | 1 | |
| | | |
| **Moderate – Significant impairment of normal operation** | | |
| *Mechanical* | | |
| Leaking cylinder/pipe/conical seat | 22 | |
| Severed outflow tube | 2 | |
| Hanger bearings[a] | | 2 |
| *Structural* | | |
| Major damage to concrete pedestal | 3 | |

[a] Problem with hanger bearings relates to an early version of this component that has since been modified.

**Figure 19 - BluePump wear and tear in The Gambia**

Broken cover at allen key bolt: (i) Toubanding, (ii) Touba Angelleh, (iii) Amdalai Pallen



Severed outflow tube: (i) Keur Ngatta, (ii) Keur Ngorr

Corrosion of cap steel box and spout: (i) Kufuta Tumbung, (ii) Karsi Kunda

Leaking pump head: (i) Toubanding, (ii) Keur Ngorr

Damage to concrete pedestal:
(i) Njoofen; (ii) Sung Kunda; (iii) Keur Malick Sarr

Disconnected bearing bolt at Kufuta Tumbung

Rocking concrete pedestals: (i) Touba Angelleh, (ii) Keur Ngonian LBS

Corrosion of spout:(i) Mandinari, (ii) Ormothoh

Worn shock absorbers

There was a degree of uncertainty and confusion among communities about who could repair BluePumps in the event of a breakdown. This may partly be a by-product of a more robust technology: as mechanical faults occur less frequently, the first breakdown may take place several years after the point in time when communities would usually be informed about maintenance arrangements. In contrast, a well-established and widely-known network of area pump mechanics has been servicing Mark II pumps across the country for three decades (see Box 2). Five area mechanics were interviewed as part of this assessment, and all expressed a strong desire for training and tools so they could respond to the requests for help they receive from BluePump users.[13]

[13] Such an approach has reportedly been adopted for BluePump maintenance in Mozambique.

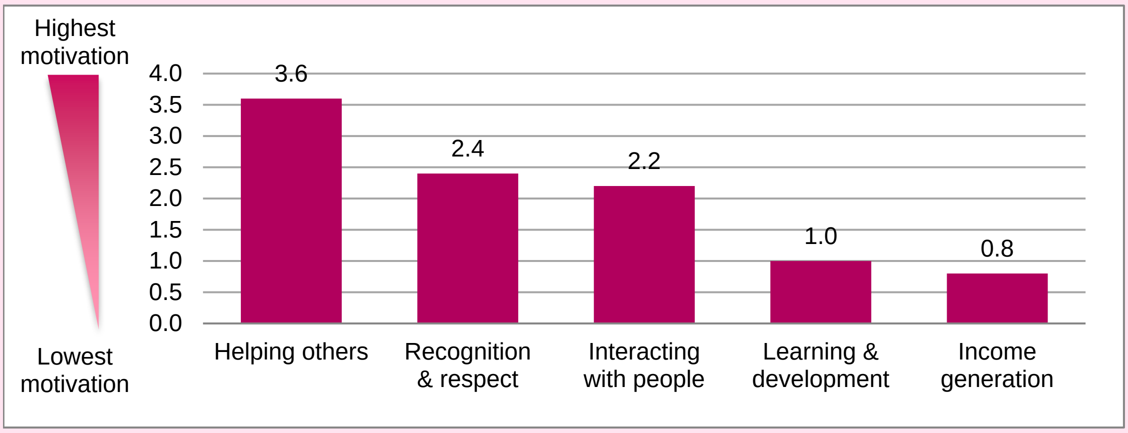
However, up until now the BluePump supplier Swe-Gam has elected to take responsibility for repairs and technical back-stopping. While in some cases this has worked effectively, in others it has resulted in lengthy downtimes, which is perhaps unsurprising given the pumps are scattered throughout all regions of the country. For example, ten of the BluePump visited in and around Fatoto in the country's east would involve an 800km round trip from Swe-Gam's headquarters in Serrekunda. There is also a lack of clarity around the commercial viability of the repair service. While community payment is not always forthcoming, Swe-Gam has felt compelled to carry out repairs regardless. The company makes a relatively thin profit margin for each BluePump sold and in some instances this is not enough to cover the cost of carrying out one free repair.

**Box 2. Handpump mechanics in the Gambia**

A network of handpump mechanics was established in rural Gambia during the 1980s and 1990s in concert with a large German-funded handpump installation programme. Initially, village chiefs nominated candidates for the role. They were then trained to repair the PB Mark II, equipped with tools and provided a horse and cart for transport.

