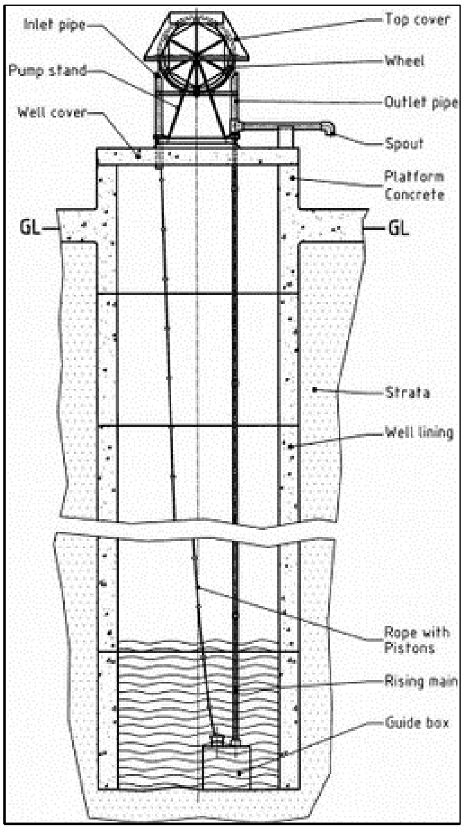

Africa wide water, sanitation and hygiene technology review

Deliverable 2.1

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Water, Sanitation and Hygiene Technologies
WASHTech, 2011

Authors
Cranfield University. Skat, WaterAid and IRC International Water and Sanitation Centre

Cover figure Nicaraguan Rope Pump by RWSN, 2011

The **Water, Sanitation and Hygiene Technologies (WASHTech)** is a three-year action research initiative that aims to facilitate cost-effective investments in technologies for sustainable water, sanitation and hygiene services (WASH). Through action research and the development of a set of methodological tools and participatory approaches, WASHTech embeds the practice of multi-stakeholder learning, sharing and collaboration – instilling individual and collective ownership and responsibility for sustainable WASH services.

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Abbreviations

ACORD	Agency for Cooperation and Research in Development
ADA	Austrian Development Agency
ADPP	*Ajuda de Desenvolvimento de Povo para Povo*
AIDS	Acquired immune deficiency syndrome
AusAID	Australian Agency for International Development
BBC	British Broadcasting Corporation
CAWST	Centre for Affordable Water and Sanitation Technology
CDC	Centre for Disease Control
CFPAS	*Centro de Formação Profissional de Águas e Saneamento*
COSDEF	Community Skills Development Foundation
CREPA	*Le Centre Régional pour l'Eau Potable et l'Assainissement à faible coût*
DAPP	Development Aid from People to People
DFID	Department for International Development
DTU	Development Technology Unit
EcoSan	Ecological Sanitation
EEPCO	Environmental Engineering and Pollution Control Organization
EU	European Union
GIZ	*Gesellschaft für Internationale Zusammenarbeit*
GTZ	*Gesellschaft fuer Technische Zusammenarbeit*
HIP	Hygiene Improvement Project
HIV	Human immunodeficiency virus
IAS	International Aid Services
IFC	International Finance Corporation
IWA	International Water Association
JICA	Japan International Cooperation Agency
JMP	Joint Monitoring Programme
KVIP	Kumasi Ventilated Improved Pit
KWAHO	Kenya Water for Health Organisation
LSHTM	London School of Hygiene and Tropical Medicine
MoU	Memorandum of Understanding
MSABI	*Maji Safa kwa Afya Bora Ifakara*
NGO	Non-Governmental Organization
ODA	Oromia Development Association
PE	Poly Ethylene
PPEU	Policy, Planning and Evaluation Unit
PVC	Poly Vinyl Chloride
RAIN	Rainwater Harvesting Implementation Network
RWSN	Rural Water Supply Network
SHARE	Sanitation and Hygiene Applied Research for Equity
SHIP	Seeds of Hope International Partnerships
SHIPO	Southern Highlands Participatory Organisation
SIDA	Swedish International Development Cooperation Agency
SNNPR	Southern Nations, Nationalities, and People's Region
SuSanA	Sustainable Sanitation Alliance
TAF	Technology Assessment Framework
UDDT	Urine Diverting Dry Toilet
UMCOR	United Methodist Committee on Relief
UN	United Nations
UNDP	United Nations Development Programme
UNHCR	United Nations High Commission for Refugees
UNICEF	United Nations Children’s Fund

USAID	United States Agency for International Development
WEDA	Wera Development Association
WHO	World Health Organization
WP	Work Package
WRC	Water Research Commission
WSP	Water and Sanitation Programme
WSUP	Water and Sanitation for the Urban Poor
VIP	Ventilated Improved Pit
VVIP	Volta Watertight Ventilated Improved Pit

1. Introduction

The aim of the review is to understand how technologies have been developed, how they were introduced, whether they have gone to scale and to start to explore the reasons why they were successful or not. The review is focused on technologies used in Africa in the water sanitation and hygiene (WASH) sector for long-term development (although some technologies are also used and have even been developed for emergency relief purposes).

The review discusses technologies from their first introduction to their ultimate scale up. A definition of scale up is provided by Olschewski (2010): "accelerated service coverage from islands of success to entire populations, ensuring adequate institutional arrangements are in place to support sustainable management of services". However many of the technologies included in this review have not yet been scaled up.

For the purpose of the review, a series of technologies have been selected (see Table 1) across water, sanitation and hygiene. There are many water and sanitation technologies and only a small number could be considered in this review. The technologies were selected because they:

- performed different roles, including water lifting, water treatment, tapping groundwater, water storage. sanitation user interface, sludge collection, sludge treatment and hand washing facilitation
- had been introduced using different financial models, including different levels of subsidy
- had been developed at different times; that is some technologies were developed many millennia ago, whereas some have been developed only in the last few years

Thus the technologies give an overview of a range of conditions relating to successful uptake

This review will be complemented by a technology report from each country (WP2.2), where the uptake of five technologies is described in depth, from the literature and key informant interviews, and a synthesis of these reports (WP2.4). Together, these reports will inform the development of the Technology Assessment Framework (WP 3).

The material used in this literature review was collated from a variety of sources using standard search methods, including Google and academic search engines like Scopus and Web of Science. Other literature, including case studies were either found through personal contacts or through the internet. A summary of the type of literature used in the review can be found in each section, so that the balance between grey and peer reviewed literature is clear; the bias of grey literature is also assessed.

1.1 Review method

It would have been ideal to rely solely on peer reviewed literature for this review. However this topic has not received enough attention from the academic community, and where it has, academics tend to focus on technical performance rather than social issues and business models. Even academics can be biased if they have an established research portfolio focused on a particular technology, and it would be unwise to assume that the peer review process is sensitive to this.

With grey literature, it is even more necessary to question the motives of the author. Do they stand to gain from presenting the technology positively or negatively? This "gain" could be financially if they are engaged in manufacturing or distributing the technology. Alternatively the "gain" could be in esteem – if they are heavily engaged in promoting a technology even on a not-for-profit basis they will want to present it in a positive light. This could ultimately result in financial gain if a donor decides to support a particular technology or organisation that is promoting it. Accuracy is another issue which needs to be considered with grey literature. For the purposes of this review it has been assumed that facts and figures presented are accurate as it is not possible to independently verify these – although sometimes it was possible to triangulate figures from various sources. All websites were accessed in July and August 2011.

Appendix 2A further discusses the bias in the different types of literature cited and Appendix 2B lists the different literature cited by type for each technology.

This review is limited by what material could be found online or provided by key informants. Some key material will have been missed; some key interventions have not been documented. Only documents in English were included.

1.2 Success Criteria

Although a full development of assessment criteria will be fully undertaken in Work Package 3 (TAF development) it was useful at this stage to develop some simple success criteria:

1. Technical criteria - is there independent verification that the technology sustainably performs its intended role if used correctly?
2. Financial criteria - has the technology *never* been criticised for being too expensive for purchase, operation and maintenance either by the users or by district scale development programmes.
3. Social criteria – if users are given the technology, will the majority use it with satisfaction?
4. Institutional criteria - has the technology been accepted by governments and donors?

