



STOP THE ROT

Report III: Handpump standards, quality and supply chains with Zambia case study

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

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Ask for Water
WATER

 **RWSN**
Rural Water Supply Network

skat foundation

thewaterloofoundation*

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Cover Photo: Afridev components on sale at Uncle Thom Hardware and General Dealers, Phalombe, Malawi, October 2021 (source: Tristan Salmon).

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ABBREVIATIONS AND ACRONYMS

BIS	Bureau of Indian Standards
CNC	Computer Numerical Controlled
GI	Galvanised Iron
HDPE	High-Density Polyethylene
HPB	Handpump Borehole
HTN	Handpump Technology Network
IIA	Independent Inspection Agency
IPC	International Plumbing Code
ISO	International Organization for Standardization
JMP	Joint Monitoring Programme
MLGH	Ministry of Local Government and Housing
NGO	Non-Governmental Organisation
RWSN	Rural Water Supply Network
SOMAP	Sustainable Operation and Maintenance Programme (Zambia)
SGS	Société Générale de Surveillance
SS	Stainless Steel
SSA	Sub-Saharan Africa
UNICEF	United Nations Children's Fund
WARMA	Water Resources Management Authority
WASH	Water, Sanitation and Hygiene
WHO	World Health Organization
ZABS	Zambia Bureau of Standards

SUMMARY

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

Handpumps have revolutionised access to safe, reliable water supplies in low-income countries, particularly in rural areas. They provide a viable alternative to contaminated surface water, open wells and unprotected springs. It is estimated that almost 200 million people in SSA (18.5% of the total population) rely on about 700,000 handpumps to provide them with their main drinking water supply. Handpump reliance is highest in Malawi, South Sudan, Zimbabwe, Guinea and Burkina Faso, ranging from 42% to 61%. The India Mark II pump and the Afridev pump are the two most common community handpumps, while the Vergnet pump is probably the third most common pump. The people of Zimbabwe rely on the Bush Pump.

Published or grey literature in the public domain on handpump component quality is limited, but physical audits undertaken in Burkina Faso in 2013 and 2014, as well as recent studies in Ethiopia, Malawi and Uganda, indicate non-conformance issues in components for between 32% and 90% of samples. While no conclusions over wider prevalence within these four countries or beyond can be drawn from these figures, they do provide a stark warning of potential widespread risk. This is particularly concerning given that participants of the 2021 RWSN groundwater survey expressed concerns about the quality and durability of handpump parts in 13 SSA countries.

Concerns about handpump component quality collated by this study concern riser pipes, pump rods, the steel plate, cylinder assemblies, centralisers, seals, joint to hook or eye, hook, eye, plunger and foot valve, centraliser, head assembly, bearings and flanges – in fact most handpump components. Inexpensive, poor-quality and fake/counterfeit parts, cost-cutting measures and corrosion-related issues were the most common issues cited by respondents to the recent RWSN survey.

Estimates for component life of the Afridev components are available, and the expected fast-moving parts for India Mark handpumps are documented. However, in the three decades of experience of handpump installation since the end of the UN Water Decade in 1990, field data on the service life of handpump hardware and different components remains lacking. This may reflect the lack of asset management and lack of preventative maintenance with respect to handpump technology and services in SSA.

In order to improve the supply chains of spare parts, many countries have standardised on a few public domain and/or propriety handpump models. In the case of public domain handpumps developed for community use, international specifications are available freely in the public domain. However, analysis of the international specifications for the Afridev and India Mark handpumps as well as the Indian Standards for the India Mark pumps reveals five concerns: (i) documents that are difficult to navigate; (ii) errors in the current specifications, including reference to international standards that have been withdrawn; (iii) gaps, particularly in relation to rapid corrosion; (iv) potential difficulties in interpreting the specifications; and (v) high levels of lead in some of the brass/bronze components.

There have been attempts to improve the design of the India Mark and Afridev handpumps, including making use of modern manufacturing techniques and limited field testing. However, a lack of formal oversight mechanisms for the international handpump specifications, which have essentially been frozen since 2007/8, coupled with very limited interest in funding handpump technology development makes it extremely difficult to address or validate these problems, or to incorporate design innovations.

Guidance is available for quality control and inspection of the Bush Pump, Afridev pump and India Mark pump. More guidance materials are available on quality assurance for the Bush Pump, including manuals in written form for end inspection as well as photo illustrations and videos. Although there are no inspection videos for the Afridev, the guideline document for quality control is detailed and extensive, covering manufacturers, independent inspection agencies and buyers. Unlike the more recently published Bush Pump inspection manuals, the Afridev guidance contains very few photographs. Of the three pumps, the India Mark pump has the least number of guidance materials available to support quality control. The international specifications for the India Mark and Afridev both contain a section on visual and dimensional tests, routine tests and conformity criteria. Short training modules on quality control are also available.

The guidelines for quality control and quality assurance of the Afridev provide details on:

- (i) internal quality control (for manufacturers);
- (ii) external quality control/quality assurance/pre-delivery inspection by an inspection agency; and
- (iii) end inspection of delivered goods.

The guidelines also emphasise:

- (iv) pre-qualification of suppliers; and
- (v) the placement of a clearly defined purchase order.

The 2021 RWSN survey of groundwater pumps (Furey and Danert, 2022) found that of the 33 responses by those that buy handpumps directly, there are a diversity of practices, with 33% having no procedures in place. Of the 25 respondents that buy handpumps as part of a borehole drilling package, only 36% stated that they inspect the pump before and after installation, while 48% only inspect the pump before installation and 12% only inspect it after installation. Only one respondent did no inspection. A total of 22 out of 32 respondents (69%) have received feedback or complaints about pump quality, indicating that there are feedback mechanisms in place for some handpump buyers, as well as quality concerns. What was striking in the survey were the variety of opinions, even for the same country of government regulation and activity of regulators, indicating varying levels of awareness and understanding. The Government of Zimbabwe does undertake quality control of the Bush Pump, including inspections at the premises of the manufacturer. In 2020, these inspections raised concerns about various components and resulted in the replacement of non-conforming parts.

Despite the RWSN's previous long involvement in handpumps since it was established in 1994, very little effort to examine or strengthen handpump supply chains have been undertaken since the mid-2000s. Documentation or knowledge sharing on handpump supply chains appears not to have been undertaken by the World Bank, The United Nations Children's Fund (UNICEF) or any other organisation operating in SSA or beyond after 2014.

Most handpumps seem to be manufactured in India, with pumps or pump components also imported into SSA from France, the USA and China. There is also manufacture in Zimbabwe and Tanzania. There are at least five links in the supply chain of handpumps or handpump spares – raw materials, handpump manufacture, in-country retailer, drilling contractor, community – and there may be more. There are dozens of handpump manufacturers in India, some of whom claim to be certified by the International Organization for Standardization (ISO). Anecdotal evidence indicates that poor-quality handpumps and components do enter markets in SSA. Given the importance of quality control at point of manufacture, questions remain regarding the responsibilities and activities of the Bureau of Indian Standards (BIS) and factory inspection (if any), the issuing of licences (and potential blacklisting) and incentives to ensure quality of exports.

An ideal supply chain would have quality assurance mechanisms in place at manufacture and a secure tracking of goods throughout, with only certified suppliers allowed to import. However, the case study from Zambia illustrates that this is not the case, with numerous importers and retailers operating, and regulation and quality control procedures are weak or non-existent. According to a small number of stakeholders interviewed, there are both high-quality and poor-quality handpumps available on the market, and capacity among buyers to tell the difference is limited.

Complementing the recommendations from Report II of the Stop the Rot initiative on rapid handpump corrosion (Danert, 2022b), this report recommends that:

- **RWSN, other global platforms and funding agencies** should:
 - Raise awareness and understanding of the important yet under-recognised issue of poor handpump quality with network members and (in the case of funding agencies) grantees.
 - Encourage organisations to produce user-friendly guidance in the form of illustrative manuals and videos for ensuring quality, including end inspection by buyers.
 - Document and share good procurement practices and feedback mechanisms, including evidence of their effectiveness.
 - Encourage investment in raising the capacity of handpump buyers (i.e. governments, drilling contractors, non-governmental organisations and private users) to identify key defects and quality in accordance with specifications and standards.
 - Undertake a study to document quality controls at point of manufacture and export from India, including the setting out of responsibilities and activities of the BIS and factory inspection, the issuing of licences and other incentives to ensure quality for export.
 - Encourage rigorous research on the expected service life of handpump components, with the results published and available in the public domain.
- **Lead international agencies** should establish an action group on handpumps (perhaps incorporating other groundwater lifting methods). In addition to the recommendations outlined in Report II (Danert, 2022b), the action group should provide a platform for exchange on mechanisms of improving handpump quality, and could include the issue of brass/bronze components containing high levels of lead. The action group force should also engage organisations that have been working (with very limited funding) to improve handpump design and ensure that handpump manufacturers and standards agencies are brought into dialogue to develop improvements.
- **Skat Foundation, which published the international specifications, or another suitable organisation** should:
 - Republish international handpump standard specifications to address errors and make them more accessible and searchable online.
 - Issue recommendations on alternatives to the India Mark handpumps with galvanised iron for areas where there is corrosive groundwater (especially low pH, salinity and chloride), including information regarding experiences, concerns and unknowns about these alternatives to date.
 - Develop detailed guidelines for end inspection of India Mark handpumps to include, for example, guidance around component weight and make reference to X-ray dispersive analysis, which is a standard test for measuring coating/plating composition and thickness and other mechanisms.
- **National governments** should:
 - Explore how to start or improve the regulation of handpump imports, in-country fabrication (if appropriate) and in-country supply chains, drawing on examples from other industries. Initiatives should be documented so that others can learn from them.
 - Establish an effective feedback mechanism for communities and users to register their experiences of poor handpump quality and use this information in efforts to improve handpump quality.
 - Ensure that rehabilitation programmes systematically collect data on the reasons behind handpump failure, including data on hardware problems such as – but not limited to – corrosion.
 - Explore asset management mechanisms that can incorporate expected component lifetime to support preventative and reactive maintenance programmes, thus helping to alleviate unrealistic burdens on communities.

HANDPUMP COMPONENT NOMENCLATURE

Figures 1 and 2 will assist readers with the handpump component nomenclature that is used in this report.

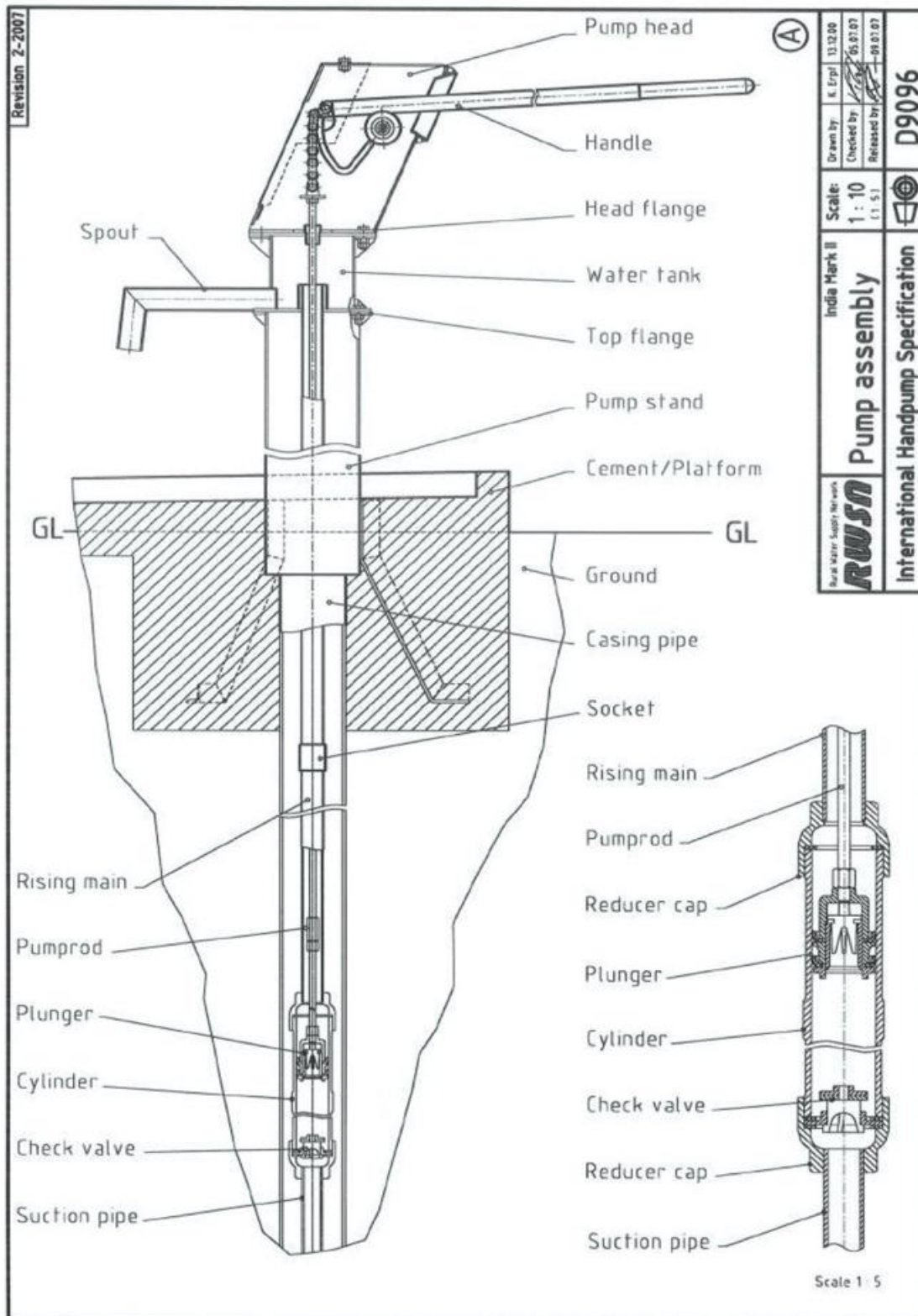


FIGURE 1 INDIA MARK II HANDPUMP COMPONENTS

Source: Skat/RWSN, 2007b.

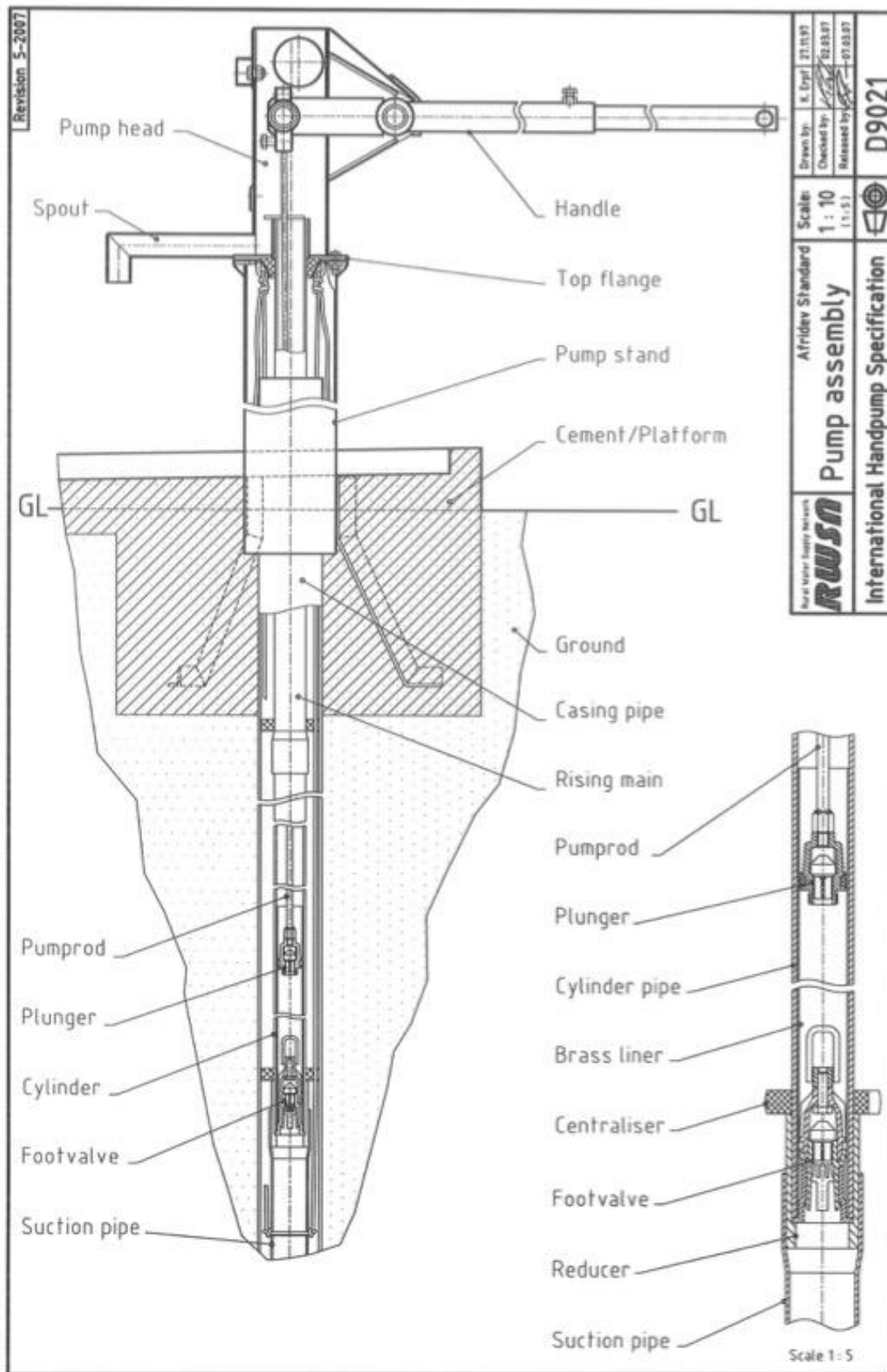


FIGURE 2 INDIA MARK II HANDPUMP COMPONENTS
Source: Skat/RWSN, 2007a.

INTRODUCTION

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

This is the third of a set of three reports produced by the initiative. It collates component quality concerns, reflects on component life and reviews handpump standards. It also examines guidance on quality control and inspection, as well as procurement alongside current practices, and develops a conceptual framework for handpump supply chains in SSA, which is used to map out handpump supply chains in Zambia.

Report I of the Stop the Rot initiative estimates the reliance on handpumps in SSA,² reviews the literature on handpump functionality and performance, and synthesises information on handpump technical quality from a number of studies and assessments (Danert, 2022a). Report II examines handpump corrosion in detail, with an overview of what is known and what has been done to address the issue in specific SSA countries and by select organisations (Danert, 2022b).

Based on analysis of the most recent data published by the World Health Organization (WHO) and the United Nations Children’s Fund (UNICEF) through the Joint Monitoring Programme (JMP), it is estimated that almost 200 million people, corresponding to 18.5% of the SSA population rely on about 700,000 handpumps to provide them with their main drinking water supply. Reliance is highest in Malawi, South Sudan, Zimbabwe, Guinea and Burkina Faso, ranging from 42% to 61% of the population (Danert, 2022a). Handpumps have revolutionised access to safe, reliable water supplies in low-income countries, particularly in rural areas, providing a viable alternative to contaminated surface water and open wells. On the negative side, limited ability to transport large quantities of water coupled with a lack of storage capacity at the home means that water from a handpump is usually fetched on a daily basis (Curtis, 1986).

It has been estimated that between 16% and 58% of handpumps in SSA countries are non-functional, varying by country and definition (Foster et al., 2019; Danert, 2022a). Concerns over low performance, breakdown and abandonment of handpumps have been raised for decades. A breakdown of even a short duration can result in the use of unsafe surface water supplies or require users to spend more time collecting water from a more distant source (Anscombe, 2011; Thibert, 2016). Water service failure impacts negatively on health and can inhibit other human development gains (Hunter et al., 2009; 2010; Baguma et al., 2017). Handpump breakdowns can also lead to overcrowding at neighbouring improved sources and even to conflict (MacDonald et al., 2019).

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

¹ RWSN developed out of the Handpump Technology Network (HTN).

² This study includes Sudan within its definition of SSA. Several island states (Cape Verde, Mayotte, Mauritius, Reunion, Seychelles and St. Helena) have not been included due to a lack of data on groundwater point sources.

Water supply practitioners have been discussing the related challenges of: (i) ensuring the quality of handpump components; and (ii) preventing rapid corrosion of certain components since the 1980s. The consistent quality of handpump components and the use of appropriate materials is underpinned by national and organisational policies and practices. Since the shift away from the centralised, hardware-based water supply projects of the 1980s, the challenges of rapid corrosion and poor-quality components have largely been neglected. Exceptions include efforts in some countries to mitigate rapid corrosion (notably Uganda, The Gambia and Ghana), interest to understand and/or address the corrosion challenge by select organisations,³ and attempts to improve quality assurance within the supply chain by some organisations. Reflecting the reduction of interest in handpump technology by international donors from the mid-2000s, the RWSN is no longer involved in handpump quality assurance or design modifications, and handpump standards committees are no longer active.⁴

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

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

The scope of this initiative covers two public domain handpumps that are used extensively in SSA – the India Mark II and the Afridev, which are the community handpumps of choice of governments and development agencies in many SSA countries (MacArthur, 2015). It also incorporates learning from the Bush Pump. Annex 1 provides a brief description of all three pumps. Other handpumps in the public domain, propriety pumps, including the Vergnet pump,⁶ or locally made pumps for household use⁷ are not covered by this study.