As part of this evaluation, five handpump mechanics were interviewed in order to understand more about their roles, motivations and challenges. On average, each of these mechanics repaired handpumps in around 30 villages. There are no fixed prices and mechanics generally negotiate labour charges with communities on a case by case basis, and would commonly range from US $5-15, depending on the nature of the repair. Only one of the mechanics suggested they carried out more than 1 repair a week on average – unsurprisingly he was the only one who did not depend on alternative sources of income. The remaining mechanics generated most of their income from other means, such as carpentry and farming.

Overall, the mechanics expressed great satisfaction with their profession, with prosocial motives generally trumping financial incentives. Chief motivations included the desire to help their surrounding communities, followed by the recognition and respect they earned from their role. In contrast, income generation featured lowly, and all interviewees felt the amount of money earned from handpump repairs was insufficient. A lack of transport was seen as a major challenge by all mechanics (the horses originally provided had long since died), and some needed to renew their tools but could not afford the expense.

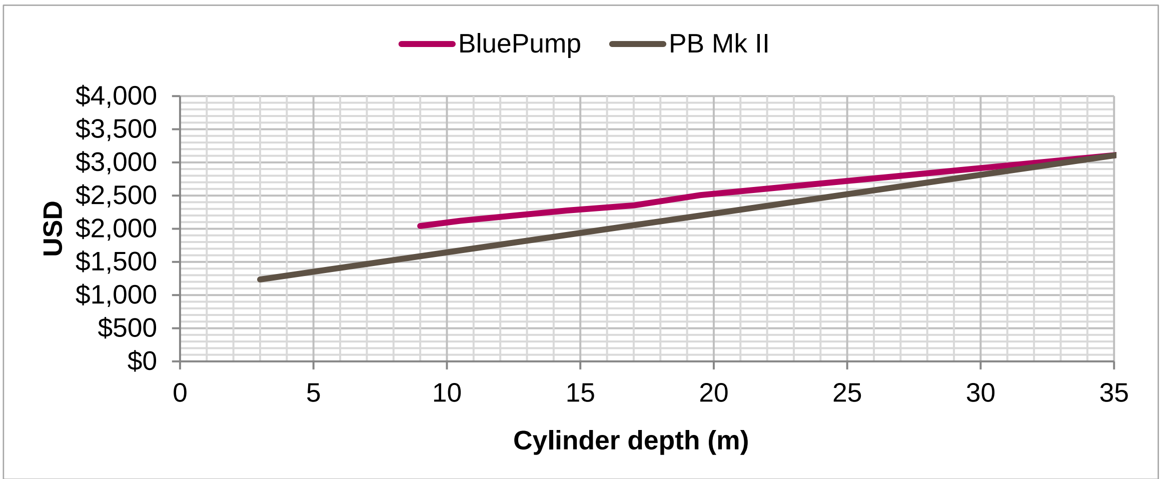


# 6.3 FINANCIAL DIMENSIONS

## 6.3.1 Capital costs

The upfront cost of the BluePump in The Gambia is similar to Kenya, ranging from US $2,100 for an installation depth of 10m up to US $2,800 for a depth of 30m (Figure 20).[14] For the shallowest depth, the pump is around $600 more expensive than the PB Mark II, but the difference is negligible at a cylinder depth of 30m. The price disparity is likely to be greater for an India Mark II; however applicable price data was unable to be obtained. Swe-Gam noted that one of the major challenges of the price point occupied by the BluePump is that it is only marginally cheaper than solar-power pumps, a situation not dissimilar to what DoL highlighted with the Duba in Turkana.

**Figure 20 - Upfront cost of handpumps by installation depth in The Gambia**




Data sources: Swe-Gam & Pumpenboese distributor in The Gambia

## 6.3.2 Maintenance costs

Given the small number of repairs that had been carried out on BluePumps in the previous 12 months, it was difficult to estimate repair costs. BluePump users reported just five repairs (across only two pumps) for which they paid Swe-Gam, at an average cost of $96. An additional two repairs were reportedly conducted for free, reducing the average cost to communities down to $69. In contrast, the average repair cost for PB Mark II pumps was $78, reduced to $68 when including free repairs. When factoring in the lower breakdown frequency, the annual maintenance costs would appear to be substantially less for the BluePump. However, in addition to the small number of repair events reported, there are two other qualifications. First, even when Swe-Gam does collect payment, it is unclear to what extent the amount paid covers their actual costs. Second, the repair costs estimated in The Gambia were self-reported by users, and it was not possible to verify the reliability of responses.