These are certainly not comprehensive and may be interdependent. However, they have been developed iteratively throughout this review and the failure to meet one or more of these criteria have formed a barrier to the widespread uptake of a particular technology across Africa. Each question can be answered from the documents cited, and where possible multiple case studies are considered to give a balanced judgement.

Two criteria require a little further discussion. For criteria (1), we assume that all the intended functions of the technologies are valid. Criteria (3) is probably the most subjective as users are sometimes ignorant of harmful water and sanitation behaviours, or they may be dissatisfied because they have aspirations for technologies beyond their (or donors) financial means. In judging whether a technology has been socially unsuccessful, we are assessing whether a lack of user acceptability has been a real barrier to scale-up, and whether this could be overcome with better introduction to the communities and more education. In some cases this can be observed through users abandoning installations of the technology.

As the criteria have been developed as the review was in progress, the focus has been on the main benefits and criticisms documented for each technology. Most report authors seem to focus on technical criteria, so these are discussed in more detail. This does not imply that the other criteria are secondary, rather that they are less well documented. The financial and introductory models used are certainly key.

1.3 Report structure

Each technology is approached separately, and is described in five sections:

- A description of the range of *literature* available on the technology. This allows the reader to assess the likely bias and comprehensiveness of the review.
- A concise *description* of the technology
- A description of the *application* of the technology. This is supplemented by Appendix 1, which describes the introduction and scaling up process of the technology in each country in Africa.

- A selection of interesting *case studies*
- An explanation as to whether the technology meets each of the *success* criteria described above.

2. Overview of WASH technologies

Table 1: Overview of WASH Technologies reviewed

	Technology	Technically successful?	Financially successful?	Socially successful?	Institutionally successful?
Water	Rope pump	Yes, assuming high quality manufacture and adequate maintenance	Yes	Yes	No
Water	India Mark II	Yes, assuming functional maintenance system	Yes	Yes	Yes
Water	Playpump	No	No	No	Yes, assuming significant advocacy
Water	Bio-sand filters	Yes	Yes	Yes, assuming ongoing training	No
Water	Hand dug wells	Yes	Yes	Yes	Yes
Water	Constructed rainwater harvesting jars	Yes, assuming high quality construction	No	Yes	No
Water	Water jetting	Yes, assuming suitable rock type	Yes	Yes	No
Water	Life straw	Yes	No	Unknown	Yes
Water	Jerry cans	Yes	No	Mixed reports	Unknown
Sanitation	Bio-additives	No	No	Unknown	Yes
Sanitation	VIP latrines	Yes	No	No	Yes
Sanitation	Urine Diversion Dry Toilets	Yes, assuming waste can be removed	No	Yes	Mixed reports
Sanitation	Gulper	Yes	Unknown	Unknown	Unknown
Hygiene	Tippy tap	Yes	Yes	Yes	No

2.1 Rope pumps

Literature

There is a mix of grey and academic literature reviewed in this section. Whilst there are individuals and organisations in the sector who are advocating for rope pumps, there have not yet been any who are financially motivated (it is a public domain design) and their sheer number suggests that any positive bias towards rope pumps may be well founded.

Description

The rope-pump, also known as the rope-and-washer pump, has been around for at least two thousand years when it was first applied in China (Alberts 2000). The pump consists of a continuous rope, with pistons attached to it, which passes over a flywheel, down into the well or borehole, and up through a vertical pipe, the bottom of which is submerged in water. When the flywheel is turned the rope is pulled through the pipe and each piston traps a column of water inside and raises it to an outlet above the ground surface (Harvey and Drouin 2006).

Figure 1 illustrates the rope pump's main components and mechanism. Rope pumps may be installed in hand-dug wells and drilled boreholes. A variety of rope pumps are available for different applications. The maximum standard depth for rope pumps is 40m. As the minimum well water depth required for a rope pump is only 10 cm, rope pumps will keep on working even if the water table sinks significantly in a very dry season, provided the well is deep enough (Alberts 2004).

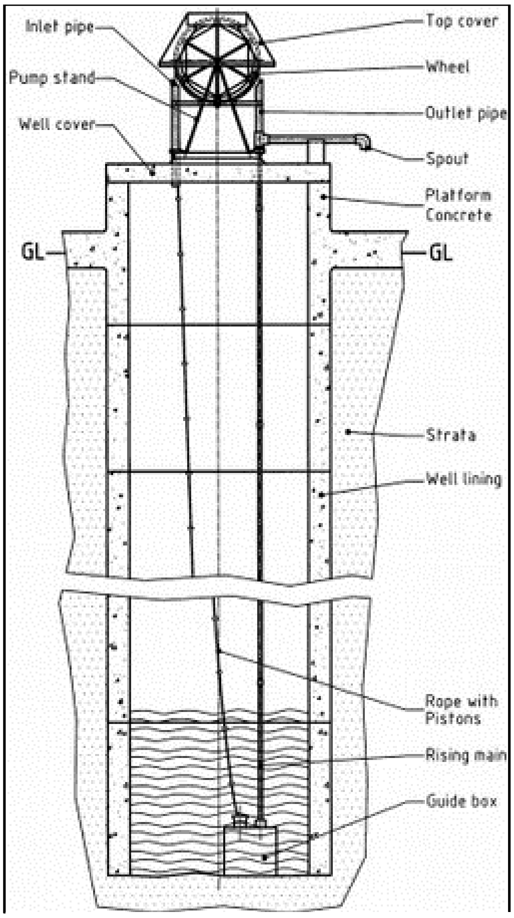

Figure 1: Nicaraguan Rope Pump (RWSN 2011)

Estimates of costs for installation vary from $150 (Zambia, Holstslag and Mgina 2009) to $400 (Congo, Jadot 2008) depending on local costs but also some estimates include well improvement or even digging.

Application

The rope-pump was simultaneously introduced to Africa and Latin America during the 1980s as a result of various water development projects (Arlosoroff et al. 1987). A major evolution in rope-pump technology took place in Nicaragua in 1984 when a small workshop created a rubber washer made by injecting moulds (Alberts 2000). Nicaragua subsequently became the world leader in rope pump production and installation, with multiple attempts to transfer it to Africa (see Appendix 1). These started as early as 1976, with Demotech introducing pumps to Burkina Faso (Sutton and Gomme 2009). However, the more serious attempts started in Mauritania in 1995 (Technology Transfer Division 2011) and continue to the present day. Rope pumps are now present in 20 countries in Africa, with the most being in Zimbabwe where 4000 pumps have been produced (Holtslag and Mgina 2009). The process everywhere has been for a local or international NGO to train local artisans to build the pumps, install them and provide a repair service. Some projects are 100% donor supported, some encourage individuals to invest and there are many options in between. In every case uptake has been slower than expected and in no country could rope pumps really be said to have gone to scale.

Case Study: Ghana

A major attempt to introduce the rope pump to Ghana was made in 1999. It is reported on the website of the Technology Transfer Division (2011) by the Ghanaian manufacturers. The World Bank funded exchange visits between Ghana's Community Water and Sanitation Authority and Nicaragua. They subsequently set up two workshops to manufacture and install the pumps. However, the workshops were not mandated to promote the pumps. Hence the uptake was low, and installed pumps were a long way apart, meaning follow up visits by the workshops were unfeasible.

In addition, of the pumps that were installed, 80% of rope pumps funded by a World Bank project did not function after one year, because of a lack of user involvement and errors in design, production and installation (Holtslag and Mgina 2009). The rope needed to be replaced too often and could easily be broken if it was misused. The metal frame also rusted quickly (WaterAid 2004).

As a result, government acceptance of this technology has been very low. In 2003, the NGOs RuralAid and WaterAid decided to reintroduce the rope pump as a low cost option to enhance water quality in the large number of open wells in Ghana. RuralAid identified the receptor communities, who then made a financial contribution. Manufacturer Janamese Enterprise installed the rope pumps, provided spare parts, training, monitoring and evaluation in collaboration with RuralAid. Adaptations were made to the pump design so the problems mentioned above were overcome. Thirty pumps were installed in this pilot phase, and quickly some private well owners have started buying them directly from the manufacturer (WaterAid 2004). By 2009 this had been scaled up to 1600 pumps installed, with some other producers combining rope pump supply and low cost drilling services. Community response to rope pumps is mixed with some finding them unappealing and hard to repair, whilst in other regions there are long waiting lists for pumps. However, production and installation is still NGO dependent with only 10% of rope pumps bought privately. Giving away pumps for free creates an unhelpful attitude towards paying for goods and services (Sutton and Gomme 2009; Smit 2011).