The study primarily used qualitative research methods, combining deductive and inductive approaches in analysing the limited information available. The research comprised a literature review, online exchange with water sector practitioners, an online survey, and discussions with select stakeholders both in groups and one-to-one. The author thus drew out key issues and experiences, and structured, and re-structured the findings into the series of three study reports as described above.

A reference group comprising stakeholders (from NGOs, donor agencies and academia) and consultants that were interested in the topic was formed, meeting every four months throughout the initiative to review the research progress and findings. The reference group members provided ideas, literature, reports and other related information.

³ Namely WaterAid, the British Geological Survey and UNICEF.

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

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

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

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

For this report, contact was made with a leading global testing, inspection and certification company, the Société Générale de Surveillance (SGS). They were contacted because of their previous involvement in handpump supply chains (following the Water Decade). SGS responded to queries, asked their own questions, and this dialogue (via email) formed the basis of an initial schematic mapping of the handpump supply chain. Two organisations that operate internationally in handpump procurement were contacted, and both kindly shared their quality assurance and procurement mechanisms, providing insights into practical requirements, checks and balances. A representative of the Government of Zimbabwe and Aquamor Zimbabwe independently responded to a question posted by the researcher in the RWSN discussion forum. They shared their experiences of quality control with respect to the Zimbabwe Bush Pump, which is manufactured within the country. These enquiries provided a conceptual framework for a literature review of the guidance on supply chains and handpump quality assurance for the Afridev and India Mark II handpumps. This formed the basis for the conceptual framework questions to be addressed in the Zambia study. Twelve stakeholders,⁸ representing drilling companies, implementation programmes and handpump retailers, were interviewed to map out the Zambia handpump supply chain. An interview guide covering handpump sources, quality and quality control, and changes, trends and advice was also prepared.⁹

⁸ Given the high number of drilling organisations, NGOs and projects engaged in the Zambian water sector, it was not possible to engage with all stakeholders. Further, the Covid-19 pandemic means that a mission to Zambia was not realistic, eliminating the possibility of focus group discussions or visits to the premises of handpump retailers. The selection of interviewees and interviews was undertaken remotely. Given previous experience on another project, it was decided to start with individuals who already knew about the Stop the Rot initiative (e.g. as a member of the reference group). More potential interviewees were drawn from a snowball from those interviewees, and were selected from published lists in Zambian water sector documents. Twenty-two stakeholders were contacted in total, with anyone who did not respond to the first email contacted a second time.

⁹ The researcher ensured that all interviews were booked in advance via phone or email. In the emails, and then again at the interview, the purpose of the study and expected time commitment was explained. The anonymity of all interviews was explained, and consent obtained from the respondent before questions were asked. There was no audio recording. The draft report was sent to all interviewees with an opportunity to provide comments within four weeks.

1. QUALITY CONCERNS

In the seminal handpump document of the UN Water Decade of the 1980s, Arlosoroff et al. (1987) recognised that problems would occur if GI pipes materials were of poor-quality materials, the threading was poorly cut or if pipe connectors were of poor quality. Report I of the Stop the Rot initiative (Danert, 2022a) found that, despite observations of low handpump functionality and premature failure, relatively little research and documentation on handpump technical quality has been undertaken. Published or grey literature in the public domain on handpump component quality is scant.

1.1 TYPES OF HANDPUMP QUALITY PROBLEMS

The photographs in Figure 3 illustrate examples of component quality problems.



(a) Broken flanges on Afridev pump in Malawi
Source: Larry Bentley.



(b) Broken hook on Afridev pump in Malawi
Source: Larry Bentley.



(c) Corroded pipe snapped off India Mark II cylinder in Uganda (old pipe threads being carefully peeled out to salvage cylinder)
Source: Larry Bentley.



(d) Broken handle on Afridev pump in Malawi
Source: Larry Bentley.



(e) Weld failure in riser pipe
Source: Tony Beers.



(f) Squashed pipe from lifting (most likely not correct grade)
Source: Richard Carter.

FIGURE 3 PHOTOGRAPHS OF SELECT QUALITY PROBLEMS

Table 1 provides an overview of specific concerns about the quality of certain handpump components over the last seven years as collated by this study.¹⁰ All of these concerns can result in major defaults and thus threaten the long-term viability of the water supply service. Although riser pipes are most frequently mentioned, Table 1 is not representative and should not be used for statistical analysis.

TABLE 1 EXPERIENCES OF HANDPUMP COMPONENTS WITH QUALITY PROBLEMS

Pump	Component	Material	Quality concern	Country(s)	Source
India Mark	Riser pipe	GI	<ul style="list-style-type: none"> Variability of $\pm 15\%$ in the thickness of the rising main sections in India Mark II (GI) Thickness below the specifications (3.25 mm \pm 0.2 mm) Galvanised thickness less than the specifications (70–80 μm) 	Ethiopia	Kebede et al. (2019)
			<ul style="list-style-type: none"> Significant variation ($\pm 75\%$) in the thickness of the rising main section Rising main thickness below the specifications (3.25 mm \pm 0.2 mm) Galvanised thickness less than the specifications (70–80 μm) 	Uganda	Owor et al. (2019)
			<ul style="list-style-type: none"> Overall weight was lower than others built to Skat specifications GI pipes can be 5 kg instead of the heavier duty 8.8 kg of RWSN/Skat Specifications. The thinner walls corrode faster 	South Sudan, Uganda, Zambia	Enangu (in Furey, 2014); Anscombe (2019b); Carter and Guo (2021);
			<ul style="list-style-type: none"> Non-standard pipes purchased from pipe brokers rather than handpump manufacturers Unscrupulous traders pass off cheaper pipes by changing colour coding or markings 	Uganda, Zambia	Anscombe (in Furey 2014); Enangu (in Furey, 2014)
			<ul style="list-style-type: none"> Light pipes and threads which are not deep enough to hold the weight of the pipe and water 	South Sudan	Furey and Danert (2022)
			<ul style="list-style-type: none"> Difficult to find riser pipes that are strong and won't corrode 	Sierra Leone	Campbell (in Furey, 2014)
			Riser pipe	SS	<ul style="list-style-type: none"> Samples tested did not conform to the material type specifications
	<ul style="list-style-type: none"> Weld failures on rising main couplings (difficult to manufacture) 	Mali, Niger			Beers et al. (2013)
	Not stated	<ul style="list-style-type: none"> Thickness of the pipe not conforming to standard. 		Kenya, Uganda	Bernard (in Furey, 2014); Enangu (in Furey, 2014)
	Pump rod	SS	<ul style="list-style-type: none"> Samples tested did not conform to the material type specifications 	Burkina Faso	Danert (2019)
	Pump rod	Not stated	<ul style="list-style-type: none"> Rods were actually electroplated mild steel 	Zambia	UNICEF and GRZ (2017)
			<ul style="list-style-type: none"> Narrow diameter (11.2–11.6 mm rather than 12 mm \varnothing) with the result that male and female threads do not connect properly, leading to premature failure 	In-factory issue	Anon (in Danert, 2019)
			<ul style="list-style-type: none"> Bending of rods due to soft (incorrect) material 	In-factory issue	Anon (in Danert, 2019)
Pump rod		<ul style="list-style-type: none"> Traders importing mild steel pump rods 	Zambia	Anscombe (in Furey, 2014)	

¹⁰ Other concerns documented that are beyond the scope of this study relate to the headworks, including the strength of the concrete in Malawi (Anscombe, 2011) and Zambia (Anon, 2021a), length of the drain as well as not following other aspects of the apron and drainage specifications in Zambia (Anscombe, 2011).

Pump	Component	Material	Quality concern	Country(s)	Source
	Steel plate		<ul style="list-style-type: none"> Thinner than the specifications and 3rd plate missing 	Zambia	Anscombe (2019b)
	Upper valve	Brass	<ul style="list-style-type: none"> Non-conformant lead content (Annex 3) Breaking into two parts due to casting failures 	Ghana, Mali, Niger	Fisher (2021); Beers et al. (2013)
	Galvanised components		<ul style="list-style-type: none"> Concerns about the quality of the galvanising, non-compliant galvanising processes and a lack of/insufficient pre-treatment ahead of the hot dip galvanising Rusting 	In-factory issue	Anon (in Danert, 2019); Danert (2022b)
	Cylinder assembly		<ul style="list-style-type: none"> Chemical composition of the cylinder sleeve includes higher lead, which makes it softer 	In-factory issue	Anon (in Danert, 2019)
	Centralisers		<ul style="list-style-type: none"> Defective materials 	Uganda	WaterAid (2021)
	Piston bucket seals		<ul style="list-style-type: none"> Defective materials 	Uganda	WaterAid (2021)
	Cylinder		<ul style="list-style-type: none"> Light weight 		Anon (2021b)
Afridev	Riser pipe	Unplasticised polyvinyl chloride (uPVC)	<ul style="list-style-type: none"> Variability of $\pm 15\%$ in the thickness of the rising main sections in Afridev (uPVC) Rising main thickness less than or greater than the specifications 	Ethiopia, Malawi	Kebede et al. (2019); Mwachungu et al. (2019)
	Welded joint to hook or eye		<ul style="list-style-type: none"> Welded joint sheers off due to imperfect welding 	Malawi	Anscombe (2011)
	Hook	SS	<ul style="list-style-type: none"> Hook shears across the thin part (due to imperfections as casting cools) 	Malawi	Anscombe (2011)
	Eye	SS	<ul style="list-style-type: none"> Eyes on the connecting rods were cracking and breaking (believed to be caused by low grade SS) 	Sierra Leone	Norris (2019)
	Plunger and foot valve	Plastic	<ul style="list-style-type: none"> It has been alleged that these are often manufactured from second hand plastic 	Malawi	Anscombe (2019b)
	Pedestal		<ul style="list-style-type: none"> Non-genuine parts (especially the pedestal of Afridev pumps) 	Ethiopia, Ghana, Kenya, Malawi, Mozambique, Niger, South Sudan, Tanzania, Zambia	
	Cup seal	Nitrile rubber	<ul style="list-style-type: none"> Has often been an issue in terms of quality and durability in the field 	Malawi	Salmon (2022)
Not stated	Rod centralisers	Nitrile rubber	<ul style="list-style-type: none"> Excessive wear and friction in a few days. Rubber was tested and not nitrile (blend with little nitrile) and hardness below the specifications (70 Shore rather than 80–90) Testing in a lab revealed negligible nitrile content 	Kenya, Uganda	Furey (2019); Polak and Nabasiye (2021)
	Piston seals and pump buckets	Rubber	<ul style="list-style-type: none"> Pump bucket rubber do not last for long Poor-quality cup seals and foot valves Weak rubber buckets Thin rubber 	Dem. Rep. of Congo, Malawi, South Sudan, Uganda, UK-based	Furey and Danert (2022)

Pump	Component	Material	Quality concern	Country(s)	Source
	Foot valve	Brass	<ul style="list-style-type: none"> High levels of lead by weight (14.8–52.9%) in all 15 samples 	Ghana, Mali	Fisher et al. (2021)
	Head assembly	Various	<ul style="list-style-type: none"> Materials not of the correct sectional thickness so that what should have a weight of 25 kg in practice only weighs 20kg. The thinner materials will result in a lower-strength component and reduce the strength of the welds 	In-factory issue	Anon (in Danert, 2019)
	Bearings		<ul style="list-style-type: none"> Use of lower quality roller bearings and reduction in bearing housing sectional size 	In-factory issue	Anon (in Danert, 2019)
	Flanges		<ul style="list-style-type: none"> Pump stands and flanges do commonly suffer from early fatigue and not always caused by loose bolts Weak 	Dem. Rep. of Congo, Sudan, Uganda	Matthews-Frederick (in Furey, 2014); Furey and Danert (2022)
	Not specified		<ul style="list-style-type: none"> Poor threading and poor finishing 	Zimbabwe	Furey and Danert (2022)
	Various		<ul style="list-style-type: none"> The quality of plungers, foot valves and centralisers vary dramatically by batch (from same suppliers). At times, whole orders have been useless or the pump would break just days after maintenance 	Rwanda	Furey and Danert (2022)

Respondents to the 2021 RWSN groundwater pumps survey (Furey and Danert, 2022) were concerned about the hardware quality/reliability of handpumps. The majority had received complaints regarding the quality of spare parts, with specific comments referring to:

- The internal lining of the cylinder and galvanisation.
- Surface threading leading to lost pipes, and holes formed due to tightening with clamps during repairs.
- Variation in the quality of the plungers, foot valves and centraliser between batches for the same company; at times, whole orders were deemed useless as the pump would be broken after three days (Rwanda).
- Poor threading and poor finishing (Zimbabwe).
- Thin rubber parts that wear frequently, even after just three days of installation (Malawi).

71% of respondents reported that rapid pump corrosion was a problem (widespread or in a few areas), particularly across SSA. Problems are associated with a combination of aggressive groundwater and poor pump quality.

1.2 PREVALENCE

Unfortunately, the prevalence of handpump quality problems is not known, but the 2021 RWSN survey and a few published studies indicate cause for concern. In a study in Uganda, the main physical factors affecting functionality performance of 50 forensically examined handpump boreholes (HPBs) were the poor condition of handpump components and the complex aquifer resource. Over 60% of the handpumps an (India Mark II variant called the U2) had a rising mains thickness below the handpump specification. GI thickness was also below the specification in 90% of the HPBs. (Owor et al., 2019). Furey and Danert (2022) report concerns about the quality and durability of specific handpump parts, and more broadly from several SSA countries including Burundi, Ethiopia, Ghana, Kenya, Malawi, Mali, Mozambique, Niger, Rwanda, South Sudan, Tanzania, Zambia and Zimbabwe, as well as India and Nicaragua. Physical audits in Burkina Faso in 2013 and 2014 found non-conforming pumps in 32% and 34% of the HPBs constructed and installed (CABINET NTU INTERNATIONAL A/S, 2013; 2014).

Inadequate checking and enforcement of standards means that cheap components find their way onto the market that do not have the lifespan that they should. Furey (2014) reported allegations by one driller from Uganda that India Mark II/U2 failed handpump components had been marked according to the ISO standard from their country of origin but did not conform to that standard and that unscrupulous traders pass off cheaper pipe by changing the colour coding or markings on the pipe. However, further details or measurements were not given.

1.3 OTHER TECHNICAL QUALITY CONCERNS

There are other technical quality issues that affect the quality of the installation, but which are beyond the scope of the Stop the Rot initiative. These include:

- Poor installation, which can lead to unnecessary and abnormal handpump wear.¹¹
- Pumps that are operated beyond their design depth, leading to early wear and tear or causing arduous pumping.
- Poor drilling and well development, resulting in the borehole silting and pump component abrasion¹² among others.
- A lack of replacements. For example: ‘The pumps are exposed to weather, water, air, or type of pollution that affect the viability of materials over time and human health. In my opinion, replacements are rarely made and no information is available on the corrosion of pumps. No information is available on the existence of a water supply and sewerage network and the type of materials and risks involved’ (Consultant, Cameroon).

Report I of the Stop the Rot initiative (Danert, 2022a) provides an overview of the literature regarding the technical quality of boreholes and handpumps.

¹¹ Issues include an off-vertical pedestal, loose pedestal in the concrete block and insufficient tightening of riser pipe threads.

¹² Arlosoroff et al. (1987) were concerned about abrasion of the cylinder wall and rapid wear of cup seals and valves if there is sand and silt in the well, which had even burst the diaphragm of some Vergnet pumps.

2. HANDPUMP COMPONENT SERVICE LIFE

Participants of a World Bank workshop in 1994 reported that with regular maintenance of fast-moving parts, the India Mark II and Afridev pumps have a lifespan of 10 years and that with an overhaul of other components the lifespan would be 18–25 years (World Bank, 1996).¹³ The latter most likely reflects the life of a borehole, which Driscoll (1986) estimates should exceed 25 years provided that wells and boreholes are properly designed and constructed.

The Afridev Installation and Maintenance Manual states that the expected time of the Afridev lifetime is 10–15 years, but adds that the lifetime is determined by many factors including: whether the material and/or workmanship is per specification; if preventative maintenance is undertaken or not; pump damage due to incorrect, excessive or abusive operation, water quality (e.g. salinity, silt or sand); climatic and environmental conditions; poor fishing of the borehole or poor installation of the pump and finishing of the borehole (Skat/RWSN, 2007c). Table 2 reproduces the replacement intervals of Afridev wearing parts from the Afridev Installation and Maintenance Manual.

TABLE 2 REPLACEMENT INTERVALS OF AFRIDEV WEARING PARTS

Drawing number	Description of spare part	Qty per pump	Approximate lifetime	Recommended replacement interval
	Pump head with pump handle			
B2024	Fulcrum pin assembly	1	5–8 years	Replace as required
B2033	Hanger pin assembly	1	5–8 years	Replace as required
B2028	Rod hanger assembly	1	5–8 years	Replace as required
C2044	Bearing bush outer	4	1–2 years	Every year
C2045	Bearing bush inner	5	1–2 years	Every year
	Pump rods			
B2207	Top rod assembly	1	3–5 years	Replace as required
B2214	Pump rod assembly	1–15	3–5 years	Replace as required
C2212	Centraliser (threaded and FRP)	1–15	2–3 years	Every second year
C2109	Centraliser (hook and eye connectors)	1–15	2–3 years	Every second year
	Rising main			
B2106	Riser pipe assembly	1–15	3–5 years	Replace as required
C2046	Riser pipe	1–15	3–5 years	Replace as required
C2042	Top sleeve	1	3–5 years	Replace as required
C2043	Flapper	1	3–5 years	Replace as required
C2076, C2077, C2078, C2079	Centraliser 6", 5", 4.5", 4"	2–15	3–5 years	Replace as required
	Pump cylinder			
B2297, B2071	Cylinder assembly with brass foot valve receiver or with polyoxymethylene foot valve receiver	1	5–8 years	Replace as required
	Plunger and foot valve			
B2085	Valve body assembly	1 to 2	3–5 years	Replace as required
C1011, C1021	O-Ring (for brass or plastic foot valve)	1	2–3 years	Every second year
C2088	Bobbin	2	2–3 years	Every second year
C2578	Cup seal	1	2–3 years	Every second year
	Other parts			
C2059	Gasket	1	5–8 years	Replace as required
C2095	Compression cone	1	5–8 years	Replace as required

Source: Adapted from Skat/RWSN, 2007c.

¹³ The World Bank (1996) report quotes Sarkkinen (1994) on the economic lifespan of the India Mark II (8–10 years) and Afridev (9–12 years) and the working lifespan of the India Mark II (15–20 years) and Afridev (18–25 years). Unfortunately, no hard or soft copy of the Sarkkinen report could be found.

There is no equivalent table for the India Mark handpumps, but there is a list of fast-moving parts (Table 3), which would be expected to have a shorter life. Given that riser pipes and pump rods are not considered as fast-moving parts, they should last several years. Components that are submerged in and out of water will eventually corrode.

Table 3 Fast-moving spare parts for the India Mark II handpump with preferred number of parts

Purpose	Moving parts	Preferred no. of parts available
For regular maintenance	Grease multi-purpose – for greasing chain assembly	1 can
	Grease (and hemp fibres) or sealing compound for riser pipe connections	1 can
For head assembly	Hexagonal bolt for pump head and water tank	8
	Hexagonal nut for pump head, water tank and handle axle	18
	Hexagonal bolt for inspection cover	1
	Washer for inspection cover	1
For handle assembly	Hexagonal bolt for chain assembly	1
	Hexagonal lock nut for chain assembly	1
	Washer for handle axle	1
	Spacer for handle axle	1
	Ball bearing	2
For cylinder parts	Cup seal for plunger assembly	2
	Rubber seating	1
	Rubber seating	1
	Sealing ring	1

Source: Skat/RWSN, 2008c.

Despite over three decades of handpump use since the end of the UN Water Decade in 1990, there is very limited field data on the service life of different handpump components. In fact, Hutton and Varughese (2016) note a lack of data on the lifespan of water, sanitation and hygiene (WASH) hardware. The WASHCost project (Burr and Fonseca, 2013) collected financial data of recurrent investment for a very small sample of handpumps in its analysis and so is unlikely to be representative. Recent estimates of life-cycle costs in Malawi (Truslove et al., 2019) used on the component estimates presented in the Afridev Installation and Maintenance Manual in Table 3 designated a 15-year total lifetime for the pump. Franceys and Pezon (2010) note that mechanisms of financial planning and budgeting generally do not account for the life-cycle costs of maintaining a water service over time.