[14] An exchange rate of US $1 = 40 GMD is used throughout

## 6.4 WATER USER PERCEPTIONS

Water user perceptions in The Gambia are consistent with the findings on operational performance (Table 19). Overall, users of the BluePump and PB Mark II are satisfied with their handpump to a similar extent, though communities served by India Mark IIs are less so. User perceptions once again reinforce the notion that reliability is the BluePump's strong suit. However, the lengthy downtimes cause greater concerns for BluePump users, as does the difficulty of operation. Trends in BluePump satisfaction are similar for both male and female respondents (Table 20). For direct head-to-head comparisons, neither pump came out on top. Though the BluePump is viewed as more reliable – an attribute that is the most highly prized by female and male users alike (Box 3) – this is evidently offset by the Mark II's shorter downtimes and easier operation.

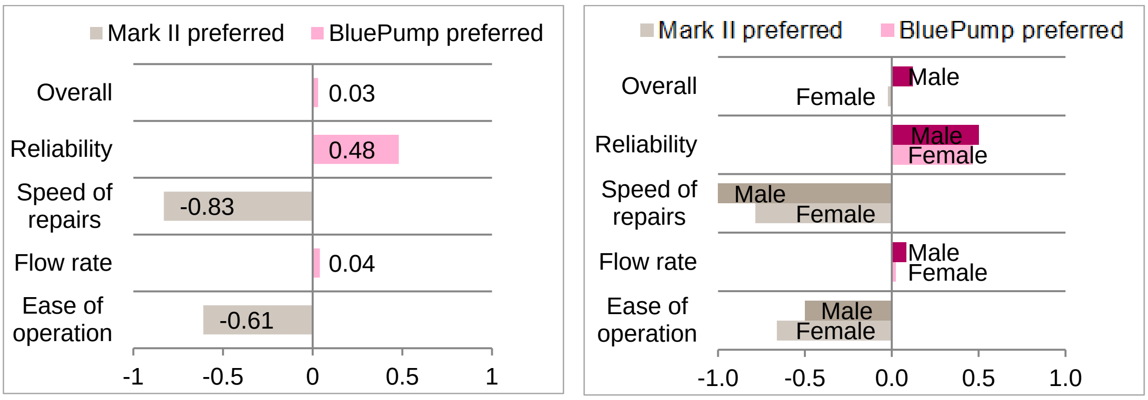
**Table 19 - Percentage of water users satisfied with water supply in The Gambia**

| | Overall (%) | Reliability (%) | Speed of repairs (%) | Flow rate (%) | Ease of operation (%) |
|---|---|---|---|---|---|
| **All handpumps** | | | | | |
| BluePump | 76 | 84 | 13 | 74 | 26 |
| All Mk II | 74 | 65 | 32 | 72 | 65 |
| *PB Mk II* | 81 | 71 | 37 | 69 | 67 |
| *India Mk II* | 54 | 46 | 17 | 85 | 57 |
| | | | | | |
| **Handpumps 1-7 years** | | | | | |
| BluePump | 76 | 83 | 7 | 74 | 25 |
| All Mk II | 77 | 58 | 22 | 69 | 59 |
| *PB Mk II* | 81 | 63 | 30 | 63 | 63 |
| *India Mk II* | 67 | 44 | 13 | 89 | 50 |

**Table 20 - BluePump satisfaction levels by gender in The Gambia**

| Respondent | Overall (%) | Reliability (%) | Speed of repairs (%) | Flow rate (%) | Ease of operation (%) |
|---|---|---|---|---|---|
| **Female** | 78 | 83 | 18 | 78 | 19 |
| **Male** | 71 | 86 | 0 | 67 | 38 |