Smit (2011) found that staff in the government's Community Water Supply Agency were unaware that rope pumps could be installed on boreholes. Boreholes are a focus as groundwater levels are falling below the limit for hand dug wells. Problems from the early pilots were still remembered and data had not been provided to show that the problems had been resolved. There are still concerns about hygiene. All of these factors contribute to the fact that the pump is not yet accepted by the Ghanaian government. These concerns are not shared by NGOs who continue to promote rope pumps.

Case Study: Ethiopia

In 2005 in the SNNPR (Southern Nations, Nationalities, and People's Region) of Ethiopia, JICA (Japan International Cooperation Agency) and the Practica Foundation trained ten local artisans and local water staff for a month, with additional follow-up training. Artisans had to produce 15 good quality pumps before they could be certified. However, marketing proved hard in rural, sparsely populated areas. The government and donors do not promote the pump as it regards low cost options to have no place alongside conventional alternatives. In addition the cost of imported materials is increasing, and the reputation of the pumps has suffered due to poor site selection and low quality manufacture. As a result, over half the manufactured pumps are in storage having never been installed. Of those that have been installed, a survey 4 years after installation found 68% to be working. The high rate of breakdown was attributed to poor selection of wells, poor maintenance of pumps (or inability to maintain pumps because they were sealed) and poor installation. Repairs were usually carried out within a week at the cost of the local water office, although there were concerns that this may become unsustainable. Repairs that took longer were usually because of poor community management of the well (Sutton and Hailu 2011).

Technical success

Rope pumps are a low-cost technology, suitable for both shallow and deep wells. Because of their high pump capacity they can potentially serve productive uses such as car washing, animal watering and irrigation of small plots, although their capacity should not be overestimated (Holtslag and Mgina 2009). In summary, the rope-pump has the following advantages over conventional handpumps (Harvey and Drouin 2006; Holtslag, undated):

- Can be produced locally with common materials and basic skills (public domain design);
- Easy repair and maintenance (no specialist skills or equipment; lack of reliance on imported specialist components);
- Non corrosive and simple pump parts (PVC tubes, rope and PE pistons);
- Pumping parts are 5 to 10 times lighter than conventional pumps (no need for lifting tools);
- 3 to 5 times cheaper than piston pumps;
- Affordable at family level.

Arguments against the rope pump mainly focus on the presumption that it might be more susceptible to bacteriological contamination than conventional hand pumps. The pumping principle applied in the rope-pump by which the rope passes in and out the well is often considered as not entirely satisfactory in terms of protection of the water source compared to conventional hand pumps in which the water-contacting parts are enclosed. This may in fact be the main reason for resistance to the introduction of the rope-pump in sub-Saharan Africa (Bartle 2004). This is to some extent supported by Sutton and Hailu (2009) who found that water quality was only half as good as using a conventional hand pump. However, they did comment that the poor construction of the wells on which rope pumps are installed may have more of an influence on water quality and a rope pump did reduce contamination five-fold compared to using a rope and bucket. Conversely, a study carried out by Harvey and Drouin (2006) in Ghana showed that there was no reduction in microbial water quality for a rope pump compared to a conventional hand pump. Adaptations to the design are being made to try and reduce the potential for contamination, generally without any evidence of their effectiveness (Sutton and Gomme 2009).

Another problem is the variable quality of manufacture. Since most governments are not yet convinced by the rope pump, quality control is usually the responsibility of NGOs and donors (Sutton and Gomme 2009).

In conclusion, rope pumps are technically successful as long as the manufacture is of high quality, they are installed on well constructed wells and they are not overused.

Financial success

Rope pumps are designed as a low cost pump. However there is a tendency for them to be given to communities so communities are not required to make any investment themselves, although there are examples of households investing in their own pumps when they can be used for irrigation, for example in Kenya (Njue 2011).

Social success

People are mostly happy to use rope pumps when they are working, although they have a bad reputation for breaking easily and remaining unrepaired. However, when they are installed on wells where previously buckets were used, queues can form as only one person at a time can draw water. In some cases this resulted in the rope pump being abandoned. Care needs to be taken to ensure there are not too many users per rope pump (Smit 2011).

Communities may be taught how to replace the ropes and pistons when the pump is installed, however when the time comes they have forgotten how to do it or who to call so pumps can be left in disrepair (Smit 2011).

Institutional success

Only in Mozambique and Ethiopia has the government authorised the use of rope pumps (Butterworth 2011, WaterAid 2011b). Elsewhere they are still seen as poverty pumps, that is they are low cost, low quality technologies only used by the poorest, although there is little information about why they have not been authorised in other countries.

2.2 India Mark II handpump

Literature

There was surprisingly little literature on the India Mark II, and no academic literature. There are many manufacturers, but few reports of implementation. Therefore, information in Appendix 1 should not be considered comprehensive.

Description

The India Mark II first appeared on the market in 1979 and was designed to replace previous (first generation) models which were often difficult to repair when they broke down and unsuitable for heavy communal use (Colin, 1999). The India Mark II Pump is a robust conventional lever action hand pump, designed for heavy-duty use serving communities of up to 300 persons. The maximum recommended lift is 50 m. The India Mark II is a public domain pump defined by Indian Standards and it requires special skills for installation as well as for maintenance; it is not considered suitable to be maintained at a village level, although this was the original intention (Rural Water Supply Network, 2011b).

The pump's primary components consist of the pump handle, the riser main which carries the water to the surface, the pump cylinder which pushes water up the riser main, and the connecting rod which connects the pump handle to the pump cylinder at the bottom of the well. This model is a reciprocating pump.

Application

Prior to 1967 cast iron hand pumps that had been used in the previous century in America and Europe were used in Africa. The Jalna Jalwad and Sholapur pump, developed in India, was the first pump specifically for developing countries, but its design was not standard which meant sourcing spare parts was hard. UNICEF subsequently facilitated India's Mechanical Research and Development Organisation and Richardson and Cruddas to develop the India Mark II as a standardised hand pump suitable for community use. By 1978, Richardson and Cruddas were manufacturing 600 per month. Other manufactures were subsequently encouraged by UNICEF (there was no patent of the original design) and exports to Africa began. By 2000, it was being manufactured in Nigeria, Mali, Togo and Uganda (Baumann 2000), although India remains a primary manufacturing base for India Mark II pumps with some components assembled in African countries (Harvey, 2011).

Technical success

Mudgal (1997), summarising lessons learned in two decades since the India Mark II was first deployed in rural India, concluded that it was a good technical solution to the problems of providing water to large numbers of people situated in various terrains; as intended by the designers. It was robust enough to withstand the careless and often very rough handling to which it was subjected. However, when a pump broke down quick and efficient repair was hampered by the lack of trained mechanics, the lack of spare parts and a relatively sluggish administration unmotivated to facilitate a prompt solution.

Indeed, a major criticism of the India Mark II is that its design makes it difficult to repair at the village level and hence, without government support, NGO intervention, or community savings systems in place, the pump is susceptible to extended periods of non-functionality or permanent failure. With extensive use, the most vulnerable parts of the India Mark II, such as the above ground chain assembly and the below-ground cup washer, need maintenance and repair. Sustained usage and misuse also takes a toll on other above ground and below ground components with varying degree of frequency. The below ground repairs require trained mechanics with heavy hand tools (Mudgal, 1997). Therefore, high maintenance costs and the need to frequently replace key components can make the pump financially unsustainable in a poor community (Baumann et al, 2010).

To address these limitations, its introduction in India was accompanied by an innovative three-tier maintenance system, leading (initially) to a substantial reduction in downtime. The community (first tier) was expected to do preventive maintenance but not repairs, while local mechanics (the second tier) carried out more difficult repairs (with an individual mechanic responsible for 100 pumps). The government provided a third tier of mobile teams at the District level, each responsible for 1,000 hand pumps, for complex below ground tasks (Mugdal 1997). Yet, as the number of hand pumps grew the system became overloaded and the average time between breakdown and repair increased to 45 days due to the lack of third-tier support (Colin, 1999). The three tier maintenance system has not always been replicated in Africa (Wood, 1994).