Based on experiences from InterAide and partners, Salmon (2022) provided insights regarding the lifetime of select components of the Afridev pump. In order to avoid major and expensive breakdowns, InterAide recommended that the following five parts be replaced regularly: rod centralisers (twice per year); bush bearings (three times per year); cup seals (three times per year); O-rings (three times per year); and bobbins (three time per year). Notably the Skat/RWSN (2007c) guidance indicates that these components should last three to five years, one to two years, two to three years, two to three years, and two to three years respectively (Table 2). What is not known are the reasons for the lower-than-expected service life, which could be due to poor quality, extensive handpump use or perhaps an overestimation of service life in the first place. As well as quality issues, the extent of pump usage will affect component wear and the need for replacement. Poor or improvised on-site maintenance practices, such as breaking riser pipes when removing the Afridev, can also affect component service life.

The lack of data on actual lifetimes most likely reflects the lack of asset management, coupled with a lack of preventative maintenance with respect to handpump technology services in SSA. Ideally, maintenance schedules should be aligned with component lifetimes. In the case of preventative maintenance, this would mean replacing fast-wearing parts before they reduce pump performance or lead to a breakdown.

3. STANDARDS, STANDARDISATION AND SPECIFICATIONS

3.1 STANDARD DESIGNS, GUIDANCE AND STANDARDISATION

From the 1980s to about 2008 the World Bank, UNICEF, the Swiss Agency for Development Cooperation, the United Nations Development Programme, the Skat Foundation and others undertook major efforts to improve handpump quality and reliability. This included the establishment of the Handpump Technology Network (HTN) in 1992, the development of standard public domain designs (see Bauman and Furey, 2013) and guidelines for quality assurance of public domain handpumps (Prakash and Erpf, 2000; Erpf, 2007; Skat/RWSN, 2008b). In order to improve the supply chains of spare parts, many countries standardised on just a few public domain and/or propriety handpump models (MacArthur, 2015).

3.2 SPECIFICATIONS AND STANDARDS

Published specifications exist for public domain handpumps that were developed for community use (e.g. Afridev, India Mark, Walimi and Zimbabwe Bush Pump). Skat, through HTN (which became the RWSN in 2004), published standards for the India Mark handpumps, with the latest version dated 2007 (Skat/RWSN, 2007b). The Bureau of Indian Standards published the India Mark specification under the name ‘Indian Standard Deepwell Handpumps, Components and Tools’ in 2004 (BIS, 2004), with amendments in 2007, 2009 and 2012 (Figure 4). Annex 4 provides a list of standards and other key documents with hyperlinks.

In the case of the Afridev pump, Skat and HTN/RWSN issued five editions of the specification from 1989,¹⁴ with the most recent published in 2007 (Skat/RWSN, 2007a) plus a variant (Afridev with bottom support) published in 2008. The Afridev Handpump Specification (Skat/RWSN, 2007a) refers to specific publications of International Organisation for Standardization (ISO) Standards and one British Standard. In the case of steel, comparable graded or other national standards are also listed. The specification includes sampling procedures that are in accordance with ISO 2859 – Sampling procedures for inspection by attributes.⁸ There is also a publication on the engineering design and installation of the Afridev with bottom support (Skat/RWSN, 2008a).



(a) India Mark Handpump Specification (Skat/RWSN, 2007b)



(b) Indian Standard Deepwell Handpumps, Components and Special Tools – Specification (BIS, 2004)

FIGURE 4 STANDARD SPECIFICATIONS FOR THE INDIA MARK PUMPS

The Zimbabwe Standard Specification (Government of Zimbabwe, 2013), originally published in 2004, is based on the international specifications published by Skat/HTN (1999) and revised in 2008. The Zimbabwe Specifications refer to

¹⁴ For links to all editions, see RWSN (n.d.(a)).

specific publications of British Standards, European Standards and International Organisation for Standardization Standards and guideline by Skat Foundation.

The term 'variant' refers to a pump of the same basic design but with differences in the design of some components. An example is the India Mark III, a variant of the India Mark II with an open top cylinder (rather than a closed top) and larger diameter riser pipe. The India Mark III, U3M and Ghana Modified India Mark II are examples of variants of the India Mark II handpump. For more details, see Baumann et al. (2010). There are also different 'arrangements', 'types' or 'options' of one pump (such as a long or a short spout, rod material or connector design, plunger and foot valve material and design).

To date, there has been no involvement of any of the internationally recognised international certification bodies (e.g. ISO, NSF International, or ASTM International) in publishing handpump standards.

3.3 CONCERNS ABOUT SPECIFICATIONS

This study raises five concerns with respect to the handpump specifications for the Afridev and India Mark pumps: (i) documents that are difficult to navigate; (ii) errors; (iii) gaps in the standards, especially in relation to rapid corrosion in aggressive groundwater; (iv) challenges in interpreting the specifications; and (v) high levels of lead in brass/bronze components. These are summarised below.

DIFFICULTY IN NAVIGATING THE DOCUMENTS

The international specifications for the India Mark and Afridev pumps cannot be text searched without specialised software. This means that when checking a particular part number, or the dimensions of a particular part or group of parts, readers need to scroll through the whole document. It is time consuming and tedious. Efforts should be made to re-issue the specifications in a modern, searchable pdf format.

ERRORS

Review of IS 15500 (BIS 2004) Standard for Deepwell Pumps indicates that there may be some errors in relation to material specifications and cross-referencing (Danert, 2019). Beers et al. (2013) found errors in the dimensions of the India Mark II RWSN specification part number C2529, which were reported to RWSN for inclusion in future revisions.

Both of the ISO standards for brass components that are used in the international specifications for the India Mark handpumps and the Afridev (Part 1: non-lead and special copper-zinc alloys – ISO 426-1; and Part 2: leaded copper-zinc alloy – ISO 426-2:1983) were actually withdrawn in 2000 (ISO, n.d.(a); n.d.(b)). However, there are additional considerations about these parts, as discussed in the section on brass/bronze components below.

GAPS IN STANDARDS

Rapid handpump corrosion, whereby components corrode at a very high rate, is a major concern (Arlosoroff et al., 1987; Langenegger, 1998; Danert, 2022b). There is a lack of systematic documentation and analysis of in-country efforts and results. Further, the issue of rapid handpump corrosion is not fully addressed (Annex 2). Alternative materials are not mentioned, while in practice SS and polyvinyl chloride (PVC) riser pipes are available on the market and are being ordered and used in installations. As there are no standards for these alternatives, it is up to each buyer to determine the most suitable materials and dimensions. There are reportedly cases of lower grade SS being ordered and questions about whether SS end caps should be used for PVC riser pipes. The lack of clarity in the specifications undermines the quality of purchase – a key aspect of quality assurance (see Section 4).

Unfortunately, the issue is complicated by the fact that there has not yet been systematic collation and analysis of the few studies that have been undertaken to address the rapid corrosion issue. Nevertheless, it may be prudent to issue preliminary international recommendations, alongside guidance for testing, observing, documenting and sharing of the findings. Ongoing concerns, such as galvanic corrosion of the water tank for SS riser pipes, PVC strength and challenges of re-threading (Danert, 2022b), should be included in these recommendations.

CHALLENGES IN INTERPRETING THE SPECIFICATIONS

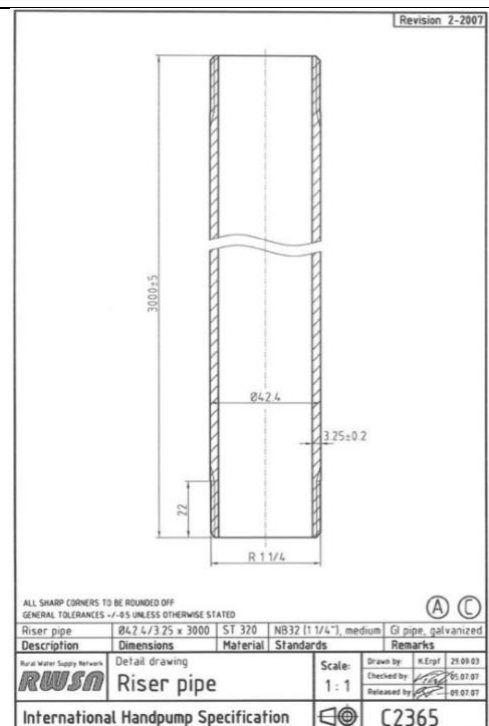
While the international specifications provide standard requirements and technical drawings, it may be difficult for those without sufficient training to interpret them, incorporate them into purchase orders or check the quality. Riser pipes provide an example of these challenges and guidance could be improved (Box 1). This example does not suggest dumbing down the specifications, but provides the starting point for simple yet rigorous quality control guidance for certain components.

The lack of information about technical specifications was mentioned by one respondent to the 2021 RWSN survey, while the availability of non-genuine parts on the market was mentioned in the case of Ethiopia, Ghana, Kenya, Malawi, Mozambique, Niger, South Sudan, Tanzania, Zambia and Nicaragua. Clearer guidance for buyers would at least improve their understanding.

BOX 1 HOW DO BUYERS KNOW IF RISER PIPES ARE TOO LIGHT?

Thin or light riser pipes are a key quality concern (Table 1). It is very difficult to tell the lightness of the pipes from a visual inspection, but weight provides essential information. While checking the weight of the pipes is fairly straightforward, quite some effort is involved in finding out what the weights should actually be. The following points set out the reasoning and calculations undertaken by a colleague¹⁵ in preparation for fieldwork in Northern Bahr el Ghazal, South Sudan, where failing riser pipes have been noted as problematic:

- The drawing for the riser pipe for the India Mark II in the India Mark Specification (see Figure 6) specifies an outer diameter of 42.4 mm, thickness of 3.25 mm and length of 3,000 mm (Skat/RWSN, 2007b: 77 drawing no. C2365). The material is ST 320 to standards NB32 (1½ inch), medium. It is a GI pipe.
- Dimensions of the pipe are specified to conform to ISO 65, 'Carbon steel tubes suitable for screwing' (Skat/RWSN, 2007b: 10).
- ISO 65 recognises four carbon steel pipe types: heavy, medium, light series 1 and light series 2. All types can be seamless or welded tubes, except light series 2, which is only for welded tubes. The outer diameter of India Mark II rising main in the Skat/RWSN (2007b) specification (medium series, nominal diameter 32 mm or 1¼ inch) is 42.4 mm, which exactly corresponds to ISO 65. ISO 65 applies to both medium and light grades.
- Unit pipe weights can be obtained from standard tables such as: <https://www.zssteeltube.com/gi-pipes-weight-chart/>
- The calculated unit weight of ISO 65 medium 32mm pipe is 3.10 kg/m (plain end) or 3.13 kg/m (screwed and socketed). In ISO 65, light pipe has a wall thickness of 2.9 mm (series 1) or 2.6 mm (series 2). It has a unit weight of 2.82–2.85 kg/m for series 1 and 2.54–2.57 kg/m for series 2.
- A 3 m length of 'light' weighs 7.62 kg, while the same length of 'medium' weighs 9.3 kg.



DETAILED DRAWING OF THE INDIA MARK II RISER PIPE FROM INDIA MARK SPECIFICATION
Source: Skat/RWSN, 2007b.

HIGH LEVELS OF LEAD IN BRASS AND BRONZE COMPONENTS

Exposure to lead is associated with irreversible neurodevelopmental impairment (Järup, 2003; Sanders et al., 2009; Rauh and Margolis, 2016; WHO, 2017;). National standards set limits for the acceptable leaching of lead (and other toxic metals) from drinking water components (ANSI, 2020). The International Plumbing Code (IPC) sets out a maximum lead

¹⁵ Prof. Richard Carter of Richard Carter and Associates, Ampthill, UK.

fraction of 8% in pipe and pipe fittings, including valves and faucets in a water supply system, and 0.25% by weight when the system is used to supply drinking water (ICC, 2017).

Nevertheless, lead exposure through drinking water systems does occur (Addis and Moore, 1974; WHO, 2011; Harvey et al., 2016; Pieper et al., 2017). For more information on lead contamination see Wren et al. (2020), who synthesise information on the sources of toxic metals and metalloids contamination in small rural drinking water systems and solutions. The study found contamination due to natural occurrence (geogenic), catchment pollution and corrosion of water distribution system materials. It is worth noting that the review found the literature to support preventative over corrective actions.

Recent research by Fisher et al. (2021) on pumped groundwater found a correlation between lead concentration in brass components and levels of lead in the water, although it has been pointed out that with an R^2 value of 0.66, the correlation may be overestimated (Anon, 2022). The study found very high lead fractions (14.8–52.9%) in all 15 brass foot valves sampled, thus shining a spotlight on handpump components made out of brass and bronze.¹⁶ Brass components of the India Mark handpumps are found within the cylinder assembly and comprise the brass liner, plunger body, follower, spacer, upper valve, follower, check valve, check valve seat and seat retainer (Figure 5).

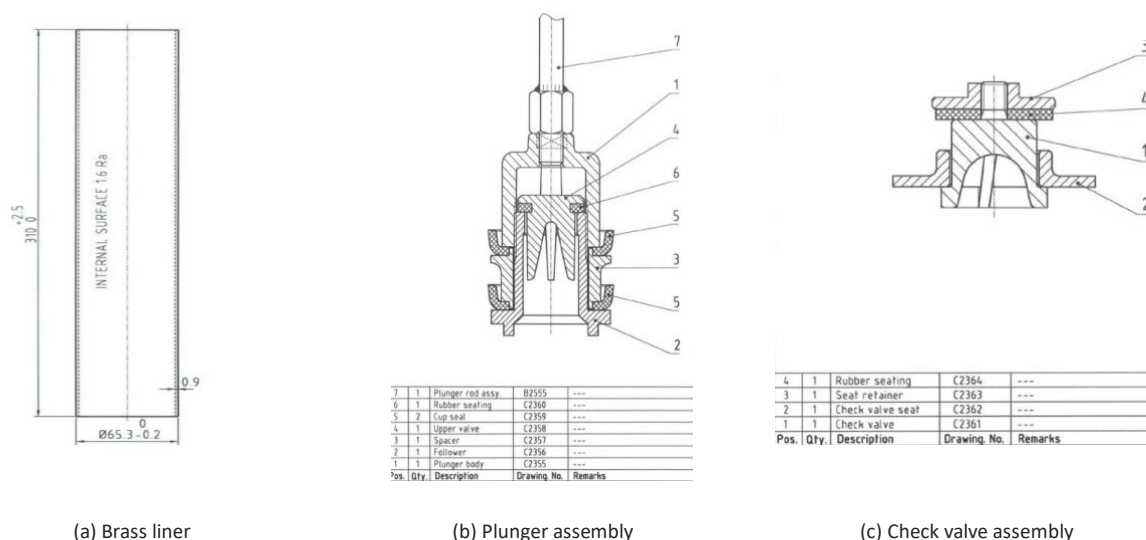


FIGURE 5 BRASS COMPONENTS OF INDIA MARK HANDPUMP CYLINDER ASSEMBLY BRASS

Source: Skat/RWSN, 2007b.

The specified composition of the brass liner confirms to the IPC. However, the specification for the India Mark II by Skat/RWSN (2007b) and the standard by BIS (2004), as well as the international specification for the Afridev (Skat/RWSN, 2007a), all specify brass/bronze plunger and check valve components with a lead content of 3.5–4.5% by weight. This is over 10 times higher than the IPC standards of 0.25%. From a human health perspective, such a high lead fraction content is a cause for concern.

Fisher et al. (2021) note that ‘given the hundreds of millions of people relying on boreholes and public taps in SSA, the public health impacts resulting from the use of unsafe water components in SSA are likely substantial’. The study recommends future work to examine other components, including borehole casings, pipe solders and pump cylinders, and emphasises the importance of preventing the introduction of leaded water components in new drinking water systems. High levels of lead in brass components of locally made handpumps have also been found in coastal Madagascar

¹⁶ Skat/RWSN (2007a; 2007b) specifications refer to brass, whereas BIS (2004) specifications refer to brass and bronze. Brass is an alloy composed of copper and zinc, whereas bronze is copper and tin.

(Akers et al., 2015),¹⁷ although it has been noted there may be other sources of lead contamination, including the (brass) well screen (Anon, 2022).

Given the importance of lead in easing the machining of copper alloys, and the technical requirements of the plunger and foot valve to withstand significant weight (the column of water) as well as move at a relatively slow rate, revising these standards requires consultation with the manufacturing industry and may require component testing.

Lead has also been used as a stabiliser in PVC piping. While the figures on mass fractions of lead in plastic components in Fisher et al. (2021) do raise concerns (Annex 3), the data is not as reliable as the method used for testing lead is intended for metals. Nevertheless, it is worth noting that although PVC containing lead was banned from use in China from 2006, lead remains in use in PVC pipes in China and it has been quoted to be used in 95% of PVC pipes in India and 86% in Africa and the Middle East (Plastics News, 2013).

3.4 A LACK OF OVERSIGHT AND ‘FROZEN’ STANDARDS

Since the India Mark and Afridev handpumps were developed in the 1980s there have been considerable changes to manufacturing methods, including the use of computer numerical controlled (CNC) manufacturing, which automates machine operating processes and enables fine precision components to be manufactured at relatively low cost.¹⁸ In addition, field data has been collected resulting in new information to inform the design. Computer-aided 3D design and simulation tools have also evolved, resulting in new capabilities for improving handpump design.

Messiah College (Beers et al., 2013) have designed and validated corrective actions to address specific failures of the India Mark II handpump with respect to unthreading of couplings, weld failure on pump stands, weld failure in SS rising mains, weld failure in SS pump rod couplings, plunger valve failure, bearing water on bushing, valve seal wear and pump rod centraliser disintegration. There has also been extensive work undertaken to radically improve handpump design (Polak and Nabasiye, 2021). The RWSN Secretariat has collated ideas for design changes to the Afridev (summarised in Annex 5). This indicates that, despite the lack of sizeable funding, there are a few organisations and individuals that are highly motivated to improve the design of public domain handpumps.

Proposed changes to the standards require validation with field testing. There is currently no formal mechanism for verification. There is also no mechanism in place to update the specifications. The international committees that were established to oversee changes to public domain handpump designs during the Water Decade no longer exist. These issues, combined with a lack of funding for the topic of handpump design, have meant that the international specifications have essentially been ‘frozen’ since 2007/8.

¹⁷ In coastal Madagascar, thousands of people rely on locally manufactured pitcher pumps for drinking water, cooking and household use. These pumps typically include components made from lead. Akers et al. (2015) monitored concentrations of lead in 18 household pitcher pumps in Tamatave over three sampling campaigns. The concentrations frequently exceeded the WHO’s provisional guidelines for drinking water of 10 µg/l: ‘Based on measured Pb [lead] concentrations, a biokinetic model estimated that between 15% and 70% of children living in households with pitcher pumps may be at risk for elevated blood lead levels (>5 µg/dL) ... In two of the 18 systems, Pb valve weights were replaced with iron, which decreased the observed Pb concentrations in the water by 57–89% in one pump and by 89–96% in the other. Both systems produced samples exclusively below 10 µg/L after substitution’ (Akers et al., 2015: 2685). Akers et al. (2015) conclude that straightforward operational changes on the part of the pump system manufacturers and pump users might reduce lead exposure.

¹⁸ Beers et al. (2013) propose CNC manufactured prototypes for the upper valves, which could solve the problematic casting problem noted in Table 1.

4. QUALITY CONTROL AND INSPECTION GUIDANCE

4.1 OVERVIEW OF AVAILABLE GUIDANCE

As discussed in Section 3, technical specifications are available for the Bush Pump, the Afridev and the India Mark II. Guidance available for quality control and inspection varies (Table 4). In summary:

- More materials are available on quality assurance for the Bush Pump (Figure 6) than the Afridev or India Mark handpumps (Figures 1, 2 and 7), including manuals in written form for end inspection, as well as photo illustrations and videos.
- Although there are no inspection videos for the Afridev, the guideline document for quality control is detailed and extensive, covering manufacturers, independent inspection agencies and buyers. Unlike the more recently published Bush Pump inspection manuals, the Afridev guidance contains very few photographs.
- Of the three pumps, the India Mark II has the least number of guidance materials available to support quality control. The Skat/RWSN (2007b) specification contains a section on testing that is similar to that within the Afridev specification.
- Short training modules on quality control are available on the RWSN website (Erpf, 2007).