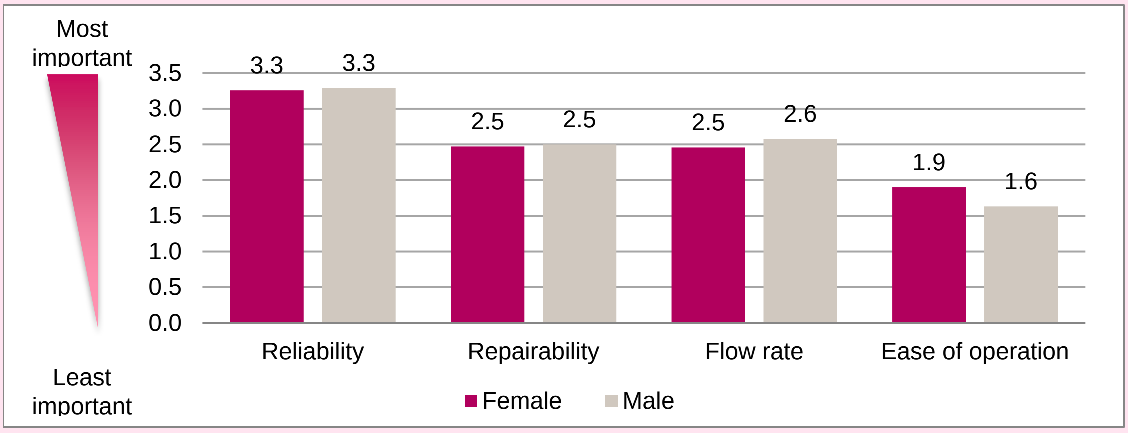
**Figure 21 - Direct head-to-head handpump preferences in The Gambia**




Note: These head-to-head preferences were only elicited from users who had used both types of handpumps. A score of -1 was assigned to a preference for the Mark II, +1 was assigned to a preference for the BluePump, and 0 if performance was considered to be equal.

**Box 3. How do handpump users in the Gambia rank the relative importance of different water supply attributes?**

Handpump users in the Gambia were asked to rank the relative importance of four key attributes as they pertained to their waterpoint: reliability, reparability, flow rate and ease operation. Reliability emerged as the most highly valued attribute. On average, water users placed a similar importance on reparability and flow rate, while ease of operation was considered the least important characteristic.



# 7 CONCLUSIONS

Notwithstanding the contrasting contexts in which this evaluation took place, a number of consistent messages emerge. Evidence suggests the BluePump is a robust handpump that breaks down less often than other mainstream handpump technologies in Turkana and The Gambia, both for deep boreholes and shallow wells. This is supported by self-reported breakdown frequency, maintenance data, and perceptions of users. Lower maintenance costs are a likely corollary of this; however information over a longer timescale is needed to make more definitive conclusions about lifecycle costs and value-for-money. That said, evidence from Turkana suggests that the disparity in operational performance between the BluePump and the India Mark II might be greater if communities had to bear the full costs of repairs.

The BluePump does have disadvantages. First, the upfront cost is higher than competing handpump technologies. The exception to this is the Duba, which is at least three times the cost of a BluePump. Second, there is widespread dissatisfaction among users with regard to the heaviness of the BluePump's operation. As installation depths increase, young children become unable to operate the pump, and multiple users are required to fill a jerrican. However, it warrants mention that both male and female users regard ease of operation as a less important attribute than reliability.

An uptick in reliability does not supplant the importance of effective maintenance arrangements and other building blocks for sustainability. That one in four BluePumps visited was not producing water indicates that the benefits of a more robustness technology will dissipate over time without effective maintenance arrangements for which users are willing and able to pay. As with other handpump models, BluePumps encounter problems with rods, pipes, and cylinders. In response to these and other issues, the developer has been receptive to feedback and has sought to improve the pump's design, though future investigations will be needed to ascertain the longer term impact of these changes.

In both Turkana and The Gambia, spare part supply chains are coupled with centralized maintenance providers that have extensive BluePump experience and technical know-how. Yet, awareness of these repair services among communities does not appear to be universal, particularly in The Gambia where downtimes are lengthy. The longevity of BluePumps in The Gambia face an additional hurdle: unlike in Turkana where the DoL has made a long-term commitment to provide a subsidised maintenance service, Swe-Gam is a private enterprise whose existence hinges on a commercial return. As it stands, the company has had trouble extracting financial contributions from communities, and their margins on BluePump sales are too small to offset these losses. Resolving this dilemma is urgent as the maintenance needs will only grow in the coming years. Harnessing the existing network of Mark II area pump mechanics presents an obvious alternative, and there is a clear appetite among mechanics to learn new technical skills and grow their customer base.

In conclusion, the BluePump can be a suitable and effective handpump technology in diverse settings, but it must be accompanied by responsive and sustainable maintenance arrangements. Given the predominant policy prescription of community-based financing of operation and maintenance, it is important to recognize that BluePumps are inevitably encumbered with the same collective action challenge as any other community handpump, in that user groups must have the capacity and willingness to pay the cost of repairs when needed. Addressing this fundamental issue – irrespective of chosen the technology – will be vital if handpump water services are to be sustained long into the future.

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