In conclusion, the India Mark II is technically successful if the maintenance system is working effectively.

Financial success

According to Wood (1994) the India Mark II "is still, arguably, the most cost-effective hand pump for groundwater depths up to 45m, even in Africa where high freight costs make imported pumps more expensive than in India".

Social success

People are happy to use India Mark II pumps when they are functional.

Institutional success

The India Mark II (or a locally modified version) is one of the national standard pumps in Sudan, Nigeria, Ghana, Mali and Uganda (Baumann, 2000). This is critical as having a spare parts and maintenance network ensures the pumps continue working. The fact that the design is in the public domain has also contributed to its success.

2.3 Play pump

Literature

There were no academic papers or other unbiased sources to provide a balanced view about Play pumps, and the grey literature is very polarised. There are many authors who have hailed the Play pump as a fantastic technology but few are cited here as their praise is superseded by later criticisms. While this could be considered biased, all the later authors are agreed about the failures of the technology, and indeed the patent holder has ceased operations. As the PlayPumps International website has been taken offline, a lot of useful details about country-level uptake are also unknown.

Description

Play pumps, also known as roundabout pumps, were first developed in the 1990s in South Africa. The system attaches a playground merry-go-round to a water pump. Children, by playing on the merry-go-round, provide power for the pump which delivers water into a 2500-litre tank standing about 7 metres (21 feet) above ground. Users access the water in the tank through a tap valve. Any excess water raised by the pump is diverted back into the ground. The storage tank has panels on its four sides available for posting signs. Two have the potential to carry advertisements yielding revenue that helps pay for maintenance of the pump. The other two carry public health messages, often focused on HIV/AIDS prevention (see Figure 2) (Peterson 2008). A single Play pump is claimed to be able to produce up to 1,400 litres of water per hour at 16 rpm from a depth of 40 metres and to be effective up to a depth of 100 metres (Water For People, 2011).

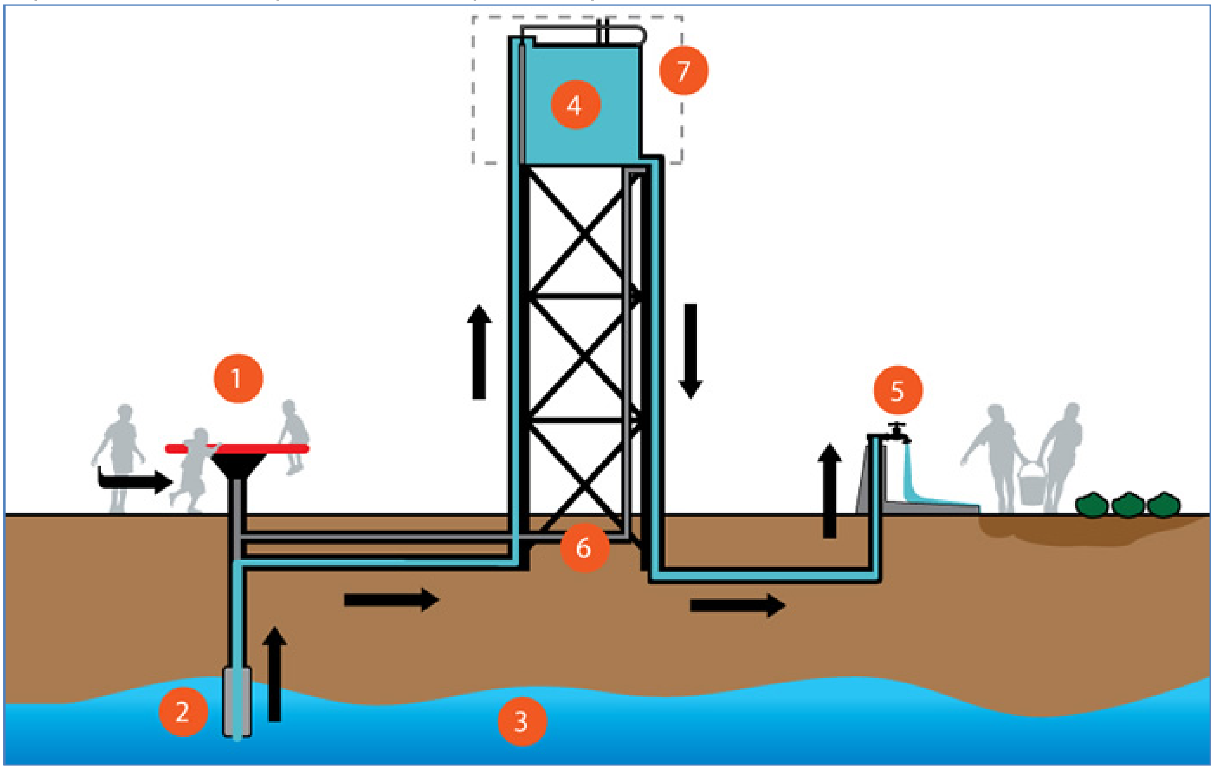

Figure 2: The Play Pump. (from Water for People, 2011)

Application

The Play Pump was developed by Trevor Field in South Africa in the 1990s, who set up the for-profit company Roundabout Outdoor, to install and maintain Play Pumps. The company is still active to this day. Play Pumps were gradually installed in South Africa, and in 1999 Roundabout Outdoor won a contract from the government to supply water to all of South Africa by 2008. The first installations outside South Africa were in Swaziland and Mozambique. At this stage the company began to attract more external donor funding, helped by organisations like PlayPumps International and Roundabout Water Solutions, not-for-profit companies set up to fundraise for Play Pump installations (Purkayastha, 2009) and eventually expanded into seven more countries (Freschi 2010). They signed MoUs with the Zambian and Malawian governments, but an evaluation found that these governments had been put under pressure by donors labelled by UNICEF as “non-traditional” (UNICEF, 2007). There were plans to expand into Ethiopia, Kenya, Tanzania and Uganda (Purkayastha, 2009; Freschi, 2011) but to date no installations have been made (Hayes, 2011). Playpumps International also wanted to install their pumps in Zimbabwe, but could not overcome the barriers of the volatile political situation and the 32% import tax (Purkayastha, 2009).

Despite several prestigious awards (for example the World Bank Development Marketplace Award in 2000) and 1887 installations (Hayes, 2011), there was criticism that Play Pumps were inappropriate for Africa (UNICEF, 2007; Obiols and Erpf, 2008; Chamber, 2009; WaterAid, 2011a). In Mozambique some Play Pumps were removed and replaced with Afridev pumps at the request of villagers (Campana, 2010). Installations are not happening at present in Mozambique and Zambia (Hayes, 2011). In 2010 PlayPumps International selected Water For People as its implementing NGO, and they are planning to offer Play Pumps as part of a broader portfolio of technologies and solutions, with significant community choice and support, and sustainable service delivery (Water For People, 2011). 155 pumps were taken by Water for People, but only a few have been installed to date (Breslin, 2011). Roundabout Water Solutions continues to fundraise for Play pumps (Hayes, 2011).

Case Study: Mozambique

An example of application is in Mozambique where 100 Play pumps have been installed in Maputo and Gaza provinces by UNICEF and Save the Children. An evaluation by Obiols and Erpf (2008) found that many billboards were blank as no companies want to pay for advertising in rural Mozambique. They observed that children did not play constantly (except while being watched by outsiders!). Only older children are tall enough to keep the wheel in constant motion. Although they enjoyed playing 31% said they would prefer an Afridev pump. Often the pumping tasks fell to women, but it was hard if they were old or pregnant, and when asked they said they preferred a conventional pump with a handle. Although the system is designed so that excess water is stored in the tank, in every pump visited only enough water was pumped for immediate needs, none was stored. Boreholes also have to be drilled away from trees, so there is no shade for playing children. Another problem was that the pumps could only be used on 150mm diameter boreholes, whereas Mozambique has lots of 100mm diameter boreholes. The average downtime when the pump was broken was 100 days. The corrosion of down-hole parts is another problem. This problem had been previously identified by the Mozambique government who recommended the Afridev pump which has non-corrosive down-hole components.