TABLE 4 COMPARISON OF AVAILABLE SPECIFICATIONS AND QUALITY CONTROL GUIDANCE¹⁹

	Bush Pump	Afridev pump	India Mark pumps
Specification documents and national standards	Zimbabwe Standard Specification (Government of Zimbabwe, 2004; 2013)	Afridev Handpump Specification (Skat/RWSN, 2007a)	India Mark Specification (Skat/RWSN, 2007b) Bureau of Indian Standards (IS 8035:1999 Handpump – Shallow Well; IS 12732: Deepwell Handpump – Nomenclature Identification and Packaging of Components; IS 15500: Part 1 to 8:2004 – Deepwell handpumps components and special tools)
Testing and inspection information within specifications	Zimbabwe Standard Specification includes (a) Information on testing and inspection of samples (b) Examination inspection charts (c) n/a (d) n/a ²⁰	Skat/RWSN Specification includes (a) Section on testing of samples (b) n/a (c) Guarantee clause (d) Marking requirements	Skat/RWSN Specification includes: (a) Section on testing of samples (b) n/a (c) Guarantee clause (d) Marking requirements
Guidelines for quality control of manufactures	None	Guidelines for quality control and quality assurance of Afridev handpump (Skat/RWSN, 2008b) cover manufacture, independent inspection agencies and buyers	None
Guidelines for end inspection	Three manuals/guidelines with photographs: <ul style="list-style-type: none"> ▪ Pump head inspection manual (Morgan, 2012b) ▪ Down the hole components: inspection manual (Morgan, 2010) ▪ Practical guidelines for the inspection (Morgan, 2012a) 	End inspection of delivered produce is included within the guidelines for quality control (Skat/RWSN, 2008b). It includes: <ul style="list-style-type: none"> ▪ List of measuring tools for customer's end inspection ▪ Guidance for general and specific checks 	None
Inspection videos	Set of videos explaining pump head, rod movement and cylinder with tips on what to check in inspection and how to use templates (see RWSN, n.d.(b))	No inspection video available ²¹	No inspection video available

¹⁹ Annex 4 provides a list of standards and other key documents with hyperlinks.

²⁰ Not available.

²¹ WEDC (2019) has prepared a video of how the Afridev and India Mark II are designed, operated and removed.

4.2 SPECIFIC GUIDANCE ON TESTING AND INSPECTION OF SAMPLES BUSH PUMP

The specification for the Zimbabwe Bush Pump includes sampling procedures in accordance with ISO 2859 – Sampling procedures for inspection by attributes.²² The Standard Specification (Government of Zimbabwe, 2013) includes:

- Definitions of visual and dimensional tests for characteristics including:
 - Welding, workmanship, finish, visual defects and surface coating.
 - Conformity with drawings.
 - Select dimensions.
 - Fitment of hooks and connection threads.
 - Cylinder assembly leakage tests.
- Description of routine tests and pump tests.
- Requirements for supporting documents, i.e. the installation and maintenance manual, inspection guide and examination chart for inspection.

In addition to the specification itself, there are two guidance documents for inspection (i.e. pump head and ‘down the hole’ components), both of which make extensive use of photographs and simple descriptions, and a third publication provides specific guidelines for inspecting the geometry and measuring parts (Figure 6). A fourth publication provides templates that can be made and recommended tools for inspection (Morgan, 2012a).



(a) The Zimbabwe Standard Specifications Bush Pump (Government of Zimbabwe, 2013)

(b) The Zimbabwe Bush Pump Inspection of the “B” type Bush Pump Part 1. The pump head. Inspection Manual (Morgan, 2012b)

(c) The Zimbabwe Bush Pump Inspection of the “B” type Bush Pump Part 2. “Down the hole” components. Inspection Manual (Morgan, 2010)

(d) Practical Guidelines for the inspection of the Zimbabwe “B” type Bush Pump. Geometry and preliminary inspection (Morgan, 2012a)

FIGURE 6 STANDARD SPECIFICATION AND INSPECTION GUIDELINES FOR THE BUSH PUMP

Further useful information for inspection includes Appendix B and Appendix C of the Standard Specification (Government of Zimbabwe, 2013). These set out a number of critical points, such as:

- Pump head: angle and alignment of pump head; pivot pin holes; floating washer housing, free movement and size; discharge assemblies; pivot pin quality; spring washer; pivot block; U-bolts for handle and casing pipe, centre bolt; discharge assembly sockets; U-bracket; rubber buffer; handle size; spout assembly; welding quality; marking and general appearance.
- Down the hole components: for steel, GI, brass and leather components – origin, dimensions, galvanising quality (GI only), surface quality.

²² This ISO standard ‘was developed primarily for the inspection of a continuing series of lots all originating from the same production or servicing process’ (ISO, 2017).

Very accessible guidance, and an excellent entry point for the inspection of the above-ground components and installation of the Bush Pump, is available in the form of four videos prepared by Dr Peter Morgan and available online²³ (Box 2).

BOX 2 ZIMBABWE BUSH PUMP INSPECTION VIDEOS

The videos explain what the different components are called and what they do, how the pump works properly, alignment of components (including use of templates, spirit level and set square), the rationale for certain design features, checking that components are properly made and essential maintenance of the headworks. The type and dimensions of components are given verbally, with use of a ruler to illustrate the components in question. In addition, the installation is explained clearly, including what will go wrong if dimensions are not correct or if components are misaligned (RWSN, n.d.(b)).

Videos can be accessed at: <https://www.rural-water-supply.net/en/training-research/bush-pump-inspection>



SCREEN SHOT OF VIDEO EXPLAINING BUSH PUMP COMPONENTS AND INSTALLATION

Source: Peter Morgan, Aquamore, Zimbabwe.

AFRIDEV PUMP

The specification for the Afridev (Skat/RWSN, 2007a) includes a section on testing that features:

- Definitions of visual and dimensional tests for characteristics including:
 - 100 percent interchangeability of sub-assemblies and components
 - Welding, workmanship, finish, visual defects and surface coating
 - Conformity with drawings
 - Select dimensions
 - Fitments, protrusion
 - Cylinder assembly dimensioning and leakage tests
- Description of routine tests including discharge tests
- Criteria for conformity
- List of supporting documents

The specification includes a guarantee statement.²⁴ Marking is specified in the form of a nameplate permanently attached to the pump head, with the manufacturers name and address, serial number and year and month of manufacture. All flanges and the cylinder assembly should also be marked with the manufacturers name, identification mark and year of production.

The specification does not contain examination or inspection charts, but more guidance is provided in the 'Guidelines for quality control' (Skat/RWSN, 2008b). Important supplementary publications for manufacturers include a manual on

²³ <https://www.rural-water-supply.net/en/training-research/bush-pump-inspection>

²⁴ '[U]nless otherwise specified in the contract or order, the AFRIDEV Handpump and its accessories shall be guaranteed for 12 months from the date of installation, or 18 months from the date of supply, whichever is earlier, against faulty workmanship and/or materials' (Skat/RWSN, 2007a: 14).

injection moulding (Skat/HTN, 1999); moulding guidelines for rubber components (Skat/RWSN, 2003); and packaging guidelines (Mudgal and Kumar, 1992).



(a) Afridev Handpump Specification (Skat/RWSN, 2007a)

(b) Afridev Handpump with Bottom Support System (Skat/RWSN, 2008).

(c) Afridev Handpump Specification – Injection Moulding Manual (Skat /HTN, 1999)

(d) Moulds for Afridev Rubber Components (Technical Drawings) (Skat /HTN, 2003)

(e) Guidelines for Quality Control and Quality Assurance of Afridev Handpump (Skat/RWSN, 2008b)

FIGURE 7 STANDARD SPECIFICATION, MANUFACTURE AND INSPECTION GUIDELINES FOR THE AFRIDEV

The Skat/RWSN (2008b) guidelines for quality control and assurance provide details on: (i) internal quality control (for manufacturers); (ii) external quality control/quality assurance/pre-delivery inspection by an inspection agency; and (iii) end inspection of delivered goods. These three aspects are summarised in Box 3.

The guidelines also emphasise two other very important aspects:

- **Pre-qualification of suppliers** – an overall assessment of a manufacturer’s capability and capacity to deliver goods conforming to specifications. Includes evaluation of production facilities, organisational set-up, quality control set-up, inspection techniques, skilled workforce, manufacturing tools, jugs, fixtures, inspection gauges, instruments and test equipment, procedure of calibration and maintenance of gauges and instruments. The guidelines state that pre-qualification should be undertaken by an experienced independent inspection agency (IIA) and provides a format and checklist for evaluation. In an effort to keep out ‘ghost suppliers’ and ensure quality, it is advised that only pre-qualified suppliers should be invited to bid.
- **Placement of a clearly defined purchase order** – requires full details of product quantity, pre-delivery inspection, supply conditions and commercial terms and conditions. Options such as pump rod materials and spout length need to be clearly specified. Notably an incomplete purchase order can result in incorrect supplies and delays.

BOX 3 SUMMARY OF QUALITY CONTROL MEASURES FOR AFRIDEV HANDPUMPS**Procedures for internal quality control (by manufacturer):**

1. Important physical and chemical properties of raw materials
2. General checks during handpump production
 - a. Procedure for inspection of raw materials and bought out items
 - b. Stage inspection of components and sub-assemblies during production
 - c. Final inspection and marking procedure
3. Inspection of raw materials and bought out items
 - a. General checks on incoming materials (quantity, completeness, visual inspection, verification of test certificates for conformity of standards, in case of certification discrepancy, independent laboratory to check conformity, dimensions) with rejected material not taken into stock
4. Specific checks for Afridev handpumps
 - a. Checks for raw materials and bought out items (visual checks, verification of markings, dimension checks, physical and other tests). Specific physical tests are recommended for carbon and SS, hot tolled plates/bars, cold rolled sheets, and specific parts
 - b. Stage inspection during production
 - c. Checks on components and sub-assemblies (including pump head, handle front, handle rear, fulcrum pin, rod hanger, hanger pin, cover, stand, anchor, steel cone, cylinder, rising main assemblies and sub-assemblies, pump rod arrangements and tools)
5. Inspection check list for main assemblies – general and specific item checks
6. Final inspection and marking

Deviations or non-conformant goods and materials should be segregated and reported, and analysis undertaken to determine whether the deviation is allowed, corrective action is required, or the goods should be rejected. Deviations are to be recorded. Measuring instruments and gauges are required, and templates can be used to check the dimensional conformity of some components. Special testing equipment is required for certain assemblies (e.g. spin welding of valve bodies and leakage and discharge of cylinder assemblies).

Internal quality control should have verifiable records of the inspection activities and findings as above, as well as periodical checks of gauges, measuring instruments, templates, jigs and fixtures.

Pre-delivery inspection (by independent inspection agency):

The IIA receives a copy of the purchase order and agrees an inspection schedule with the manufacturer. The manufacturer lays out all of the completed pumps systematically, assembly-wise for inspection and provide the IIA of relevant data on raw materials, production and testing. The subsequent components are:

1. Test certificates are verified against the specifications and checks are made to verify the effectiveness of the internal quality control system, including checks of the manufacturing process in progress and quality of personnel to conduct quality control checks
2. Random samples are selected according to the sampling plan for detailed checks of attributes and variable. The following checks are undertaken:
 - Dimension check
 - Visual check
 - Interchangeability check
 - Performance check

If checks are satisfactory, quantity check and inspector stamping and stencilling follows. If the checks indicate defects beyond the acceptable limit as per the sampling plan, then the total quantity is rejected.

End inspection of delivered products (by buyer):

1. General checks (acceptance note and dispatch documents)
2. Specific checks of:
 - Specific fabricated items for transit damage, welding, damages, free movement of handle, corrosion or pitting and supply of all fasteners
 - Cylinder assembly – breakage of packaging and damage, cylinder smoothness, straightness and fit of pre-assembled plunger
 - Pump rod bundles – proper packaging, quantity, identification marks, inspection stamp, interchangeability of connectors

Source: Skat/RWSN, 2008b.

INDIA MARK II PUMP (AND VARIANTS)

The specification (Skat/RWSN, 2007b) includes a section on testing, containing:

- Definitions of visual and dimensional tests for characteristics including:
 - 100% interchangeability of sub-assemblies and components.
 - Welding, workmanship, finish, visual defects and surface coating.
 - Conformity with drawings.
 - Stroke length, position of pump head and handle, lateral play of handle and verticality of riser pipe compared to flanges.
 - Fitment of threads.
 - Cylinder assembly dimensioning and leakage tests.
- Description of routine tests including discharge tests.
- Criteria for conformity.
- List of supporting documents.

The Skat/RWSN (2008b) specification includes a guarantee statement and marking guidelines similar to that for the Afridev. The specification does not contain examination or inspection charts (Skat/RWSN, 2007a) and there are no additional quality control guidelines as are the case for the Afridev.

4.3 CASE STUDY: GOVERNMENT INSPECTION OF BUSH PUMP

In Zimbabwe, there are currently only two companies who make the Bush Pump (Annex 1). In the past, the quality of the B type pump varied enormously and lots of poor-quality pumps were made. In 2012, Peter Morgan was tasked to put measures into place to correct this problem (with UNICEF assistance). As a result, the system (i.e. the government) rejected pumps that did not follow the specifications. From this point on, the government was in control of the quality (Morgan, 2021a).

Documentation shared for this study describes the pre-delivery inspections of Bush Pump components by national and provincial stations in 2020 and 2021 by the Government of Zimbabwe (Anon, 2020; 2021a). Inspections were undertaken at the supplier premises by a technical team of three or four officers. The inspections were undertaken in line with the commitment to maintain hardware quality of all WASH materials procured by the government and partners by the National Action Committee WASH Sector. The inspection procedures comprise measurement and checking specifications, sub-assembling and dis-assembling of components and visual checking, and quantity checks. Spares and tools are checked and inspected against five dimensions (Table 5), with documentation of components that have been accepted or rejected.

TABLE 5 DIMENSIONS OF QUALITY FOR PRE-DELIVERY INSPECTIONS OF THE BUSH PUMP

Dimension	Description
Performance	Spares or tools are expected to meet the functional demands during use or application
Reliability	The tools or spares should not fail during use or application
Conformity	The tools inspected should conform to samples provided by supplier during the samples inspection phase
Durability	The tools inspected and passed are expected to be durable for a long time without significant deterioration
Aesthetics	Even though it has no bearing on functionality, spares or tools supplied should be pleasing to look at

While most components passed the inspections, several non-conformities were found:

- GI pump rods not adequately and sufficiently galvanised.
- Wooden blocks undersized, not adequately treated and with adverse cracks.
- Floating washers required flattening of sharp edges and re-dipping.
- Rubber buffers showed lines of weakness along the surface leading to the formation of cracks.

- Sprockets not correctly positioned on the short casing; undercoating not adequate.
- Leather cups cracking and height undersized.
- Misaligning short rods (5 out of 453), faulty U-brackets (4 out of 453), leaking cylinders (15 out of 385), rubber seals not properly seated (15 out of 170).²⁵

Following one of the 2020 inspections, the supplier was able to replace all materials that were not up to standard and did not meet specifications, with a promise that one component would be corrected for the subsequent inspection. Pre-delivery inspections in 2021 raised concerns about the high number of pump rods that required replacement (200 out of 3,000), with problems included poor galvanising, collapsing and rusting threads.

These pre-delivery inspection reports (Anon, 2020; 2021a) illustrate the importance of such inspection in identifying non-conformant components to ensure that quality handpumps are installed in communities.

²⁵ It was also noted that pipe threads were rusting in storage as they were not covered and thus exposed to rain.

5. QUALITY CONTROL BY RWSN MEMBERS

As part of this initiative, in late 2021, a survey of RWSN members on groundwater pumps was undertaken. The main purpose of the survey was to obtain an updated view from RWSN members on the state of groundwater pumping technology and the opportunities and challenges being faced with design, quality control, procurement and supply chains for the handpumps and their spare parts. As well as providing a situation update from a previous survey on handpumps in 2013, the survey was designed so as to inform the Stop the Rot initiative. A total of 132 valid responses were received (Furey and Danert, 2022).²⁶ The survey found that:

- Of the 33 responses by those who buy handpumps directly, there are a diversity of practices (Figure 8), with 33% of respondents having no procedures in place to check that the pumps have been manufactured according to design specifications.
- Of the 25 respondents that buy handpumps as part of a borehole drilling package, only 36% stated that they inspect the pump before and after installation, while 48% only inspect the pump before installation and 12% only inspect it after installation. Only one respondent did no inspection. Of the 25 respondents, 16 (64%) stated that they also rely on national quality control mechanisms.

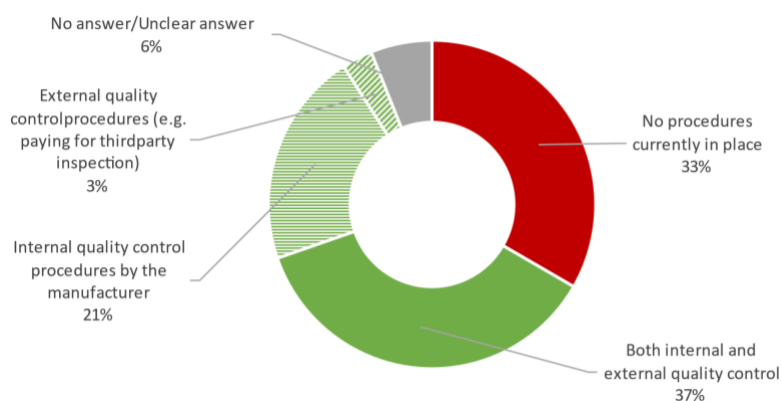


FIGURE 8 ORGANISATIONAL PROCEDURES FOR CHECKING HANDPUMP MANUFACTURING SPECIFICATIONS

Source: Furey and Danert, 2022.

Note: Responses were in answer to the question: 'What procedure does your organisation adhere to in order to check that the pumps have been manufactured according to design specifications?'. There were 31 responses.

Notably, 22 out of 32 respondents (69%) have received feedback or complaints about handpump quality. This indicates that there are feedback mechanisms in place for some handpump buyers, as well as quality concerns. In the case of government regulation and enforcement of hardware standards, the survey found that most respondents seemed to think that there is a government regulator, but that they are not active or effective. However, there were a variety of opinions, even for the same country, on government regulation and activity of regulators, thus indicating varying levels of awareness (Furey and Danert, 2022).

Some agencies, including Inter Aide Sierra Leone (n.d.), have developed simplified guidelines that touch on component quality. As one of the major importers of public domain handpumps worldwide, UNICEF's Supply Division has a process in place of certifying manufacturers in India. A collation or review of agency guidance and respective materials was unfortunately beyond the scope of this study.

²⁶ The survey was conducted using Google Forms, with a branching structure depending on whether the participant answered that they were a buyer of borehole + handpump, handpumps only, or a seller/manufacturer of handpumps. The online survey was open from 15 September to 15 November 2021. A total of 132 valid responses were received. The relatively low response rate means that broad generalisations of attitudes, trends and practices should be undertaken with care. However, the highly targeted nature of the survey and the RWSN membership means that the majority of those that did respond have direct operational experience and knowledge of pump procurement, quality and/or supply chains. The completion rate of the valid responses to the survey was 100%.

6. HANDPUMP SUPPLY CHAINS

6.1 BRIEF HISTORY OF ANALYTICAL WORK

Despite the RWSN’s long history of in handpump work since it was established in 1994, no efforts to examine or strengthen handpump supply chains have been undertaken for almost 15 years. The most recent work includes the RWSN/World Bank Water and Sanitation Programme’s 2006 publication on spare parts supplies, which explained how to develop and support supply chains (Oyo, 2006). In 2009, the RWSN published a short opinion piece on the topic (Baumann, 2009). In 2009, UNICEF commissioned a mapping study which made recommendations on how to improve supply chains (Sansom, 2009; Sansom and Koestler, 2009). However, the topic of handpump supply chains topic was effectively sidelined by the RWSN with the launching of the new Sustainable Services theme in 2012, which did not have a strong emphasis on technology. UNICEF commissioned a study of handpump supply chains in the Democratic Republic of the Congo (Koester et al., 2014). Since then, further documentation or knowledge sharing on handpump supply chains does not seem to have been carried out by the World Bank, UNICEF or any other organisation operating in SSA or further afield.

6.2 GENERIC (AND IDEAL) HANDPUMP SUPPLY CHAIN

The widespread belief that most handpumps come from India was corroborated by the 2021 RWSN survey, which indicates that 82% of handpumps are imported from India. Other notable exporters include France, the USA, Tanzania and Zimbabwe (Furey and Danert, 2022). It has been mentioned that in the case of Zambia handpumps are actually imported from Malawi, Mozambique and South Africa (Interviewees, 2021). China was also mentioned in informal exchange with professionals and by interviewees (2021), usually in relation to riser pipes and pump rods rather than entire handpumps. Some Indian manufacturers also import specific components from China. Figure 9 provides a schematic illustration of the handpump component supply chain within India, and into a hypothetical SSA *country X*. Figure 10 shows the next part of the supply chain within *country X*.

Taken together, Figures 9 and 10 illustrate there are at least five links within the supply chain (i.e. raw materials, handpump manufacture, in-country retailer, drilling contractor, community). However, there may be more. For example, the handpump may only be assembled in India by a supplier, with components manufactured elsewhere. Meanwhile, in *country X*, retailers may import from traders or buy from local stores, while handpump mechanics may install. Alternatively, a drilling contractor may import directly from India.