Technical success

In an article in the Guardian, Chamber (2009) estimated that children would have to “play” for 27 hours every day to meet Play Pump International’s stated targets of providing 2,500 people per pump with their daily water needs. Even if a pump was operated for 12 hours a day it would still only supply 20L/person to 840 people (Kimanzi and Danert, 2005). Further the WaterAid (2011a) official position on Play pumps states that even under two hours' of constant "play" every day, a play pump could theoretically provide the bare minimum drinking water requirements for about 200 people a day which is considerably less than its claimed potential. It is also necessary to build sufficient water storage capacity to cover the times when children are not playing or when pump/roundabout maintenance is required (WaterAid, 2011a).

The Play Pump is a patented design, so the patent holder has the sole rights to the manufacture of the pump and spares. This is in contrast to the many other conventional hand pumps (Kimanzi and Danert, 2005).

In addition the complexity of the pumping mechanism means operation and maintenance requires specific skills that may not exist locally. Furthermore, given that spare parts may not be as readily available as for other pumps, Play pumps could be very difficult to fix when they break down (WaterAid, 2011a).

There may, however, be a case for Play pumps to be used in a school situation, where the demand for water primarily occurs when the children are at school and playing at break times. Provided they can be persuaded to use the roundabout while playing then sufficient water might get pumped into the storage tank to meet the daily demands of the school. The problems associated with maintenance and repair remain, however (WaterAid, 2011a).

Financial success

Each pump costs around $14,000, not including drilling a borehole. For the same costs, at least four conventional wells with hand pumps and associated safe sanitation and hygiene education could be implemented (WaterAid, 2011a). Kimanzi and Danert (2005) estimated that drilling a borehole and installing a Play Pump would be 50% more expensive per capita than drilling a borehole and installing a conventional hand pump.

Social success

Women in Mozambique reported they would have preferred an Afridev pump (Obiols and Erpf, 2008), and communities in Malawi complained to the District Water Office who replaced their Afridev pumps with Play Pumps as the new pumps were hard to operate and injuries were occurring (Phiri and Molaro, 2011; Songola and Byrns, 2011). There is also some concern about the possible social consequences of using a system that encourages children to associate pumping water with "play". This association might undermine efforts to encourage water conservation or teach children to be mindful of the environment (Peterson, 2008). Using children to pump water could also be considered to be child labour.

Institutional success

Play pumps were accepted as a technology in several countries but an evaluation found that these governments had been put under pressure by non-traditional donors (UNICEF 2007). The government of Malawi have ordered NGOs not to install any more Play pumps (Songola and Byrns, 2011).

2.4 Household bio-sand filters

Literature

There are a variety of references, half of which are academic papers and theses. No real criticism of biosand filters was found, and support for them comes from a range of individuals and organisations. Appendix 1 relies heavily on a database from the Centre for Affordable Water and Sanitation Technology (CAWST) (Ngai, 2011). They ask all their partners, clients and course alumni to fill in a survey. These data are confidential, so in this report the total number of filters per country is shown, together with the organisations implementing them (or the main ones if there were many). Some organisations work in multiple countries but do not provide breakdowns per country – in this case the number per country is indicated as a minimum. In some countries there was only one implementing organisation, so the number of filters is given as an order of magnitude figure. These data were supplemented by descriptions of implementation strategies drawn principally from NGO websites.

Description

A biosand filter consists of a bed of fine sand supported by a layer of gravel. When water is poured onto the top of the filter, particulate matter is trapped at the surface, where a biological layer develops. This biological layer traps sediments, pathogens and other dissolved impurities from the water (Kubare & Haarhoff, 2010). Biosand filters can be applied in a household environment due to the fact that the design is not dependent on a continuous flow (Duke et al, 2006).

Biosand filters need to be cleaned when the flow rate becomes unacceptably low. This can be done by wet harrowing, which involves blocking the spout, filling it with water and swirling the water around. Any dirt in the filter comes into suspension and can be removed by decanting with a cup. This technique minimises the disturbance of the biosand layer and hence filter effectiveness (Biosandfilter.org, 2004).

Bio-sand filters are usually moulded in concrete using steel moulds. The moulds cost from US$250 to US$900 each (depending on where they are made) and can produce 1-2 filters per day. Material and production cost can vary from $12 to $40 per filter. Plastic versions of the filters have also been developed which weigh less and can be produced centrally at scale (Clasen, 2009).

A typical bio-sand filter is 95cm high and 36cm wide. It weighs approximately 150kg when empty and 225kg when filled with sand and water. The average flow rate is 35L/h (Duke et al, 2006).

As well as improving microbiological water quality, there are adapted versions for arsenic and fluoride (Hillman, 2007; Kubare & Haarhoff, 2010).

Application

The bio-sand filter is a slow sand filtration system developed by Dr David Manz, in the 1990s. It works in a similar way to the large-scale systems used in community and municipal water treatment for the last 150 years (Baker, 1981; Hijnen et al, 2004; Duke et al, 2006; Clasen, 2009).

The first recorded use in Africa was in 1999, simultaneously in Ethiopia by the NGO Samaritan's Purse and Kenya by the NGOs Bushproof and Medair. These countries, together with Zambia and Kenya have the largest number of biosand filters. Biosand filters have subsequently been introduced to twenty other countries, although not at the same scale. The key drivers behind the technology have been Bushproof who have distributed filter moulds (Grassroots Wiki, 2009), CAWST who have provided training and technical support and Samaritan's Purse who have used biosand filters in many of their development programmes, although many smaller NGOs, particularly Christian ones, have played a role too. A typical story is that an initial pilot programme is successful, funding is sought for a larger programme and expansion continues from there. As biosand filters become more widespread, communities learn about them and it is easy for new NGOs to respond to this demand. The only reason for any subsequent reduction in filter distribution has been a lack of funding. Most biosand filters are in Anglophone Africa as CAWST did not start to provide training in Francophone Africa until 2009 (Ngai, 2011).

Technical success

Unlike other household water treatment systems, a large volume of treated water can be produced, so as well as treating drinking water, biosand filters can produce water for other potentially health-related purposes, including personal and domestic hygiene and food preparation at no additional cost (Clasen, 2009).

Whilst there has been much research on the health impact of biosand filters in terms of diarrheal disease reduction (Murphy et al, 2010), there have been few refereed publications that critically evaluate the overall performance of these systems in the field (Lantagne et al, 2009). As there is no standard design for biosand filters, assuming universal efficacy would not be correct, however most tests do prove the efficacy of this technology assuming they are used correctly (see social success, below)(Kubare & Haarhoff, 2010).

Financial success

There are no criticisms that biosand filters are too expensive, although they are rarely paid for by households.

Social success

People are happy to use biosand filters, although there is a need for ongoing training of users with regard to maintenance. Edwards (2009) found that only 61% of 38 filter owners in Zambia could recall the correct maintenance technique. Conversely Earwaker (2006) found that 74% of 57 filter owners in Ethiopia were cleaning the filter regularly rather than just when the flow rate dropped. As cleaning disturbs the biofilm they could be unnecessarily getting a lower water quality than would be possible. This practise was also observed in Kenya (Biosandfilter.org 2004).

In Uganda, Samaritan's Purse gave households the option of having their filter painted decoratively for an additional $5. Although this is totally optional, every household took up the opportunity and it has helped with community buy-in (Holmes, 2011).

Institutional success

The only country where CAWST partners are attempting to get biosand filters recognised by the government is South Africa. It is hoped that if this is successful it might influence other African governments (Ngai, 2011)

2.5 Hand dug wells

Literature

The majority of the references for this review were practice notes and other grey literature. As governments play such a key role in constructing hand dug wells, there is quite a lot of reference to government sources.

For Appendix 1, programmes were only included that had constructed over 100 wells. There are numerous small NGOs constructing hand dug wells on a small scale, and while their work is undoubtedly valuable, for this review it is necessary to focus on interventions that have gone to scale. Interventions that had rehabilitated or chlorinated wells were also ignored as this is not "introducing" a technology. A large proportion of hand dug wells are self supplied, that is households invest in them and improve them in incremental steps. These are rarely documented and as such Appendix 1 is unlikely to be comprehensive, however it should provide a picture of what strategies have been used to introduce hand dug wells and what scale they have been able to achieve.

Description

Hand-dug wells have been used by humanity for millennia and they are still the most common method of obtaining groundwater in rural areas of the developing world. However, because they are dug by hand their use is restricted to suitable formations, such as clays, sands, gravels and mixed soils where only small boulders are encountered. To dig a well, earth is excavated below the groundwater table. The volume of water in the well below the standing water table acts as a reservoir and should replenish itself during periods when there is no abstraction (or instantly in highly permeable sediments). Depths of hand-dug wells range from shallow wells, about 5 metres deep, to deep wells over 30 metres deep. Occasionally, wells with depths of over 30 metres are constructed to draw water from a known aquifer. Ideally, wells are no less than a metre in diameter in order to provide adequate working space for the diggers. Wells are either constructed by experienced local well-diggers or by villagers themselves (WaterAid, undated a).

Wells are usually lined (cased) with stones, brick, tile, concrete (caissons), iron rings or other material to prevent collapse. Being shallow and open, dug wells have the highest risk of becoming contaminated, both because shallow groundwater is easily contaminated (e.g. by latrines) and by things falling down the well. To minimize the likelihood of contamination, a well should have a concrete cover slab and apron to reduce the possibility of contamination, as well as a fence to prevent access by animals (WaterAid, undated a). The contamination of shallow groundwater is a complex issue depending on soil type, depth of the unsaturated zone and groundwater flow direction and speed, but a good rule of thumb is to only build wells uphill and at least 15m from latrines (Lawrence et al, 2011).

Water is abstracted either by using a bucket, a bucket and windlass (which should reduce contamination) above an access hole, or less frequently a hand pump. The mode of abstraction ultimately relies on the yield of water available and the ability of the benefiting community to pay for ongoing maintenance for the hand pump, spare parts, etc. A hand-dug well fitted with a hand pump can serve the needs of about 300 people (WaterAid, undated a).

Application

Although many communities had and still have traditional methods for well digging and lining, the dug well has evolved over the last century or so from minimal, unlined holes to concrete lined structures with specified depth and yield, and with improved head-works and drainage. In the 1930s in-situ cast concrete linings were introduced to avoid collapse and exclude contamination. In the 1960s and 1970s caisson lining methods were introduced to deepen wells that were built with in-situ cast linings. However, caisson sinking is still poorly taught and performed (Abbott, undated.).

Self supply remains the most common method for people to get a hand dug well, although NGOs are frequently involved in rehabilitating or chlorinating them. Internet searches produced evidence of hand dug wells in every single country in Africa, with country wide estimates in the tens or hundreds of thousands (Louis Berger International, 1986; Gyau-Boakye and Dpaah-Siakwan, 1999; Danert and Sutton, 2010a,b,c). Winrock International (2007) has been seeking investment to upgrade household hand dug wells in sub Saharan Africa. They estimate there are 31 million such wells across the continent, and have produced a breakdown showing the numbers of beneficiaries by country (see Figure 3).

In terms of external introduction of the technology, this has been done on a small scale by numerous NGOs from the 1980s onwards. The largest programme found was UNHCR encouraging refugee host communities to construct over 5000 wells in Chilombo in Zambia (ICLEI, 2008). Government programmes started as early as 1920 in Ghana (Gyau-Boakye and Dpaah-Siakwan, 1999). They were sometimes linked with Guinea worm eradication programmes, for example in Nigeria (Miri et al, 2010). The largest in-country programme found was 3500 protected hand dug wells with pumps installed in Malawi, funded by the Malawi Social Action Fund (Vezina, 2002). Surprisingly for this technology, which could be constructed using local labour and local materials, there have been few programmes to train local communities to construct wells.

Technical success

Over the last decades, hand-dug wells have been somewhat overlooked as a solution to sustainable water supply with a much greater emphasis on drilled wells. There is a fear that the former produce low quality water. Parker et al (2010) studied water sources in Katakwi, Uganda, and found that covered hand dug wells have significantly better water quality than open water, when thermo-tolerant coliform counts and turbidity are considered. However, they had worse water quality than boreholes, protected springs and rainwater harvesting. Yields may also not be sustainable, for example, 37% of wells supplied by Lifewater in Liberia’s capital ran dry or had reduced yield in the dry season (Gehrels et al, 1995) and 42% of 169 unlined traditional wells surveyed in Mali had dried up at least once in the previous year (Sutton, 2010b).

Two NGOs, Tearfund and IAS, would consider hand dug wells to be their second choice option for local water access after protected springs (Greaves, 2011; Zetterlund, 2011).

They are placed second as they are less cost effective and sustainable as they face high problems of maintenance, repair, and spare parts supply (Greaves, 2011).

Financial success

Hand dug wells are often dismissed as being too low technology, and not “sexy” enough to attract donors. However, they are an easy way to access relatively shallow groundwater. Hand-dug wells allow the use of a wide choice of abstraction methods - a windlass or any one of a suite of pumps (at a variety of price points). They are even appropriate for communities and households unable to afford a pump at all. Furthermore, due to very low capital investment requirements, wells may be initiated and constructed locally, placing the control over the project firmly into the hands of the community or household.

Social success

The worst reported statistic for wells not in use was in Sierra Leone where 42% were not in use – these were in villages where health education received a low priority in NGO programmes (CARE, 2004). The best was in Mozambique where only 2 of 146 wells were in disrepair (Magrath, 2006). On balance, it seems the majority of users are happy to use hand dug wells. As hand dug wells are typically shared by families rather than whole communities, queues are shorter (Sutton, 2011b).

Institutional success

Hand dug wells are an accepted part of the water supply strategy in Ghana (Ghana Districts, 2006), Sierra Leone, Zimbabwe, Malawi, South Africa, Zambia (Magrath, 2006), Liberia (Liberia’s Water and Sanitation Policy, 2009), Sudan (UNICEF, 2009), Mali (Sutton, 2010b) and Nigeria (Bambgoye, 2011). There was no evidence for countries where hand dug wells were not accepted except between 2001 and 2005 in Mozambique, when hand dug wells were removed from the government Implementation Manual (Magrath, 2006), and in Mali and Zambia where large diameter wells are only considered for isolated and pastoral communities (Sutton, 2010b; Sutton, 2010c). In addition in it was resolved at the 2nd National Water and Sanitation Conference 2011 that more needed to be done to implement and enforce these guidelines (Bambgoye, 2011)