FIGURE 9: SCHEMATIC REPRESENTATION OF HANDPUMP SUPPLY CHAIN WITHIN INDIA FOR EXPORT

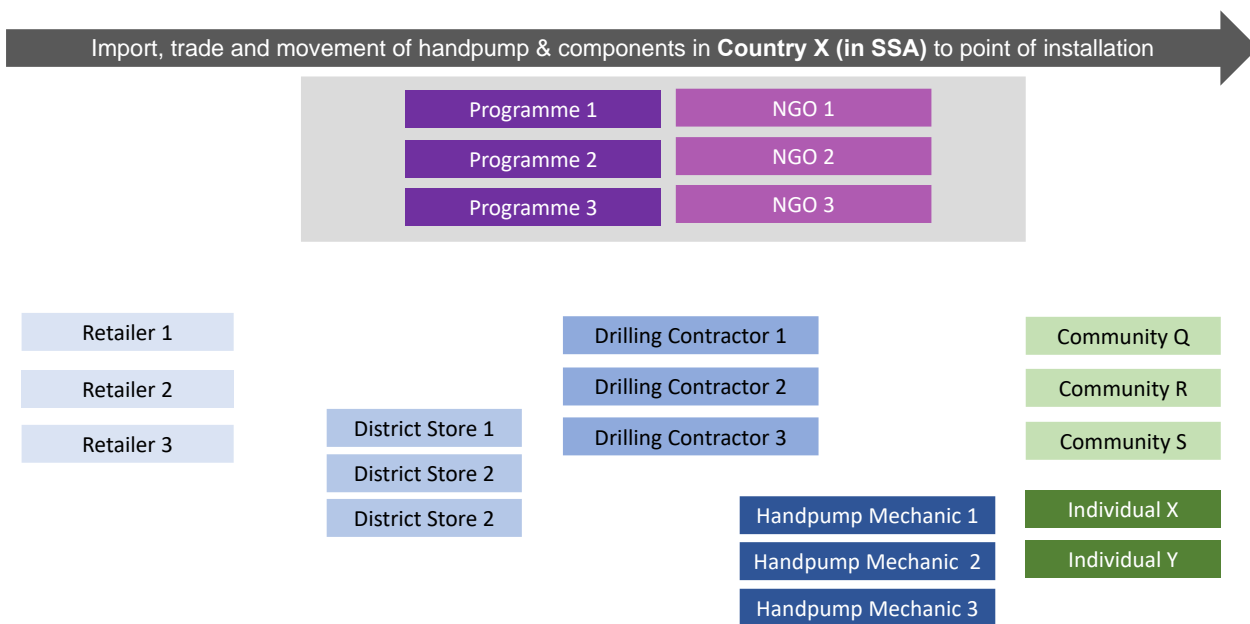


FIGURE 10: SCHEMATIC REPRESENTATION OF HANDPUMP SUPPLY CHAIN FROM IMPORT TO DISTRIBUTION IN COUNTRY X

Figures 11 and 12 illustrate an ideal supply chain, which has quality assurance mechanisms in place at the manufacturing stage and a secure tracking of the goods throughout. In such a scenario, assemblers would only be able to purchase from verified/qualified raw material suppliers and only approved traders would be allowed to undertake freight forwarding. In-country retailers or distributors would only be allowed to purchase from approved in-country traders. A warranty programme could also form part of the supply chain.

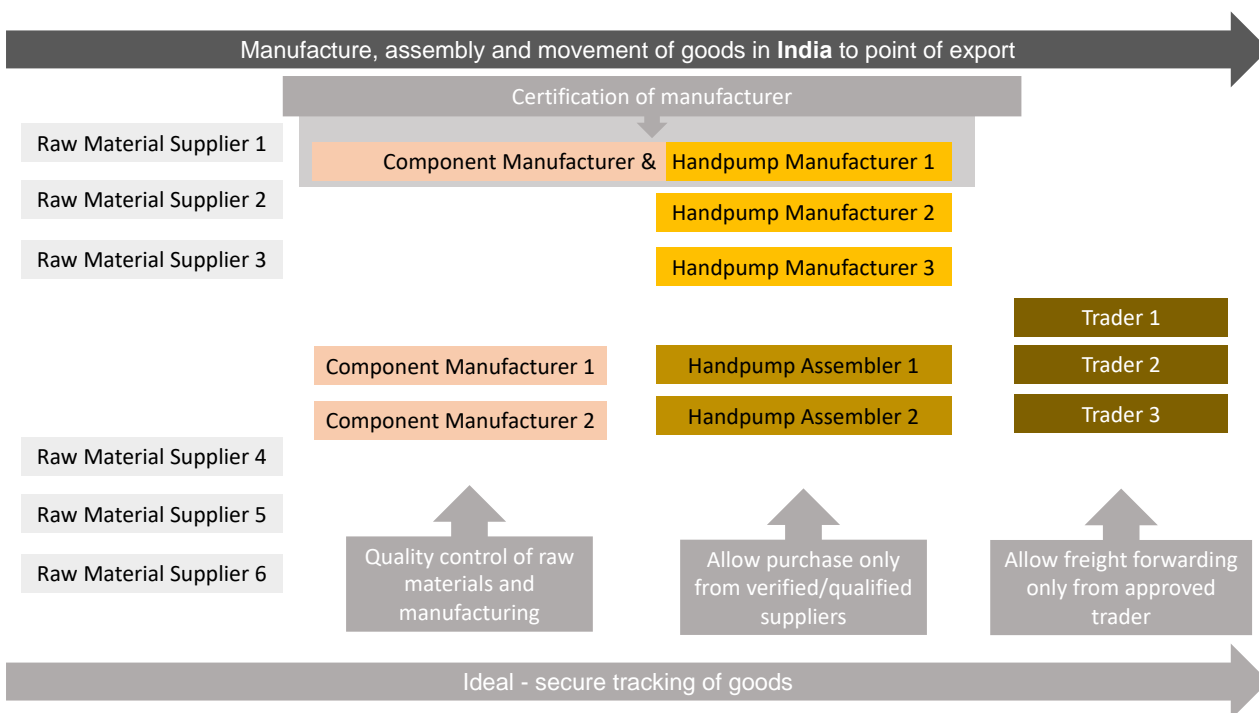


FIGURE 11: SCHEMATIC REPRESENTATION OF IDEAL HANDPUMP SUPPLY CHAIN – WITHIN INDIA TO EXPORT TO COUNTRY X

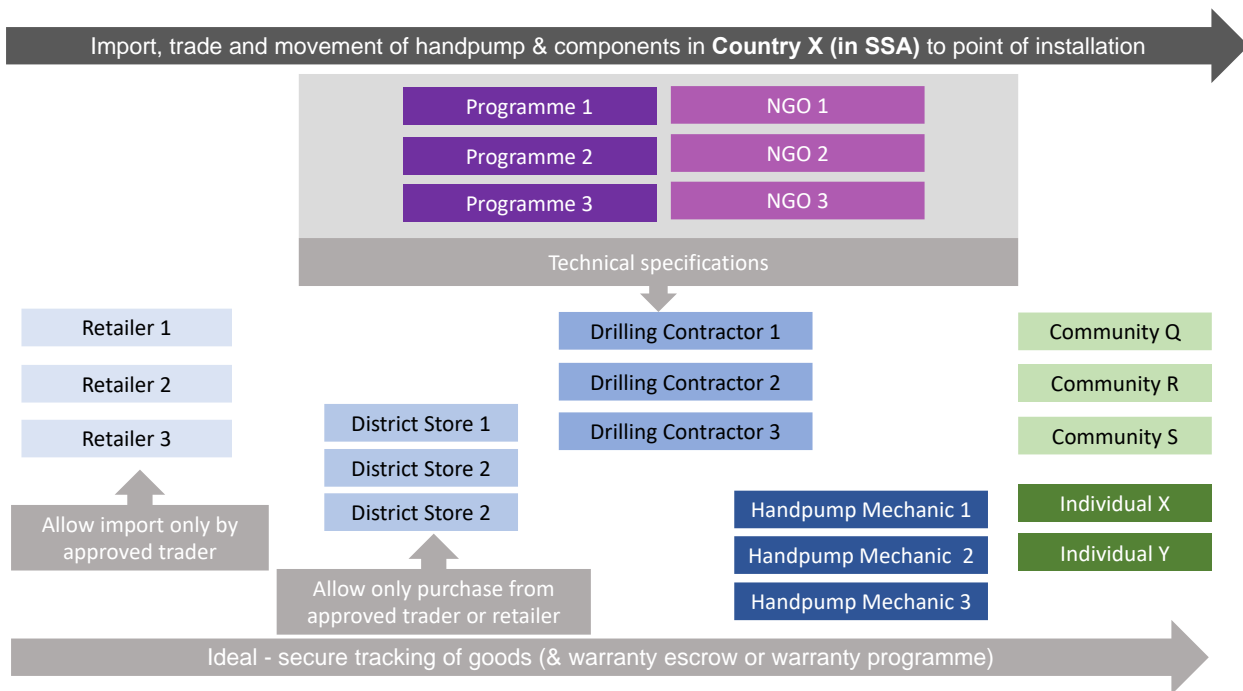


FIGURE 12: SCHEMATIC REPRESENTATION OF IDEAL HANDPUMP SUPPLY CHAIN – FROM IMPORT TO DISTRIBUTION IN COUNTRY X

6.3 MANUFACTURE AND ASSEMBLY IN INDIA

Manufacture of the India Mark and Afridev pumps is not subject to copyright. There are numerous companies in India selling these pumps, with manufacture clustered primarily around Hyderabad and Delhi (Interviewee, 2021). As an example, Table 6 lists 12 handpump suppliers that procured pumps for distribution into Malawi and/or Zambia in 2008, 2009 and 2011, indicating whether the manufacturers claim to be ISO and/or BIS certified). However, there are many more suppliers into SSA. The Indiamart website is one of the sales portals for the Afridev and India Mark pumps, providing links to dozens of handpump manufacturers.²⁷ There have been closures of factories in India that manufacture handpumps, attributed in part to reduced demand in the south of India due to a shift towards piped water supplies there (Anon, 2021b).

Concerns have been raised about manufacturers not adhering to standards with respect to several handpump components and cutting costs (Danert, 2022a; see also Table 1). Anonymous sources have alleged that some Indian-based companies assemble handpump orders for Africa from various sources, using materials that are of poor quality.²⁸ It has also been alleged that some companies hot dip their GI pipes four times while others only hot dip once. The latter are much more susceptible to rapid corrosion (Anscombe, 2021).

It has also been alleged that some handpump manufacturers will knowingly supply sub-standard materials, as illustrated by the example in Box 4. A similar story was shared by another organisation, which managed to improve the quality of components provided by the manufacturer following extensive dialogue with them (Anon, 2021). It has also been alleged that drillers can quote a reputable brand of handpump that only supply the rods and head assembly and install the pipes coming from other (inferior) sources (Anscombe, 2021). One of the drivers for poor quality is apparently the low prices that buyers are prepared to pay, which has in turn led to manufacturers cutting corners and an overall decline in quality (Anon, 2021b).

²⁷ Indiamart claims to be India’s largest online B2B marketplace, connecting buyers with suppliers: <https://www.indiamart.com/>.

²⁸ While concerns about substandard manufacture are largely anecdotal, some of the sales prices offered through the internet are so low that adhering to international specifications or Indian Standards does not seem feasible. India Mark II pumps are offered for as little as INR 3,000 – equivalent to US\$43 (Danert, 2019). While prices depend on depth and materials, a ballpark figure for an India Mark II (for an installation depth of 20 m and using GI pipes) purchased in India and adhering to BIS specifications would be around US\$260 (Anon, 2021b). Notably, the very low prices presented may simply be a tactic to attract customers, or they could be out of date.

TABLE 6 DOCUMENTED HANDPUMP MANUFACTURERS AND SUPPLIERS INTO MALAWI AND ZAMBIA

Country	Company name and website	Certification	Afridev	India Mark
India	AJAY Industrial Corporation* https://www.ajayindustrial.com ²⁹	ISO 9000; QS 9000	✓	✓
India	AOV International* http://www.aovinternational.net/	ISO 9009:2000	✓	✓
India	APEX International* https://www.apex-international.org/	ISO 14001:2015 CE Compliance certificate dated 21 April 2021 ³⁰	✓	✓
India	Balaji Industrial and Agricultural Castings (BIAC)* No company website found by the author in November 2021.	ISO 9001:2000	✓	✓
Kenya	Davies and Shirliff https://www.davisandshirliff.com/	ISO 9001: 2015 (D&S Tanzania)	✓	✓
India	Intec Tools (NTEC)* https://intec-tools.com/	Not mentioned		
India	MAYA Engineering Works* https://maya-engineering-works.business.site/	Not mentioned		
India	Meera & Ceiko Pumps Pvt. Ltd. http://www.meeragroup.com/Corporate.html	Not mentioned		
India	Span Pumps Private Ltd (SPAN)* https://spanpumpsindia.com	ISO 14001:2015 ³¹	✓	✓
India	Shree S.K. Industries http://skipumps.com/		✓	✓
India	Sai MMR Engineering Industries No company website found by the author in November 2021.	-		
India	Sukhsa Exports No company website found by the author in November 2021.	-		

* Noted by Anscombe (2011) as 'big brand names', which means (in theory) that all components are fabricated, machined and matched under a single factory roof.

Source: Adapted from MLGH, 2008; 2012; Sansom, 2009; Anscombe, 2011.

The BIS (2018) Product Manual for Deep Well hand pumps provides reference materials for BIS 'Regional/Branch Offices & licensees to ensure coherence of practice and transparency in operation of certification under Scheme-I of Bureau of Indian Standards (Conformity Assessment) Regulations, 2018 for various products' as well as 'prospective applicants desirous of obtaining BIS certification licence/certificate'. The manual includes a list of test equipment, and scheme of inspection and testing, including tests for: (i) raw material, components, subassembly and dimensions; (ii) assembly; (iii) workmanship; and (iv) anticorrosive treatment.

BOX 4 EXPERIENCE OF HANDPUMP PROCUREMENT IN SIERRA LEONE

Writing in the RWSN online forum, Norris (2019) reflected on experiences in Sierra Leone: 'There has been much criticism of NGOs installing poor quality galvanized pump components in corrosive water, but when you upgrade to much more expensive [stainless steel], there are still problems ... we started buying pump sets with Stainless Steel connecting rods from a local supplier ... [but later received] many reports of the pumps breaking down in the first few months. We ... found that the eyes on the connecting rods were cracking and breaking. We contacted the manufacturer in India and were told that the supplier we purchased from buys low quality [stainless steel] made from scrap metal. We asked ... about this and were told that no one will pay for the high quality so he does not stock it. We made a minimum purchase agreement ... so he would import the good quality for us. The quality is now very good with threaded joints instead of the hook & eye. We looked at the rods sold at other suppliers and found it was a very thin plating of stainless steel ... sometimes chipping off at the ends.'

²⁹ On its website, AJAY Industrial Corporation claims that 'Each product undergoes a prescribed range of tests based on standards under the supervision of our Quality Inspectors'.

³⁰ <http://www.aovinternational.net/certification-and-accreditation/>

³¹ The company website stated that the environment management system is in line with the ISO standards including deepwell handpumps; valid until July 2021: <https://spanpumpsindia.com/certificates-and-awards/#close> (accessed 7 March 2022)

This study has not examined the quality control mechanisms of Indian handpump manufacturers other than statements on some of the websites of the companies themselves (Table 6). Given the importance of quality control at point of manufacture (Box 3), there are a number of outstanding questions:

- What are the current requirements for marking handpump components as conforming to Indian Standards, and are they effective?
- What are the responsibilities of BIS in relation to public domain handpump manufacture in India, particularly the widely used India Mark and Afridev pumps? To what extent does BIS undertake and document its responsibilities, and what human resources are expended for this?
- Which factories are being inspected by BIS, how often, by whom, and is the information from inspections available to the public or to potential buyers? Are there examples of factories that have been requested to change procedures as a result of inspections?
- Are regulations such as the issuing of licences and certificates in India being enforced and, if so, how could this help to ensure quality of exports to SSA countries?
- Which SSA importers require pre-shipment inspection and is it effective? Is there any evidence of bribery or other forms of corruption in pre-shipment inspection and, if so, where it does exist?
- Are there any incentives to prevent low-quality handpumps and spares from being manufactured and exported from India to SSA?

6.4 PROCUREMENT

The example in Box 4 highlights that, for better or worse, procurement policies and practices drive the supply chain. The importance of a clearly defined purchase order is one of the five issues to be considered in quality assurance of handpumps (see Section 4). In a review of practices in Malawi, Anscombe (2011: 25) found very little in the way of specification for the handpump or specifically the riser pipes in the various contract documents, thus 'leaving the door wide open for substandard brands and components to invade Malawi'. This study has not been able to examine whether such practices are widespread, but the lack of inclusion of SS riser pipes in the Skat/RWSN specification or the BIS Standards (see Section 3) means that a 'clearly defined purchase order' cannot simply refer to this specification or standard, but rather needs to provide further technical details or rely on mutual understanding and trust of the manufacturer.

Good generic practices between buyers and sellers that can be applied to handpump procurement are summarised in Box 5. Additional aspects to consider are supplier documentation requirements (e.g. business registration, tax registration, ownership), adherence to codes of conduct, signing conflict of interest disclosure and anti-corruption policies. Box 5 portrays good practices between one buyer and multiple suppliers; however, in reality there are multiple buyers procuring handpumps from multiple sellers in any given country, as illustrated by the Zambia case study (Section 7). A key question is how to incentivise all buyers to uphold standards and assure quality.

Box 5 Good Procurement Practices

Buyers have responsibility to ensure that there is evidence of quality of: origin (source); manufacturer certification; stamping and labelling; written guarantee. They must also ensure that materials received are in accordance with all applicable international and national standards, codes and ordinances, and ensure proper documentation of all supplied materials, which can be subject to audit.

Suppliers are responsible for:

- Quality assurance of goods, including meeting the following criteria:
 - Be registered and certified by appropriate International, Regional or National Standards Authority or the authorised dealer (registered and certified)
 - Ensure that the quality and sustainability of materials meet the required standards
 - Check that all technical and quality specifications meet the standards
 - Provide evidence of quality by provision of documentation, analysis or certifications showing compliance of the goods requested
 - Ensure that the product quality is known and controlled
- Provision of the following records:
 - Manufacture references; certificates of analysis; certificates of conformity with specification; results of laboratory analysis test for quality; specified composition
- Supplier performance:
 - Inform the buyer of any risks, e.g. regarding safety, reliability or function
 - Support buyer to develop technical specifications if requested
 - Cover costs to replace products that do not adhere to standards

Source: Two anonymous development organisations.

7. CASE STUDY: ANALYSIS OF HANDPUMP SUPPLY CHAINS IN ZAMBIA

Zambia was selected as a case study country for this research due to its high dependence on groundwater point sources and handpumps in particular, which are estimated to provide 17% of the urban and 52% of the rural population with their main source of drinking water (Danert, 2022a). There is widespread use of public domain handpumps in the country, in particular the India Mark II, with an estimated asset base of over 20,000 handpumps.

7.1 CONTEXT, STANDARDISATION AND STANDARDS

Zambia's population had grown from an estimated 3 million at independence in 1964 to 18 million by 2020. The World Bank (2018) states that Zambia's high population growth is increasing demands for jobs, health care and other social services, which the economy is not able to provide. Economic inequality in Zambia is among the highest in the world and, in 2015, an estimated 57.5% of Zambia's population lived in extreme poverty³² (World Bank, 2021).

In 2015, an estimated 90% of urban and 53% of rural dwellers in Zambia (67% in total) had access to an improved drinking water supply as their main source (LCMS, 2015). The availability of groundwater and the boom in the drilling industry has brought boreholes within the reach of many private households, particularly those living in urban areas, which is also creating demand for handpumps by private individuals.

An estimated 36% of the rural population and 8% of the urban population rely on boreholes as their main source of drinking water supply (LCMS, 2015).



FIGURE 13 ADMINISTRATIVE MAP OF ZAMBIA

Source: Nations Online (n.d.).

The government adopted the India Mark II as the sole standardised pump for Zambia in the early 1990s (Sansom, 2009). This was in line with standardisations taking place in other countries, which were intended to simplify maintenance requirements and the provision of spares (MacArthur, 2015). Sansom (2009) reported that the government subsequently agreed to the installation of the Afridev in some areas of the country on certain projects. In addition, the Danish International Development Agency developed their own versions of specification of the India Mark II using SS riser pipes (Sansom, 2009). Sansom (2009) recommended that the Zambian standards department should review their handpump standardisation policy but this study has not been able to clarify whether this ever took place.

Interviewees³³ (2021) pointed out that Zambia may have backed itself into a corner by not diversifying from the India Mark II pump, particularly given the widespread rapid handpump corrosion issues in the country and recurrent rehabilitation, and they recommended that new options should be considered. It was suggested that a combination of the Afridev pump (for shallow groundwater) and solar pumps with PVC or high-density polyethylene (HDPE) riser pipes

³² Extreme poverty is defined by the World Bank as a person living on less than US\$1.90 a day.

³³ Reference to 'interviewees' in the rest of this section all refer to anonymised interviews conducted in 2021 for this study.