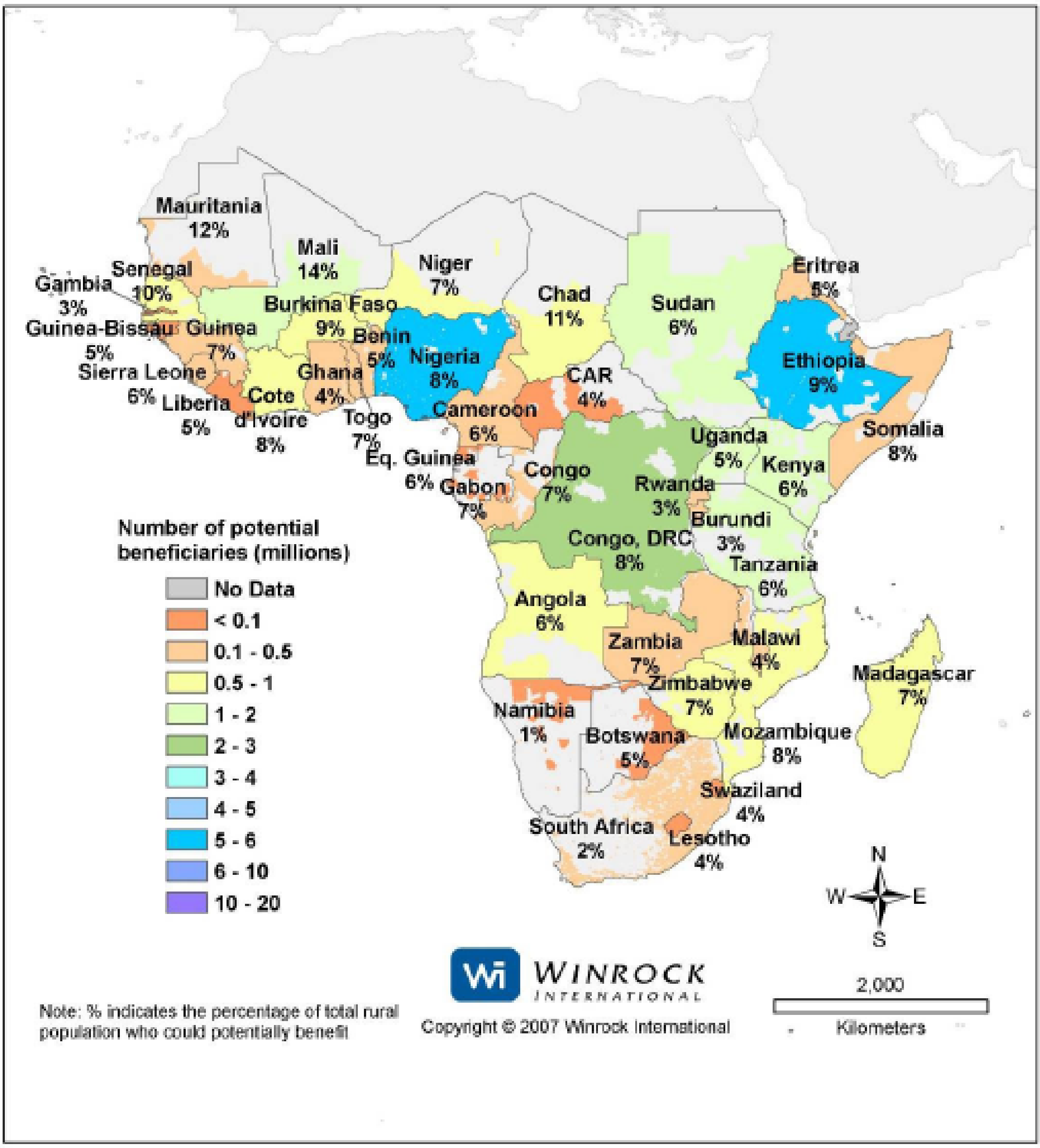

Figure 3: Map showing potential beneficiaries from a hand dug well upgrading programme (from Winrock International, 2007)

2.6 Constructed rainwater harvesting jars

Literature

Literature on general rainwater harvesting is vast. The use of jars for domestic roof water harvesting was developed and widely applied in Thailand so information about Asian case studies is plentiful. Documented cases in Africa tend to focus on higher volume tanks for water storage and information about using jars is scarce, with the exception of the academic work of Gould. Many references are several years out of date.

Description

Rainwater is an available source of clean water that can be collected from three main types of rainwater catchment systems: rock catchments, ground catchments and roof catchments

(McPherson and Gould, 1985). This review will focus on the latter. Runoff that can be collected from most forms of roofs is channelled into a guttering system and then collected in a storage unit, typically a large tank or pot, over or underground.

Domestic roof water harvesting is particularly appropriate in areas with one or two wet seasons per year (WaterAid, undated b). The capacity of the storage unit is a function of the annual rainfall, the surface area of the catchment and losses due to splashing, evaporation, leakage and overflow (WaterAid, undated b) and demand. There are several books on selecting a storage unit size, for example Pacey and Cullis (1989) and Gould and Nissen-Petersen, 1999). The simplest means of storing rainwater is to use a jerry-can or an oil drum (Nissen-Petersen, 2007). Other containers of larger volumes include jars, tanks built of bricks, blocks or plastic, ferro-cement tanks and ground tanks (Nissen-Petersen, 2007). This review will focus on constructed jars for domestic roof water harvesting, i.e. those that are made close to the site of intended use, rather than made in a factory and transported to the site.

A typical jar is made of un-reinforced plaster, cast on a wooden mould. Wooden bricks are used to build up the shape of the jar, with clay moulded onto the wood to make a smooth and uniform shape. The cement is then plastered onto this clay, and left to cure. After a few days of curing, the wooden bricks and clay are removed, and a layer of plaster with waterproofing agent applied to the inside. The base includes a sheet of fine (mosquito) mesh, which is bent up to form a good connection with the walls (Cruddas, 2007).

Application

Rainwater harvesting is a successful and ancient technology to collect water for domestic and agricultural purposes, Abdelkhaleq and Ahmed (2007) report its use 5000 years ago in semi-arid regions. The use of domestic roof water harvesting is widespread in many parts of the world but has had particular success in Asia. In the 1980s, Thailand established itself as a leader in domestic rainwater supply through a successful government-initiated project to promote the jars (Gould and Nissen-Petersen, 1999). Successful designs included not only millions of ferro-cement jars built in Thailand but also bamboo reinforced jars in Indonesia (Nissen-Petersen, 2007; McPherson and Gould, 1985).

In Africa however, the uptake has been less notable. In some parts of Africa rainfall is too low. Elsewhere roofs are too small or not made of impervious materials and there is a higher cost of constructing catchment systems in relation to typical household incomes (UN-HABITAT, 2005).

Gould (2006) notes that in Sub Saharan Africa only a fraction of rainwater is being exploited, despite the fact that it could potentially benefit hundreds of millions of people. Fry et al (2010) modelled 37 large West African cities and concluded that the disease burden from diarrhoea could be reduced by 9% if domestic rainwater harvesting technologies were implemented. In Kenya and Botswana rainwater harvesting is mainly practised in the arid and semi-arid areas and was regarded as a technology to be utilised if water could not be obtained in other ways (McPherson and Gould, 1985); i.e. if there is no surface water or groundwater available or it is of low quality. In these countries, large projects are exploiting surface water and groundwater and rainwater harvesting schemes are largely the domain of non-government organisations and are relatively small in scope (McPherson and Gould, 1985). Nevertheless, rainwater collection is becoming more widespread in Africa with projects currently in Botswana, Togo, Mali, Malawi, South Africa, Namibia, Zimbabwe, Mozambique, Sierra Leone and Tanzania (UN-HABITAT, 2005).

The documented examples are restricted to the two East Africa countries of Kenya and Uganda. In Kenya the jar designs used were not durable. In Uganda there are five separate jar construction programmes, which are mostly situated in two regions. So far these programmes have not been introduced to other regions of Uganda.

Technical success

Rainwater harvesting provides a supply of safe water close to its consumption point reducing the time involved collecting water and consequent health impacts (WaterAid, undated b). Moreover, as more water is easily available, washing becomes more frequent resulting in better health (Howard and Bartram, 2003).

Collected rainwater can be consumed without treatment (WaterAid, undated b; McPherson and Gould, 1985). Parker et al (2010) found rainwater harvesting water quality to be significantly better than hand dug wells and open water and not significantly worse than boreholes.

Common problems include contamination through faecal droppings from animals, contaminated debris on the roof and poor hygiene of vessels and users (WHO, 2006). There are however simple solutions to avoid jars becoming breeding ground for disease vectors including, for instance:

- a “first-flush” bypass whereby the initial water collected, with most of the roof debris, is diverted away from the storage vessel (see Figure 4) (WaterAid, undated b);
- a mosquito proof screen and cover fitted on the storage tank to prevent mosquito breeding (WaterAid, undated b).

Although this technology uses straightforward construction methods, problems have been identified by McPherson and Gould (1985) and include wrongly estimating the required size or number of jars and leakages due to incorrect cement mix. The two case studies in Kenya (see Appendix 1) show that the technology was abandoned because tanks are not durable. Construction of jars can be difficult (UN-HABITAT, 2005; Rees and Whitehead, 2000). Small jars are advantageous over larger tanks in this respect as they can be centrally made and transported to site, ensuring quality control in their construction (Gould and Nissen-Petersen, 1999; e.g. DTU, 2006). Assuming the jar is constructed correctly it has a long design life and can provide a stable water source for many years (WaterAid, undated b).

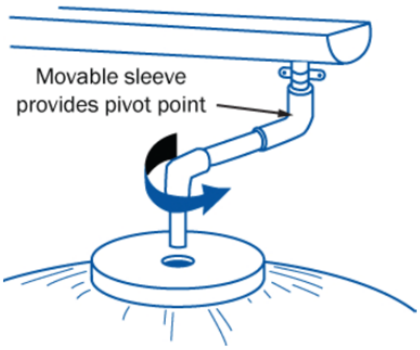

Figure 4: First flush system, from WaterAid, undated.b.