(for deeper groundwater) may be a more viable long-term solution for the country, as long as costs, spare parts and maintenance requirements were considered. Given the extent of pump breakage and rehabilitation in the country, it was suggested that more expensive pumps may actually be more cost-effective in the long term.

The government and co-operating partners in Zambia recognised the importance of handpump supply chain management, particularly that of spare parts, over 15 years ago and have undertaken noteworthy efforts to ensure that spares are available in every district, trying different models, and gaining considerable insight along the way. Currently, at district levels, spares may be stocked by local authorities (started by a stock used to build up a revolving fund) or the private sector. Three supply chain management manuals have been published since 2008 (MLGH, 2008; 2012; MWDSEP 2016) as well as a national operation and maintenance manual (MLGH, 2010). Although the manuals focus on supply chains within the country, they also list international and local suppliers, indicating that these should be converted into short lists of approved suppliers to be updated on an annual basis.

7.2 HANDPUMP PURCHASE

In Zambia, handpumps and spare parts are purchased by:

- National government (generally bought in bulk from India), including purchase for local authorities.
- Local authorities (sourced from within the country).
- UNICEF and NGOs (by supporting local partner NGOs, who purchase from in-country retailers or source the pumps through drilling contractors).
- Drillers (who purchase from in-country retailers or procure directly from abroad – usually, but not always India).
- In-country retailers, who are known to purchase from India, Malawi, Mozambique and South Africa, as well as local fabricators (of above-ground parts).
- Private individuals (for self-supply sources) to be installed at homes, and/or on farms. This includes returning professionals who are returning to their villages, or moving to rural areas to farm.
- ‘Invisible donors’ and philanthropists, particularly diaspora who support their family, or community.

Figure 14 illustrates the supply chain options available for handpump and spares purchase in Zambia for an NGO or individual engaging a drilling contractor.

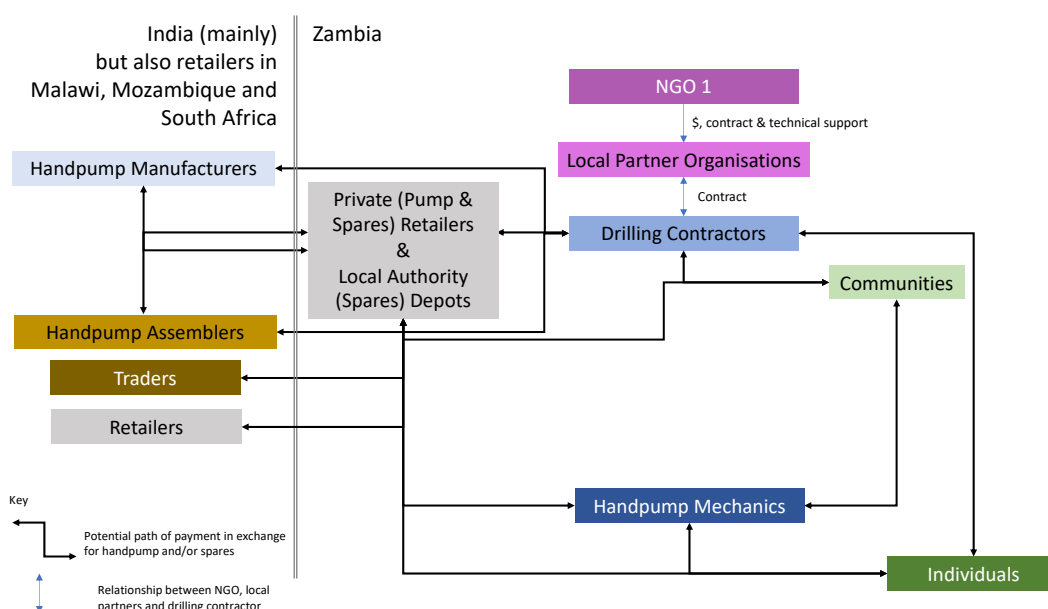


FIGURE 14: SIMPLIFIED REPRESENTATION OF HANDPUMP SUPPLY OPTIONS IN ZAMBIA

In the case of NGO-funded programmes, communities are donated a borehole and pump, which is generally bought and installed by the drilling contractor. Individuals tend to buy from a retailer or may rely on the drilling contractor. Individuals

and invisible donors are unlikely to have the skills and knowledge to determine a quality pump and may thus buy a cheaper and less robust model. Handpump mechanics may also play a role, particularly in the case of spare parts purchase.

7.3 IN-COUNTRY HANDPUMP SUPPLIERS

Broadly speaking, there are five categories of suppliers:

- Large suppliers based in the capital who may have outlets or dealers in other parts of the country. Some of suppliers specialise in complete handpumps only, rather than spares.
- Small private retailers in Lusaka and elsewhere, which may only deal in spare parts or in complete pumps. They may obtain their components from large suppliers in the country or elsewhere. There are cases of professionals from the water sector starting businesses in this field.
- Local authorities, which mainly deal in spares.
- Drilling contractors, who procure and supply handpumps in-country, or from overseas as part of their drilling contract.
- Local fabricators (apparently mainly of above-ground parts) who have entered the market in the last few years.

Without exception, all suppliers sell other goods (such as hardware, agricultural machinery, fuel) or provide services (such as drilling, construction and/or development). This is an important point as, being generalists, the suppliers are unlikely to have the technical knowhow on handpumps or detailed understanding of the international specifications, hence they may not be able to differentiate between good and poor-quality pumps.

Table 7 provides a list of the main handpump suppliers in Zambia, but it is not comprehensive. The 2012 Supply Chain Manual (MLGH, 2012) states that its list is to be converted into a shortlist of approved suppliers and must be updated at the end of every year for use in the following year.

TABLE 7 HANDPUMP SUPPLIERS IN ZAMBIA

Supplier name	Comments (where more information is readily available)
Also listed in the 2012 supply chains management manual (MLGH, 2012)	
African Brothers Corporation	Listed in the Sustainable Operation and Maintenance Programme (SOMAP) handbook as a Lusaka-based local supplier.
A F E Limited	
Simply Red Industrial and Agro Ltd	
SARO Agro Industrial Ltd	Leading supplier of agricultural equipment in Zambia, with (in 2021) six branches (Lusaka, Chipata, Kitwe, Choma, Livingston, Mongu and Mkushi) as well as about a dozen dealers throughout the country. ³⁴ Over the years, they have used a few suppliers from India – Meera Ceiko, AOV and Apex. ^a
Davis & Shirliff	Reported to be a limited supplier of handpumps in Zambia. ^a
Zambezi Drilling and Exploration	Listed in the SOMAP handbook as a Lusaka-based local supplier.
United Chemolide Industries Ltd	Was a significant handpump supplier until a few years prior to 2009. They are a big supplier of submersible pumps and cement. They were importing and supplying 2,000–3,000 pumps a year, for UNICEF and others until about 2005, but in 2009 were only selling 250 sets of India Mark II, mainly to MLGH. Ajay (AIC) were their main suppliers of their handpumps. ^a
Not listed in the 2012 supply chains management manual (MLGH, 2012)	
Star Drilling Service Limited	Listed in the SOMAP handbook as a Lusaka-based local supplier.
Aquagro Ltd	Reported to be limited supplier of handpumps in Zambia. ^a
China Jiangxi Corporation	Listed in the SOMAP handbook as a Lusaka-based local supplier.
AJAY	Mentioned by Interviewees (2021). The same company manufactures in India.

^a = Sansom and Koester, 2009

Source: MLGH, 2008; Sansom, 2009; Sansom and Koester, 2009; MLGH, 2012; Interviewee(s), 2021.

³⁴ In 2009, SARO Agro were selling in the order of 1,000 handpumps per year with 500–600 pumps in stock and 200–300 spares kits. Key customers included the MLGH and NGOs, such as Zambia Red Cross, Plan International, Care, World Vision, WaterAid, Oxfam and Village Water. Drilling companies also purchased their handpumps (Sansom and Koester, 2009).

Interviewees have noted the influx of drilling companies into the country over the years, many of which procure handpumps directly from India. They are an important source of handpump supply. In 2019, there were 105 registered drilling companies listed on the Water Resources Management Authority (WARMA) website.³⁵ The Zambian water well drilling industry is regulated by WARMA (Danert et al. 2022).

An example of a local private handpump and spares supply is in Choma and includes Choma Garage, African Builders, Farmer Roma and other small stores. Notably, these suppliers may not all have handpumps or spares in stock all of the time, but rather respond to local demand (Interviewee, 2021). Given the relatively slow turnover of spare parts, low rates of return and storage requirements, private enterprise has not flourished everywhere (Interviewee, 2021).

Thanks to efforts and learning through SOMAP over the years, there are handpump spare parts depots run by the local authorities in many districts of the country. They were all started with seed stock, to be used as revolving capital for spares. When they issue tenders for spare parts, the smaller retailers may respond, some of whom actually act as ‘middle-men’ procuring from other suppliers within the country. The national government, when implementing drilling programmes, may also issue tenders for large quantities of handpumps, which are more likely to be picked up by the larger suppliers.

However, interviewees stated that almost every district in the country now has an organisation that sells spare parts. Unfortunately, the quality of the spares is sometimes compromised, with inferior components on the market.

7.4 QUALITY ASSURANCE AND QUALITY

In 2009, most handpump purchases were paid for by donors or external support agencies, including UNICEF, with a continuing reliance on the quality assurance systems supported by those donors, such as third party inspections by recognised agencies (Sansom and Koester, 2009). The 2009 UNICEF commissioned handpump mapping study also concluded that: ‘As the Government of Zambia moves towards a [sector wide approach] there will be more in-country procurement of handpumps. The relevant government standards department will therefore need to take a more active role in procurement and [quality assurance] of handpumps, including independent inspections, if the use of sub-standard parts is to be avoided. As part of the decentralisation process, it is expected that District Councils will eventually do procurement. This will all require considerable amount of institutional strengthening’ (Sansom, 2009: 7).

In 2009, SARO Agro Industrial Ltd was the main local supplier in Zambia and was reported to rely on the quality systems of their suppliers, undertaking random check of spares when they arrived in Zambia (Sansom, 2009). If there were problems, they could return the components to the supplier in India. This is reported to still be the case today, with visits made to factories every one to two years (Interviewee, 2021). Another large in-country supplier, AJAY, is also an Indian manufacturer and so it is assumed that most, if not all, components are sourced from their own factory in India.

Interviewees explained that when undertaking bulk supply from India, the national government has procedures in place to control quality through factory inspections, although the effectiveness of such inspections was questioned by some. While there are inspection procedures for imported handpump components, which apparently can include laboratory testing, as well as procurement procedures, low-quality components do still cross borders to enter Zambia (Interviewees, 2021). It was pointed out that the Zambian Bureaus of Standards (ZABS) is under-resourced and not in a position to inspect all imports, may lack orientation and is not always present at all of the borders. A particular consignment may therefore not be checked at the border: ‘Once it has arrived in the country, it is too late’ (Interviewee, 2021). It was noted that smaller companies are more able to avoid procurement regulations when they purchase overseas. Five interviewees went as far to say that, in practice, there are actually no processes undertaken to assure the quality of handpump components coming into the country. Furthermore, there are no procedures in place to regulate up-and-coming local fabrication. Previously unknown brands of pump have also been observed in use. Interestingly, for solar pumps, all in-

³⁵ <http://www.warma.org.zm/information-center/download/>

country suppliers require a licence from the Energy Regulatory Board, although interviewees also questioned whether this is actually adhered to by smaller retailers.

At the local authority level, the Director of Works is responsible for quality control and ensuring that suppliers meet national criteria, including registration with various bodies. However, they may not have the resources, capacity or incentives to inspect fully, although they may check pumps on arrival to see if they meet the specifications.

In discussions it was noted that end inspection guidance for the India Mark pump in the specifications are very limited (see Section 4). Reflecting on end inspection by a local NGO, one interviewee listed the components that are checked and what is checked, explaining that these checks are based on experience and stories from others, rather than on a particular checklist. However, the understanding of buyers on what constitutes a quality handpump is generally extremely limited.

According to interviewees, international and local NGOs are obliged to adhere to the national procurement requirements. At least one international NGO has provided considerable technical support to local partners with respect to the procurement process for drilling contracts (which includes the pump). A technical on-site team supervises the work, but end inspection of handpumps does not seem to be fully documented. One interviewee questioned the extent to which organisations properly follow-up the paperwork noting that ‘if you are not the manufacturer, you cannot assure the quality’. Another believed that, particularly in the case of small contracts, NGOs may never see the pump before it is installed by the driller.

Interviewees explained that there is a range of component quality available on the Zambian market. In terms of poor quality, a number of specific components were mentioned and are listed below:³⁶

- Non-conformant ‘SS’ riser pipes that flake or change colour (and may be chrome plated rather than SS, with the chrome peeling off by the pipe wrenches). However, buyers can obtain quality ‘if you speak to the larger suppliers’.
- Poor-quality threads, and short threads on the pump rods.
- Headworks: non-standard water tanks, handle lengths and plates.
- Cylinder: caps not closed, rubbers (seals) not sitting properly or not sufficiently flexible.

In some cases, where poor-quality components are found, vendors are quite responsive. Discussions with interviewees about ways to improve the knowledge of buyers and installers of handpumps regarding the quality focused on simple written guidance and online videos. It was pointed out that while videos could provide a good option, these are unlikely to be accessible by area pump mechanics, most of whom currently do not have smart phones. However, good videos could add value to training courses.

7.5 PREVENTION OF RAPID CORROSION

For a synopsis of rapid corrosion and efforts to understand and address the issue, see Danert (2022b: Annex 2). Interviewees explained that some organisations and programmes are paying particular attention to aggressive groundwaters, including mandates to test pH levels coupled with the use of alternatives to GI for the India Mark II or, in some cases, the installation of an Afridev pump. Some programmes are replacing all GI pipes, regardless of pH, with SS, while others are using PVC. There are also cases of organisations installing a solar pump (with uPVC riser pipes) when the depth is too great for an Afridev. However, it was noted that Zambia does not seem to have fully assessed which type of pump is most suitable in which area and that organisations may ‘keep on doing the same things’ (Interviewee, 2021).

Interviewees further mentioned that there has been some resistance to the uptake of alternatives to GI riser pipes, but that NGOs operating in the country are gradually taking them up. Selection of SS and PVC seems to be largely undertaken between the buyers and suppliers, with varying quality on the market. In some cases, no pipe centralisers are installed with the PVC, which has been found to be problematic as the movement weakens the material and can lead to failure. Non-vertical boreholes are also problematic for PVC because of wear of bent pump rods. The importance of orienting

³⁶ Note that given the limited number of interviewees for the case study, that this is only a small sample.

contractors and area pump mechanics with respect to the different requirements for alternative (non-GI) installations was also emphasised (Interviewee, 2021).

The fact that SS and PVC options are not in the international standards has not helped with this change, and there are concerns that, in some cases, SS of inadequate quality or low grade (i.e. grade 304 rather than 316) or counterfeit 'SS' is being installed, which is also likely to be subject to rapid corrosion.

7.6 CONCERNS AND IDEAS

Interviewees raised a number of specific concerns about handpumps and handpump spares in Zambia:

- Abandonment of water points due to the use of GI in aggressive groundwater, resulting in rapid corrosion, and the installation of poor-quality components
- Corrosion of the cylinder lining, thin flanges, poor galvanising, poor welding, GI riser pipes not as strong as they should be, low weight GI pipes
- Tool sets available on the market which are not complete (according to Skat/RWSN specifications)
- Pump rods that come without locknuts, which seem to have a tendency to dislocate and snap
- Difficulties in regulation of handpump hardware quality in Zambia, 'which requires leadership by a competent authority'
- Challenges for communities to keep funds saved for handpump maintenance when there has not been a breakdown for a long time, coupled with difficulties for communities to obtain a bank account

In order to improve the situation, interviewees (2021) recommended the following:

1. To prepare a national map, illustrating which areas are subject to low pH, and thus risk handpumps with GI riser pipe and pump rods being rapidly corroded. This is in line with a recommendation in Report II (Danert, 2021b).
2. To ensure that the regulator is able to and indeed does regulate handpump quality, including certification of suppliers.
3. To find ways to enable those without the background skills and knowledge to be able to undertake simple, end inspection of handpumps.
4. To consider introducing the Afridev handpump as a standardised handpump for Zambia.
5. To significantly raise the capacity of buyers, local authorities, ZABS staff and handpump mechanics to recognise defects and identify good quality pumps.

8. CONCLUSIONS AND RECOMMENDATIONS

This report provides evidence of handpump quality problems in SSA. It highlights a plethora of quality concerns for many components, a lack of field data on handpump component lifetimes, weaknesses in the international specifications and Indian Standards, and gaps with respect to guidance for quality control. While a supply chain would ideally enable the tracing of the origin of goods and materials, and importation by certified vendors, the case study from Zambia illustrates that this is not the case. Instead, it is evident that there are numerous importers and retailers in operation and that regulation and quality control procedures, such as end inspections, are weak or non-existent. According to a small number of stakeholders interviewed, there are both high-quality and poor-quality handpumps available on the market and being installed. Capacity among buyers to tell the difference is limited.

Complementing the recommendations from Report II of the Stop the Rot initiative on rapid handpump corrosion (Danert, 2022b), this report recommends that:

- **RWSN, other global platforms and funding agencies** should:
 - Raise awareness and understanding of the important yet under-recognised issue of poor handpump quality with network members and (in the case of funding agencies) grantees.
 - Encourage organisations to produce user-friendly guidance in the form of illustrative manuals and videos for ensuring quality, including end inspection by buyers.
 - Document and share good procurement practices and feedback mechanisms, including evidence of their effectiveness.
 - Encourage investment in raising the capacity of handpump buyers (i.e. governments, drilling contractors, non-governmental organisations and private users) to identify key defects and quality in accordance with specifications and standards.
 - Undertake a study to document quality controls at point of manufacture and export from India, including the setting out of responsibilities and activities of the BIS and factory inspection, the issuing of licences and other incentives to ensure quality for export.
 - Encourage rigorous research on the expected service life of handpump components, with the results published and available in the public domain.
- **Lead international agencies** should establish an action group on handpumps (perhaps incorporating other groundwater lifting methods). In addition to the recommendations outlined in Report II (Danert, 2022b), the action group should provide a platform for exchange on mechanisms of improving handpump quality, and could include the issue of brass/bronze components containing high levels of lead. The action group force should also engage organisations that have been working (with very limited funding) to improve handpump design and ensure that handpump manufacturers and standards agencies are brought into dialogue to develop improvements.
- **Skat Foundation, which published the international specifications, or another suitable organisation** should:
 - Republish international handpump standard specifications to address errors and make them more accessible and searchable online.
 - Issue recommendations on alternatives to the India Mark handpumps with galvanised iron for areas where there is corrosive groundwater (especially low pH, salinity and chloride), including information regarding experiences, concerns and unknowns about these alternatives to date.
 - Develop detailed guidelines for end inspection of India Mark handpumps to include, for example, guidance around component weight and make reference to X-ray dispersive analysis, which is a standard test for measuring coating/plating composition and thickness and other mechanisms.
- **National governments** should:
 - Explore how to start or improve the regulation of handpump imports, in-country fabrication (if appropriate) and in-country supply chains, drawing on examples from other industries. Initiatives should be documented so that others can learn from them.

- Establish an effective feedback mechanism for communities and users to register their experiences of poor handpump quality and use this information in efforts to improve handpump quality.
- Ensure that rehabilitation programmes systematically collect data on the reasons behind handpump failure, including data on hardware problems such as – but not limited to – corrosion.

Explore asset management mechanisms that can incorporate expected component lifetime to support preventative and reactive maintenance programmes, thus helping to alleviate unrealistic burdens on communities.

REFERENCES

- Addis, G. and Moore, M.R. (1974) 'Lead levels in the water of suburban Glasgow'. *Nature* 252:120–21. <https://doi.org/10.1038/252120a0>
- Akers, D.B., MacCarthy, M.F., Cunningham, J.A., Annis, J. and Mihelcic J.R. (2015) 'Lead (Pb) contamination of self-supply groundwater systems in coastal Madagascar and predictions of blood lead levels in exposed children'. *Environmental Science & Technology* 49 (5): 2685–93. <https://doi.org/10.1021/es504517r>
- Anon (2020) Documentation on pre-delivery inspection undertaken by the Government of Zimbabwe.
- Anon (2021a) Documentation on pre-delivery inspection undertaken by the Government of Zimbabwe.
- Anon (2021b) Personal Communication [telephone] 15 December 2021; [email]. 15 January 2022.
- Anon (2022) Personal Communication [email]. 11 and 17 January 2022.
- Anscombe, J.R. (2011) 'Consultancy services: Quality assurance of UNICEF drilling programmes for boreholes in Malawi. Final Report.' UNICEF, Ministry of Agriculture, Irrigation and Water Development, Malawi. <https://www.rural-water-supply.net/en/resources/details/509> [accessed 1 March 2022].
- Anscombe, J. (2019a) [groundwater_rwsn] Problem with Stainless Steel Handpump Components [online]. RWSN Sustainable Groundwater Development, 5 April. https://dgroups.org/rwsn/groundwater_rwsn [accessed 15 October 2021].
- Anscombe, J. (2019b) [groundwater_rwsn] Problem with Stainless Steel Handpump Components, [Online] RWSN Sustainable Groundwater Development, 1 May 2019, https://dgroups.org/rwsn/groundwater_rwsn [accessed 15 October 2021].
- Anscombe, J. (2021) Personal Communication [email]. 16 June 2021.
- Arlosoroff, S., Tschannerl, G., Grey, D., Journey, W., Karp, A., Langenegger, O. and Roche, R. (1987) *Community Water Supply: The Handpump Option*. Washington, DC: World Bank.
- Baumann, E. (1998) 'Handpump technology input to the joint review of the Rural Water Supply and Sanitation Eastern Uganda Project: RUWASA Phase IIA' [online]. Skat/RWSN, St Gallen, Switzerland: <https://www.rural-water-supply.net/en/resources/details/418> [accessed 28 October 2016].
- Baumann, E. (2009) 'May-day! May-day! Our handpumps are not working!'. Perspectives No. 1, RWSN, St Gallen, Switzerland.
- Baumann, E. (2011) 'Low cost handpumps'. RWSN Field Note 2011-3, St Gallen, Switzerland.
- Baumann, E. and Furey, S.G. (2013) 'How three handpumps revolutionised rural water supplies. A brief history of the India Mark II/III, Afridev and the Zimbabwe Bush Pump'. Field Note No. 2013-1, RWSN, St Gallen, Switzerland. <https://www.rural-water-supply.net/en/resources/details/475> [accessed 15 February 2022].
- Baumann, E., Montanegro, A., Sutton, S. and Erpf, K. (2010) 'WASH technology information packages – for UNICEF WASH programme and supply personnel'. UNICEF and Skat.
- Beers, A.Q., Vader, D.T., Van Dyke, T.V. and Whitmoyer, T.B. (2013) 'India MKII Pump sustainability study report (Phase I)'. Produced for World Vision Africa WASH Learning Center, Messiah College, Grantham, PA.
- BIS (2004) *Indian Standard Deepwell Handpumps, Components and Special Tools – Specification*. New Delhi: Bureau of Indian Standards.
- BIS (2018) *Product Manual for Deep Well Hand Pumps according to IS 15500 (Part 2): 2004, PM/ IS 15500 (Part 2)/1*. New Delhi: Bureau of Indian Standards.
- Burr, P. and Fonseca, C. (2013) 'Applying a life-cycle cost approach to water'. IRC International Water and Sanitation Centre. https://www.ircwash.org/sites/default/files/20130208_8_wp_water_web_2.pdf [accessed 5 November 2021].

- Carter, R.C. and Guo, W.J. (2021) 'Handpumps in South Sudan: Sub-standard GI riser pipes and acidic groundwaters'. On behalf of Tearfund Netherlands, UK and South Sudan; and Richard Carter and Associates Ltd, UK.
- Clark, B.N., Masters, S.V. and Edwards, M.A. (2015) 'Lead release to drinking water from galvanized steel pipe coatings'. *Environmental Engineering Science* 32 (8). <https://doi.org/10.1089/ees.2015.0073>
- Danert, K. (2022a) 'Stop the Rot Report I: Handpump reliance, functionality and technical failure. Action research on handpump component quality and corrosion in sub-Saharan Africa'. Ask for Water GmbH, Skat Foundation and RWSN, St Gallen, Switzerland.
- Danert, K. (2022b) 'Stop the Rot Report II: Rapid corrosion of handpumps. Action research on handpump component quality and corrosion in sub-Saharan Africa'. Ask for Water GmbH, Skat Foundation and RWSN, St Gallen, Switzerland.
- Danert, K., Adelike, D., Malik, M., Museteka, L. and Abuuru, D. (2022) 'Achievements and lessons learned in the implementation of groundwater regulation in Zambia'. Water Resources Management Authority, Lusaka. <https://www.rural-water-supply.net/en/resources/details/1040> [accessed 28 February 2022].
- Driscoll, F. (1985) *Groundwater and Wells*. 2nd ed. St Paul, MN: Johnson Division.
- Erpf, K. (2007) 'Quality control (Training Modules 1–3)'. Skat, RWSN, St Gallen, Switzerland. <https://www.rural-water-supply.net/en/resources/details/300> [accessed 4 August 2021].
- Fisher, M.B, Guo, A.Z., Tracy, J.W., Prasad, S.K., Cronk, R.D., Browning, E.G., Liang K.R, Kelly E.R. and Bartram, J.K. (2021) 'Occurrence of lead and other toxic metals derived from drinking-water systems in three West African countries'. *Environmental Health Perspectives* 129 (4). <https://doi.org/10.1289/EHP7804>
- Franceys, R. and Pezon, C. (2010) 'Services are forever: The importance of capital maintenance (CapManEx) in ensuring sustainable WASH services'. IRC WashCost Briefing Note 1b; IRC International Water and Sanitation Centre, The Hague.
- Furey, S.G. and Danert, K. (2022) 'Stop the Rot – Groundwater pumping survey 2021. Summary of findings'. Skat Foundation, Ask for Water GmbH and RWSN, St Gallen, Switzerland.
- Government of Zimbabwe. (2013) *Bush Pump – Zimbabwe Standard Specification*. SAZY 881:2013, Harare. https://www.rural-water-supply.net/ressources/documents/default/BUSH-Pump_Specifications_Ed-2004.pdf [accessed 26 July 2021].
- Hankin, P. (2001): 'The Afridev handpump – problems and solutions'. Paper presented at the 27th WEDC Conference, Lusaka, Zambia, 20–24 August. <https://hdl.handle.net/2134/28697> [accessed 1 March 2022].
- Harvey, P.J, Handley, H.K. and Taylor, M.P. (2016) 'Widespread copper and lead contamination of household drinking water, New South Wales, Australia'. *Environmental Research* 151: 275–85. <https://doi.org/10.1016/j.envres.2016.07.041>
- Hutton, G. and Varughese, M (2016) 'The costs of meeting the 2030 Sustainable Development Goal targets on drinking water, sanitation and hygiene'. Water and Sanitation Program Technical Paper, World Bank Group, Washington, DC.
- Interviewee(s) (2021) Interviewees for the case study on the Handpump Supply Chain in Zambia. All interviewees have been kept anonymous.
- Inter Aide Sierra Leone (no date) 'India Mark 2 Guideline'.
- ICC (2017) '2018 International Plumbing Code (IPC)' [online]. <https://codes.iccsafe.org/content/IPC2018P5> [accessed 1 March 2022].
- ISO (no date (a)) 'ISO 426-1:1983 Wrought copper-zinc alloys — Chemical composition and forms of wrought products — Part 1: Non-lead and special copper-zinc alloys' [online]. <https://www.iso.org/standard/4436.html> [accessed 28 February 2022].

- ISO (no date (b)) 'ISO 426-2:1983 Wrought copper-zinc alloys — Chemical composition and forms of wrought products — Part 2: Leaded copper-zinc alloys' [online]. <https://www.iso.org/standard/4437.html> [accessed 28 February 2022].
- ISO (2017) 'Sampling procedures for inspection by attributes — Introduction to the ISO 2859 series of standards for sampling for inspection by attributes' [online]. <https://www.iso.org/obp/ui/#iso:std:iso:28590:ed-1:v1:en> [accessed 26 July 2021].
- Järup, L. (2003) 'Hazards of heavy metal contamination'. *British Medical Bulletin* 68: 167–82, <https://doi.org/10.1093/bmb/ldg032>
- Kimbrough, D.E. (2007) 'Brass corrosion as a source of lead and copper in traditional and all-plastic distribution systems'. *Journal of American Water Works Association* 99 (8):70–6. <https://doi.org/10.1002/j.1551-8833.2007.tb08008.x>
- LCMS (2015) 'Living conditions and monitoring survey 2015 data'. In WHO/UNICEF (2019) 'Joint Monitoring Programme for Water Supply, Sanitation and Hygiene: Estimates on the use of water, sanitation and hygiene in Zambia'. World Health Organisation and UNICEF. <https://washdata.org/data/household#!/> [accessed 1 March 2022].
- Maas, R.P., Patch, S.C., Morgan, D.M. and Pandolfo, T.J. (2005) 'Reducing lead exposure from drinking water: Recent history and current status'. *Public Health Reports* 120 (3): 316–21. <https://doi.org/10.1177/003335490512000317>
- MacArthur, J. (2015) 'Handpump standardisation in sub-Saharan Africa: Seeking a champion'. RWSN Publication 2015-1, RWSN, St Gallen, Switzerland. <https://www.rural-water-supply.net/en/resources/details/652> [accessed 15 February 2022].
- MLGH (2008) *Supply Chain Management Manual for Rural Water Supply*. Ministry of Local Government and Housing, Lusaka: Republic of Zambia.
- MLGH (2012) *Supply Chain Management Manual, 2nd Edition*. Ministry of Local Government and Housing, Lusaka: Republic of Zambia.
- MWDSEP (2016) Rural Water Supply and Sanitation (RWSS) Operation and Maintenance (O&M) Implementation Manual and Users Guide, Republic of Zambia Ministry of Water Development, Sanitation and Environmental Protection
- Morgan, P. (2010) 'The Zimbabwe Bush Pump inspection of the "B" type Bush Pump part 2. "Down the hole" components. Inspection Manual'. Aquamor Pvt Ltd, Harare. <https://www.rural-water-supply.net/en/resources/details/444> [accessed 26 July 2021].
- Morgan, P. (2012a) 'Practical guidelines for the inspection of the Zimbabwe "B" type Bush Pump. Geometry and preliminary inspection'. Aquamor Pvt Ltd, Harare. <https://www.rural-water-supply.net/en/resources/details/447> [accessed 26 July 2021].
- Morgan, P. (2012b) 'The Zimbabwe Bush Pump inspection of the "B" type Bush Pump part 1. The pump head. Inspection Manual'. 2nd Edition, Aquamor Pvt Ltd, Harare. <https://www.rural-water-supply.net/en/resources/details/444> [accessed 26 July 2021].
- Morgan, P. (2012c) 'The Zimbabwe Bush Pump ("B" type): Useful templates and tools for examining the pump head'. Aquamor Pvt Ltd, Harare. <https://www.rural-water-supply.net/en/resources/details/987> [accessed 26 July 2021].
- Mudgal, A.K. and Kumar, S. (1992) 'Afridev: Packaging guidelines for Afridev'. Skat/UNDP/WSP, St Gallen, Switzerland. <https://rural-water-supply.net/en/resources/details/322> [accessed 28 July 2021].
- Mwathunga, E., Fallas, H.C., MacAllister, D.J., Mkandawire, T., Makuluni, P., Shaba, C., Jumbo, S., Moses, D., Whaley, L., Banks, E., Casey, V. and MacDonald, A.M. (2019) 'UPGro Hidden Crisis Research Consortium. Technical report – Malawi'. British Geological Survey Open Report, OR/19/057.

- Nations Online (no date) 'Administrative map of Zambia' [online]. <https://www.nationsonline.org/oneworld/map/zambia-administrative-map.htm> [accessed 1 March 2022].
- Nielsen, W.D. (no date) 'Metallurgy of copper-base alloys' [online]. Copper Development Association Ltd. https://www.copper.org/resources/properties/703_5/ [accessed 28 February 2022]
- Norris, K. (2019) [groundwater_rwsn] Problem with Stainless Steel Handpump Components, [Online] RWSN Sustainable Groundwater Development 5 April 2019, Available from https://dgroups.org/rwsn/groundwater_rwsn [accessed 26 July 2021].
- Owor, M., Fallas, H.C., Macallister, D.J., Okullo, J., Katusiime, F., Berochan, G., Whaley, L., Banks, E., Casey, V. and Macdonald, A.M. (2019) 'Physical factors contributing to rural water supply functionality performance in Uganda'. British Geological Survey, OR/19/056 (unpublished).
- Oyo, A. (2006) 'Spare part supplies for handpumps in Africa: Success factors for sustainability'. Rural Water Supply Series Field Note, RWSN/WSP, Nairobi, Kenya / St Gallen, Switzerland.
- Pieper, K.J., Tang, M. and Edwards, M.A. (2017) 'Flint water crisis caused by interrupted corrosion control: Investigating "ground zero" home'. *Environmental Science & Technology* 51 (4): 2007–14. <https://doi.org/10.1021/acs.est.6b04034>
- Plastics News (2013) 'China's PVC pipe makers under pressure to give up lead stabilizers' [online]. <https://www.plasticsnews.com/article/20130906/NEWS/130909958/china-s-pvc-pipe-makers-under-pressure-to-give-up-lead-stabilizers> [accessed 6 May 2021].
- Prakash, G. and Erpf, K. (2000) 'Afridev: Guidelines for quality control and quality assurance of Afridev handpump. (Revision 1-2000)'. Skat / SGS India Ltd., RWSN, St Gallen, Switzerland.
- Polak, S. and Nabasiye, L. (2021) 'Piloting a new variant of the India Mk2 handpump to combat widespread corrosion problems and improve maintainability'. Poster, 42nd WEDC International Conference, 13–15 September.
- Rauh, V.A. and Margolis, A.E. (2016) 'Research review: Environmental exposures, neurodevelopment, and child mental health—new paradigms for the study of brain and behavioral effects'. *The Journal of Child Psychology and Psychiatry* 57 (7): 775–93. <https://doi.org/10.1111/icpp.12537>
- RWSN (no date (a)) 'Afridev Handpump – old specification versions' [online]. <https://www.rural-water-supply.net/fr/ressources/details/922> [accessed 1 March 2022].
- RWSN (no date (b)) 'Bush Pump inspection videos – Peter Morgan/Aquamor' [online]. <https://www.rural-water-supply.net/en/training-research/bush-pump-inspection> [accessed 2 August 2021].
- Salmon, T. (2022) Personal Communication [email]. 13 January 2022.
- Sanders, T., Liu, Y., Buchner, V. and Tchounwou, P.B. (2009) 'Neurotoxic effects and bio-markers of lead exposure: A review'. *Reviews on Environmental Health* 24 (1): 15–45. <https://doi.org/10.1515/reveh.2009.24.1.15>
- Sansom, K. (2009) 'Africa handpump market study, draft country report: Zambia'. Unpublished Report, Delta Partnership, Leeds, UK.
- Sansom, K. and Koestler, L. (2009) 'African handpump market mapping study'. Summary Report for UNICEF WASH Section and Supply Division. https://wedc-knowledge.lboro.ac.uk/resources/pubs/Handpump_market_study_summary_report.pdf [accessed 28 February 2022].
- Skat/HTN (1999) 'Afridev: Handpump specification: Injection moulding manual (Revision 1-1999)'. Skat, RWSN, St Gallen, Switzerland. <https://rural-water-supply.net/en/resources/details/319> [accessed 28 July 2021].
- Skat/HTN (2003) 'Afridev: Moulds for Afridev rubber components (technical drawings) (First Edition 2003)'. Skat, RWSN, St Gallen, Switzerland. <https://rural-water-supply.net/en/resources/details/321> [accessed 28 July 2021].

- Skat/RWSN (2007a) 'Afridev handpump specification revision 5-2007'. Skat, Swiss Resource Centre and Consultancies for Development and RWSN, St Gallen, Switzerland. <https://www.rural-water-supply.net/en/resources/details/318> [accessed 13 January 2022].
- Skat/RWSN (2007b) 'India Mark handpump specifications (Revision 2-2007) v.2'. RWSN/Skat, St Gallen, Switzerland. <https://www.rural-water-supply.net/en/resources/details/327> [accessed 1 March 2022].
- Skat/RWSN (2007c) 'Installation & maintenance manual for the Afridev handpump (Revision 2 2007)'. Skat, RWSN, St Gallen, Switzerland. <https://www.rural-water-supply.net/en/resources/details/286> [accessed 13 January 2022].
- Skat/RWSN (2008a) Afridev: Handpump with Bottom Support System. (Revision 1-2008), Skat, RWSN, St Gallen, Switzerland. <https://rural-water-supply.net/en/resources/details/317> [accessed 28 July 2021].
- Skat/RWSN (2008b) 'Guidelines for quality control and quality assurance of Afridev handpump, revision 2-2008'. Skat/SGS, RWSN, St Gallen, Switzerland. <https://www.rural-water-supply.net/en/resources/details/326> [accessed 4 August 2021].
- Skat/RWSN (2008c) 'Installation & maintenance manual for the India Mark II handpump (Edition 2008)'. Skat and RWSN, St Gallen, Switzerland. <https://www.rural-water-supply.net/en/resources/details/328> [accessed 14 January 2022].
- Tam, Y.S. and Elefsiniotis, P. (2009) 'Corrosion control in water supply systems: effect of pH, alkalinity, and orthophosphate on lead and copper leaching from brass plumbing'. *Journal of Environmental Science and Health* 44 (12): 1251–60. <https://doi.org/10.1080/10934520903140009>
- Truslove, J.P., Miller, A.V.M., Mannix, N., Nhlema, M., Rivett, M.O., Coulson, A.B., Mleta, P. and Kalin, R.M. (2019) 'Understanding the functionality and burden on decentralised rural water supply: Influence of Millennium Development Goal 7c coverage targets'. *Water* 11 (3): 494. <https://doi.org/10.3390/w11030494>
- UNICEF and GRZ (2017) 'Consultancy services to conduct sustainability check for water and sanitation program (WASH) UNICEF programme'. 2016 Sustainability Assessment, UNICEF and the Government of the Republic of Zambia.
- Vergnet Hydro (2021) 'Vergnet Hydro' [online]. <https://www.vergnet-hydro.com/vh/en/100-000eme-pompe-vergnet-hydro-en-2015/> [accessed 18 October 2021].
- WaterAid (2021) 'Handpump improvement project: Assessing the impact of Installation of "Poldaw" PVC pump risers in Masindi District'. Unpublished Report.
- WEDC (2019) 'Handpumps – An Overview: Part 4b of 6 – The Afridev' [online]. <https://www.youtube.com/watch?v=gRRwAeUUwhU> [accessed 2 August 2021].
- WHO (2017) *Guidelines for Drinking-Water Quality*. Fourth edition incorporating the first addendum, WHO.
- World Bank (1996) *Hardware Elements of Handpump Technology: Field Experience and Views of the Future*. Washington, DC: World Bank.
- World Bank (2018) 'Republic of Zambia Systematic Country Diagnostic'. Report No. 124032-ZM, Washington, DC. <https://documents1.worldbank.org/curated/en/290011522954283481/pdf/Zambia-SCD-March-29-Final-04022018.pdf> [accessed 11 June 2021].
- World Bank (2021) 'World development indicators' [online]. <https://datacatalog.worldbank.org/dataset/world-development-indicators> [accessed 12 May 2021].

ANNEX 1 BRIEF DESCRIPTION OF THE PUMPS COVERED BY THIS STUDY

AFRIDEV PUMP

The Afridev is a conventional lever action handpump designed for heavy-duty use, serving communities of up to 300 persons. The maximum recommended lift is 45 m. The Afridev pump is a public domain pump defined by the Skat/RWSN (2007a) Specification. The pump is considered to be corrosion resistant with potential for community-based maintenance. The specification recommends an alternative composition of brass for the cylinders in corrosive waters (citing high chloride content as an example).

INDIA MARK HANDPUMPS

The India Mark II is a robust conventional lever action handpump designed for heavy-duty use, serving communities of 300 persons. The maximum recommended lift is 50 m. The India Mark II pump is not corrosion resistant and requires special skills for installation and maintenance; it is not considered as being maintained at village level.

The India Mark III has similar configurations as the India Mark II, with different 'down-hole components' designed to enable more maintenance at village level. The most important improvement is the 'open top cylinder', which makes it possible to remove the plunger and also the foot valve without lifting the cylinder and the entire rising main.

ZIMBABWE BUSH PUMP

The Bush Pump is a robust conventional lever action handpump developed and standardised in Zimbabwe (Government of Zimbabwe, 2013). It is designed for heavy-duty use, serving communities of 300 persons. Three different cylinders are available, with the smallest one extending the range to a maximum recommended lift of 80 m. The Bush Pump is not considered to be highly corrosion resistant as it uses GI riser pipes and pump rods. It requires special skills for installation and maintenance. A unique feature of the Bush Pump is that it is wholly manufactured within Zimbabwe. V&W Engineering and Metropole Investments Ltd are two of the main manufacturers.

ANNEX 2 HANDPUMP STANDARDS AND RAPID CORROSION

AFRIDEV AND CORROSION

With the use of SS or fibreglass reinforced plastic pump rods, the Afridev pump was conceived from the outset to be corrosion resistant³⁷ and tends to be considered as a corrosion-resistant pump. However, the specification (Skat/RWSN, 2007a) includes an arrangement with GI (specified as mild steel hot dip galvanised to ISO 1461) (Figure A2.1). This arrangement will rapidly corrode when installed in aggressive groundwater (primary low pH, high salinity or high chloride). The RWSN/Skat specification (Skat/RWSN, 2007a: 11) states that that hot dip galvanised pump rods can be used in waters with a pH value greater than 6.5.

The specification also states that there are other important factors (apart from pH) that can influence corrosion, with no further details. It is very easy to overlook this statement, which it at the end of a list of components.

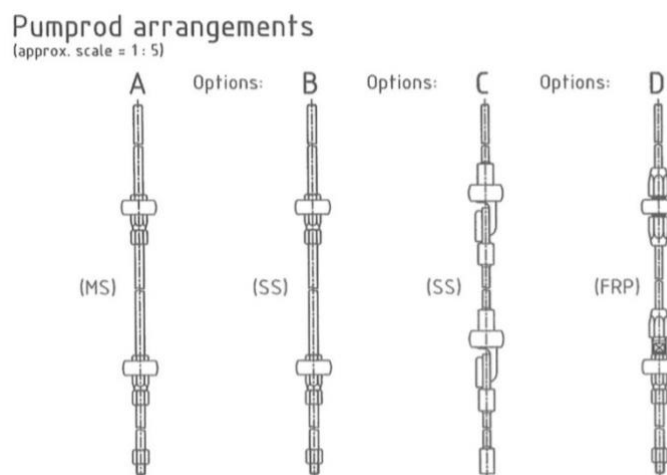


FIGURE A2.1 PUMP ROD ARRANGEMENTS FOR THE AFRIDEV

Source: SKAT/RWSN, 2007.

Note: MS = MILD STEEL; SS = STAINLESS STEEL; FRP = FIBRE-GLASS REINFORCED PLASTIC

INDIA MARK HANDPUMPS AND CORROSION

Within the section on hot dip galvanising, the International Specification notes the following: 'Hot dip galvanised pump rods can be used in water with a pH value greater than 6.5 (Note: there are other parameters that can also influence corrosion). In all other cases, Stainless Steel rods should be used' (Skat/RWSN, 2007b: 12). It is very easy to overlook this statement as it is placed at the end of a list of components.

If the India Mark is installed in aggressive groundwater, the current alternatives to GI are SS or PVC riser pipes, with SS pump rods. To prevent galvanic corrosion of the water tank, a rubber gasket has been recommended to isolate the two dissimilar metals (Baumann, 1998). There is also a fully brass cylinder option to prevent galvanic corrosion of the cast iron (Baumann, 1998) and a SS version of the cylinder (referred to in Nigeria as Sovema after the manufacturer that produces them). However, neither the international specifications nor the Indian standard offers comprehensive recommendations for what to install in aggressive groundwater. Only partial solutions are available, such as:

- SKAT/RWSN (2007b) includes a SS option for the pump rod but only GI option for the riser pipe.
- BIS (2004) includes a SS option for the pump rod but only GI for the riser pipe.
- Neither standard mentions PVC as a riser pipe option.

³⁷ Corrosion resistance, in this case, refers to resistance to rapid corrosion, as discussed in more detail in Danert (2021b).

ANNEX 3 LEAD IN HANDPUMP SOURCES AND COMPONENTS

STUDY FINDINGS

The first known multi-country study of toxic metals in the drinking water of low- and medium-income countries sampled the water quality for 261 community water systems (handpumps and public taps) for lead in Ghana, Mali and Niger, and tested the components of a subset of 61 from Ghana and Mali (Fisher et al., 2021). The samples taken are not nationally representative, but the study found that for the handpump sources 15 out of 156 (9.6%) water samples contained lead levels above the WHO guideline of 10 µg/l, with two sources having very high levels at 210 and 935 µg/l. Analysis of scrapings from pump spouts, rising mains, pump rods and the foot valve, as well as tap spouts as set out in the supplementary material to the paper, shows:

- Very high lead fractions (14.8–52.9%) in all 15 brass foot valves sampled.
- Indications of lead within 14 out of 15 plastic rising mains tested. However, due to the fact that the test procedures work best for metals, these mass fractions figures should be considered with caution.³⁸ More research is required in this regard.
- In the case of brass taps, levels were lower (0.01–8.9%) but 12 out of 15 were above the IPC guideline.

The study by Fisher et al. (2021) suggests that the source of lead is the brass components and raises concerns about the quality of the brass used in the manufacture of the taps and handpump foot valves. Lead is sometimes incorporated into brass to improve its machinability (Maas et al. 2005) and may be released as such components corrode (Kimbrough 2007; Tam and Elefsiniotis, 2009). Fisher et al. (2021) found that drinking water from systems with identified brass components was predicted to have 3.8 times the lead than for those with none. The study concluded that the corrosion of components with lead in excess of the IPC guidance is a major source of lead contamination, contributing to lead in excess of WHO drinking-water guidelines in 5–10% of first-draw water examples.

However, one manufacturing expert consulted for this study questioned these findings, doubting the brass percentage numbers for lead: ‘I could envisage up to around 10% lead possibly, but figures of 24 % to 50% are really not plausible. There is no reason to put that much lead into brass, and lead costs more than zinc’ (Anon, 2021a). Lead can also leach into water from galvanised pipes, with the lead in zinc coating ranging from non-detectable to 2% depending on manufacturer and fitting type (Clark et al., 2015).

SKAT/RWSN – INDIA MARK II

The Skat/RWSN (2007b) standard for the brass liner is ISO 426-1 (CuZn37) whereas the other brass components are ISO 426-2 (CuZn38Pb4). While the liner is lead free, the other components are specified to contain between 3.5–4.5% of lead by weight, which is above the IPC standard of 0.25%.

The ISO standards for both of these materials (i.e. part 1: non-lead and special copper-zinc alloys – ISO 426-1; and part 2: leaded copper zinc alloy – ISO 426-2:1983) were actually withdrawn in March 2000 (ISO, n.d(a); n.d.(b)).

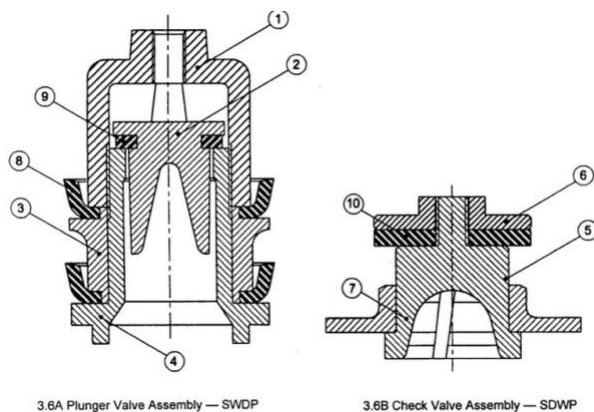
DEEPWELL HANDPUMPS (COMMONLY KNOWN AS MARK II)

The Bureau of Indian Standards (BIS, 2004) specifications for brass and bronze³⁹ components are:

³⁸ Estimating lead fraction for polymer materials was challenged by the fact that the digestion procedures that work best for metal components do not necessarily fully digest plastic components. Where we report elevated lead in a plastic/polymer/PVC component, this is a measure of what was extracted or digested from the component, but may exclude residual material that could not be fully digested or extracted. In other words, occurrence of high lead is meaningful, but the lead mass fractions for plastic samples may be less precise weight/weight measures than those for metal components in the study and should thus be taken as indicative of what might be leached from a component over time, rather than a precise mass fraction. Other methods are available to quantify lead or other toxic metals in PVCs and other polymers more precisely (Fisher et al., 2021).

³⁹ Skat/RWSN (2007b) specifications refer to brass, whereas BIS (2004) specifications refer to brass and bronze. Brass is an alloy composed of copper and zinc, whereas bronze is copper and tin.

- Part I General:
 - 5.4 Brass – ‘The brass tube used for cylinder lining shall conform to grade Cu Zn As of IS 407 and shall be temper annealed’.
 - 5.5 Bronze
 - ‘5.5.1 Bronze casting shall confirm to Grade LTB 2 of IS 318 with hardness 55 HB, *Min.* Alternatively Naval Brass conforming to IS 6912 can be used to forge the components’.
- Part 3 Handpump sub-assemblies:
 - Valve assemblies and materials (Figure A3.1)



10	1	Check Valve Seating — Standard	Fig. 7.7	Nitrile Rubber	5.6 of Part 1
9	1	Upper Valve Seating	Fig. 7.6	Nitrile Rubber	5.6 of Part 1
8	2	Pump Bucket — Standard	Fig. 7.1	Nitrile Rubber	5.6 of Part 1
7	1	Check Valve Seat — Standard	Fig. 6.12	Bronze	Grade LTB2 of IS 318
6	1	Rubber Seat Retainer	Fig. 6.11	Bronze	Grade LTB2 of IS 318
5	1	Check Valve — Standard	Fig. 6.9	Bronze	Grade LTB2 of IS 318
4	1	Follower — SDWP	Fig. 6.6	Bronze	Grade LTB2 of IS 318
3	1	Bucket Spacer — Standard	Fig. 6.4	Bronze	Grade LTB2 of IS 318
2	1	Upper Valve	Fig. 6.3	Bronze	Grade LTB2 of IS 318
1	1	Plunger Yoke Body	Fig. 6.2	Bronze	Grade LTB2 of IS 318
Part No.	No. Off	Description	Reference	Material	

NOTE — Check valve assembly to be punch locked on top at M10 joint at diametrically opposite two points after filing the two surfaces even.

FIGURE A3.1 DEEPWELL HAND PUMP VALVE ASSEMBLIES

Source: BIS, 2004.

The materials specifications that include lead are:

- The maximum lead content (chemical composition) of the brass tube (grade Cu Zn As of IS 407) is 0.07% (BIS, 1981b), which is within the standards of the international plumbing code of maximum 0.25% lead by weight.
- Grade LTB 2 of IS 318 is the standard for ‘leaded tin bronze ingots and castings’ (BIS, 2081a) and has 4–6% lead by weight, which for the Skat/RWSN (2007b) standards, does not conform the international plumbing code of maximum 0.25% lead by weight.
- Naval brass is mentioned in Part 1 of the standards but is not specified within any of the drawings. Naval brass (BIS, 2006) contains 0.2% chemical composition of lead, which is within the standards of the international plumbing code of maximum 0.25% lead by weight.

Part 1 and 5.5.2 states that bronze castings shall be free from lead segregation. This concerns the manufacturing process. According to Nielsen (n.d.), severe lead segregation⁴⁰ may occur in alloys where lead content approaches 16%.

⁴⁰ Leaded coppers undergo a two-step solidification process whereby ‘the copper fraction (pure copper or high-copper alloy) freezes over the narrow solidification range typical of such alloys. The lead solidifies only after the casting has cooled [to] 700 Celsius degrees. Segregation of lead to the last regions to solidify is therefore a potentially serious problem. Chill-casting and/or using thin sections help trap the lead in a uniform dispersion throughout the structure’ (Nielsen, n.d.).

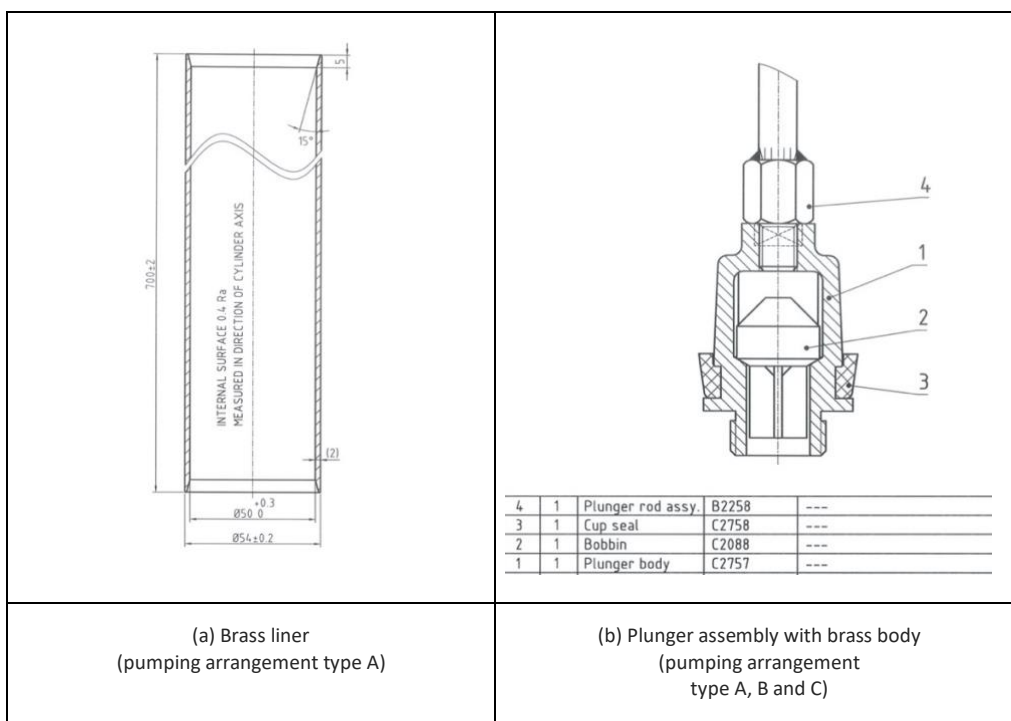
SKAT/RWSN – AFRIDEV

Brass components are not only confined to the India Mark III (and its variants). The Afridev also contains brass components in all three of arrangements (A, B and C) as shown in Figure A3.2. In the most recent Afridev 2007 standards, the liner is as brass (material specifications are the same as for the brass liner in the India Mark III described above). The Afridev plunger body (pumping arrangements A and B) is brass (specified ISO 426-2; CuZn38Pb4). The fishing connector (arrangement B) is brass (specified ISO 426-2; CuZn38Pb4).

The ISO standards for both of these materials (non-leaded and special copper-zinc alloys – ISO 426-1 and leaded copper zinc alloy – ISO 426-2:1983) were actually withdrawn in 2000 (ISO, n.d.(a); n.d.(b)).

The three⁴¹ arrangements of the Afridev plunger and foot valve are:

- A. brass plunger with plastic foot valve
- B. brass threaded plunger, brass fishing connector and plastic foot valve
- C. brass threaded plunger with brass foot valve and brass foot valve receiver



⁴¹ Anscombe (2011) notes the above three configurations in use in Malawi, plus a fourth, comprising a plastic plunger and plastic foot valve. This arrangement is mentioned in the Skat/RWSN Technology Selection Buyers Guide, but is not included in the 2007 standards (version 5). Due to challenges of obtaining materials (rubber U-seal was consistently too soft) according to the specifications, the plastic plunger became a ‘non-recommended option’ in version 4 of the standards (Skat/RWSN, 2002).

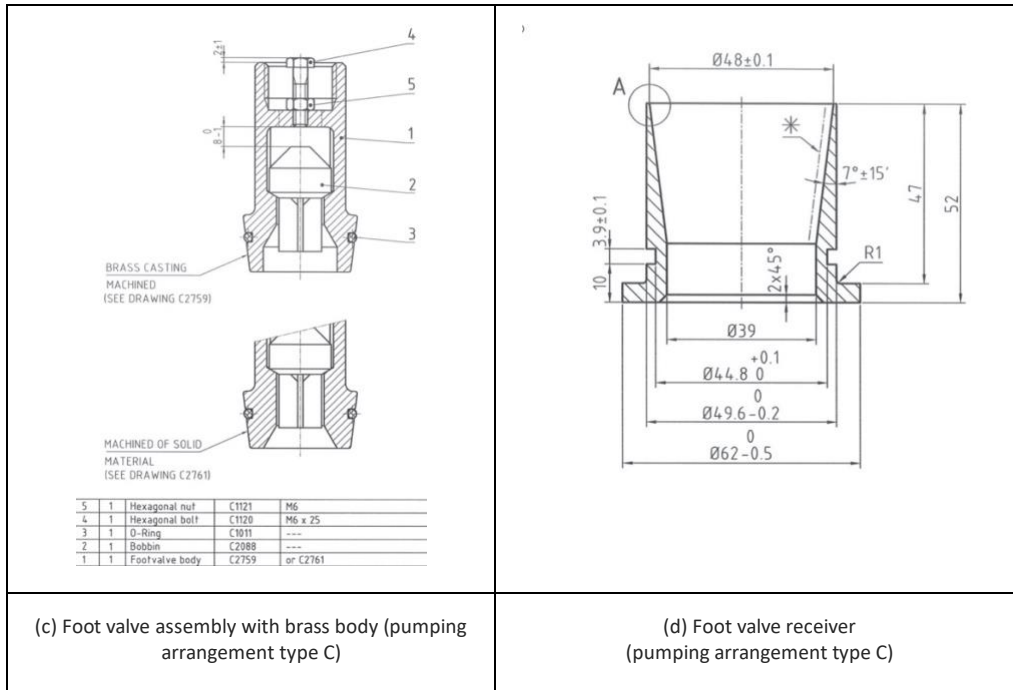


FIGURE A3.2 AFRIDEV CYLINDER ASSEMBLY WITH BRASS COMPONENTS

Source: SKAT/RWSN, 2007a.

ANNEX 4 LIST OF INTERNATIONAL HANDPUMP STANDARDS

Below is a list of international handpump standards with embedded hyperlinks:






- [Skat/HTN \(1999a\) Afridev: Handpump Specification: Injection Moulding Manual \(Revision 1-1999\)](#)
- [Skat/HTN \(2003\) Afridev: Moulds for Afridev Rubber Components \(Technical Drawings\) \(First Edition 2003\)](#)
- [Skat/RWSN \(2007a\) Afridev Handpump Specification \(Revision 5-2007\)](#)
- [Skat/RWSN \(2007b\) India Mark Handpump Specifications \(Revision 2-2007\)](#)
- [Skat/RWSN \(2007c\) Installation & Maintenance Manual for the Afridev Handpump \(Revision 2 2007\)](#)
- [Skat/RWSN \(2008a\) Afridev: Handpump with Bottom Support System \(Revision 1-2008\)](#)
- [Skat/RWSN \(2008b\) Guidelines for Quality Control and Quality Assurance of the AFRIDEV Handpump \(Revision 2-2008\)](#)
- [Skat/RWSN \(2008c\) Installation & Maintenance Manual for the India Mark II Handpump \(Edition 2008\)](#)



ANNEX 5 AFRIDEV: REPORTED DESIGN IMPROVEMENTS

Table A5.1 below is a compilation of Afridev design improvements based on observed field issues that have been collated by the RWSN Secretariat (Skat Foundation) as of 4 September 2021. For more details contact sean.furey@skat-foundation.ch

(REFERENCES TO BE ADDED TO REFERENCE LIST)

TABLE A5.1 AFRIDEV DESIGN IMPROVEMENTS

ID	Observed issue	Parts involved	Solution options	Source/notes	Image	Fail frequency	Fail impact	Priority	Status
A	Piston seal wears out < 6 months resulting in reduced discharge	C2758 Piston seal	P05-61206-P1 seal for plastic piston, P05-61207-P1 for brass piston	Hankin, P (2001).		H	H	1	Scaling
B	Piston seal escapes from groove resulting in no discharge	C2758 Piston seal	P05-61206-P1 seal for plastic piston, P05-61207-P1 for brass piston	Hankin, P (2001).		H	H	1	Scaling
F	Fulcrum bearing wear-out	C2044, C2045, Bearings. C2026 fulcrum pin sleeve.	Eliminate C2045; modified C2026 sleeve with O-ring seals; prototypes fabricated and delivered to LWI for testing	Tony Beers 18 MAR 2019, Et. Al		H	M	2	Designed / Prototyped
D	Top pump stand flange fatigues and fractures, initially along welds	C2053 Flange, M12 Flange Bolts	M12 galvanized split washers (US\$0.20) under flange bolts; relocate flange gussets as close as possible to flange bolts	Larry Bentley, William Nussbaam, 12 MAR 2019.		M	H	3	Designed / Simulated
G	C2122 pump rod centralisers disintegrate, sinks into cylinder, disabling pump	C2212 Pump Rod Centralizer	Improved low-friction, floating HDPE pump rod centralizer to reduce friction, wear, and to float out if damaged	Reported by Chris Hough (LWI) 20 FEB 2021, Et. Al. Improved HDPE pump rod centralizer designed, and prototyped with 3D printing for LWI.		M	H	4	Designed / Prototyped

ID	Observed issue	Parts involved	Solution options	Source/notes	Image	Fail frequency	Fail impact	Priority	Status
E	Spout opening too large diameter to fill jerry can resulting in spillage	C2010 Spout, C2011 Spout end	Reduce spout to 40 mm OD with swept bend instead of miter	Jerry can opening is about 45 mm. Consider reducing spout from current 48.4 mm OD to 40 mm OD (possible cost reduction)		H	L	5	Concept
C	Pump head removed to scavenge/steal internal parts resulting in no pump function	B203 Pump Head, C4021 Shroud	Add two holes to C4021 shroud to accept pad lock to block tool access	Larry Bentley, William Nussbaam 12 MAR 2019.		L	H	6	Concept
G	Brass foot valve loses seal	C2088 Bobbin, C2759 Foot valve Body	TBD	William Nussbaam, 12 MAR 2019. Next Step: Clarify failure mode.				7	

Note: H = High, M = Medium, L = Low