Financial success

The main disadvantage of rainwater harvesting jars is the construction cost (McPherson and Gould, 1985) with the guttering and roof in addition to the storage jar typically costing more than a family earns in one year (Gould, 2006). However, jars are cheaper than other tanks (Pacey and Cullis, 1989; Gould and Nissen-Petersen, 1999; DTU, 2006) and a family can start by building one jar and sometime later they build a second jar and so on until they have a line of jars that can supply water throughout the year (Nissen-Petersen, 2007). Once constructed, maintenance costs are low (McPherson and Gould, 1985; WaterAid, undated b).

Social success

The householders own the jars; therefore, they are likely to look after them (McPherson and Gould, 1985). This also removes the need for a government maintenance programme and all the costs associated with such a service (McPherson and Gould, 1985). In general people are happy to use rainwater harvesting jars.

Institutional success

Governments tend to focus on village scale infrastructure rather than household level technologies, so for the time being, rainwater harvesting technologies have only been introduced by NGOs (McPherson and Gould, 1985).

2.7 Water Jetting

Literature

The only academic papers on well jetting are in relation to the oil industry, with the exception of one 1953 paper describing well jetting development in India. In the grey literature there is some disagreement on costs, but otherwise there is agreement on the suitability of the technology for the African context. Details of the introduction and development of water jetting in specific African countries are scarce – several reports list countries where it is used but do not go into any further detail. Several reports talk about manual drilling without going into the specifics of jetting.

Description

Water jetting, also known as washboring is a low-technology manual drilling method that can create boreholes suitable for hand pumps. It is a promising low-cost, fast drilling technology but it can only be used in unconsolidated formations of sand or silt (Elson and Shaw, 1999). The water used to 'jet' is either clear water or mud.

Water is pumped (with a hand or motorized pump) down the centre of a vertically placed drill pipe. The return water brings with it cuttings and debris. The washing and cutting of the formation is helped by rotation and by the up-and-down motion of the drill-string (see Figure 5). The equipment required includes a man-powered pump or a small internal-combustion pump, jetting pipes, elbow and swivel, suction hose and flexible hose (Elson and Shaw, 1999,;Rural Water Supply Network, 2011a).

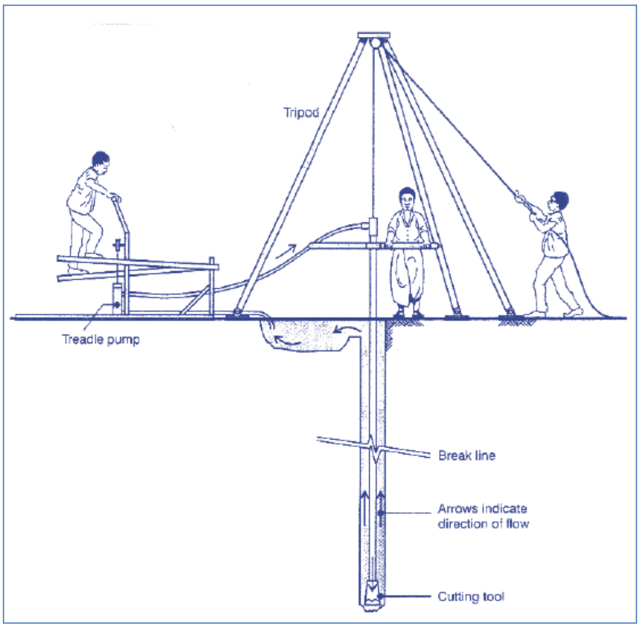

Figure 5: Water jetting equipment and technique, from WaterAid, undated.

Application

According to Wagner & Lanoix (1959), water jetting has been widely and effectively used in Brazil for prospecting for rural water supplies as well as creating boreholes for permanent well-installation. There are also references to its use in India in the 1950s (Bose, 1953). The earliest reports of water jetting in Africa are in 1965 in Chad (PRACTICA Foundation et al, 2009) and Appendix 1 shows it has been used in 14 countries across Africa. The largest scale programme was in Nigeria where 75000 wells have been jetted (Sonou, 1997; Grimm & Richter, 2006; Adekile and Olabode, 2009). Cansdale (2011) explained how the programmes in Nigeria, Senegal and Madagascar went to a surprisingly large scale after only a couple of weeks of demonstration. It is a technology that can be easily taken up by local entrepreneurs.

Case Study: Nigeria

Washbore technology, or hand-turning as it is called in Nigeria, was introduced by the World Bank as early as the 1980s in order to evaluate the irrigation potential in Northern Nigeria. By 1982, the World Bank invited the private company SWS Filtration Ltd to demonstrate well-jetting to the Agricultural and Rural Development Authority and four teams were subsequently trained in washbore techniques (SWS, 2001; Adekile & Olabode, 2009). During a return visit to the project site, in 1987, the need for an adaptation to the original well-screen system was identified which also resulted in the development of a “self-jetting well-screen” (SWS, 2001). Between the years of 1983 and 1990 more than 15,000 washbores and drilled tube wells were constructed in the States of Bauchi, Kano and Sokoto and the 1992 National Fadama Development Project aimed at constructing 50,000 shallow tube wells using jetting over a period of 4 years in Bauchi, Jigawa, Kano, Kebbi, Sokoto and other eligible states (Sonou, 1995). The average cost of a shallow tube well using the washbore technique, in 1992, in Nigeria was $79 which when compared against an average cost of $313 in Ghana in 1992, a cost over 4 times as expensive, raises questions of the financial implications of replication.

Case Study: Madagascar

Medair used water jetting in north-east Madagascar to help communities affected by cyclone Gafilo in 2004. They constructed over 200 new water points over 3 months (Robinson et al, 2006). Although the application of water jetting in Madagascar was post-emergency, the implementers (Bushproof and Medair) believe that it can be successfully applied to the development context (Mol et al., 2005). The cost of the completed water points in Madagascar was 600-800 Euros each, about 50% of the usual cost for water points in Madagascar (Robinson et al, 2006). The method used involved rapidly mobilized community participation with approximately 80% of materials prepared by the community. Mol et al., (2005) believe that the involvement was high because results were immediately apparent enabling the beneficiaries to believe that the NGO promises would be fulfilled.

Technical success

Water jetting is a simple technology and can be used above and below the water table (Elson and Shaw, 1995). The limitations are that a large amount of water is required for drilling. It can also only be used in certain unconsolidated rocks, and even if the initial assessment suggest the rock type is suitable, if a hard rock is encountered before the full depth is reached, drilling will have to stop.

Only a limited number of project impact evaluations on whether the wells created using the technique are still functioning or being used have been undertaken and yet the consensus seems to be that the technique is replicable, sustainable in terms of local adaptability of not only the well construction but also maintenance (UNHABITAT, 2006).

Financial success

The technology is considered to be inexpensive probably because it is possible to use locally available materials (Rural Water Supply Network, 2011a). However, the difference in costs between Ghana and Nigeria (see above) suggests careful cost estimates are required. Although a motor pump can be used, man-powered pumps are effective.

Social success

In this case, end users are not the ones to interact with the technology directly, and thus there have been no reports of users objecting to a jetted well as such. Drillers have taken up and used the technology with external support, and even without it in Chad (PRACTICA Foundation et al, 2009).

Institutional success
Only one country, Madagascar, is reported to have accepted well jetting as an approved drilling technique (Robinson et al, 2006). In Chad, most early jetted wells failed due to inadequate attention to well design, siting and post-drilling construction, and as such the government has refused to accept manual drilling (PRACTICA Foundation et al, 2009).

2.8 Lifestraw
Literature
Much of the material for this review came from the manufacturer's website, and interviews with two representatives from the manufacturer. NGOs distributing Lifestraws were also a key source for Appendix 1. There were two key opposing views, that of WaterAid represented in a BBC News article (2006) and that of Kevin Starr (2011) in the Stanford Review.

Figure 6: A Lifestraw in use, from Vestergaard, undated.

Description
Two forms of the Lifestraw are currently available; the LifeStraw Personal and the LifeStraw Family. The Lifestraw Personal (pictured, Figure 6) is a straw that contains a membrane that the user sucks water through. It is most suited to emergency contexts. The Lifestraw Family is a unit that sits in the home. Users pour water into a feed bucket. It then passes through a textile pre-filter and a hollow-fibre membrane. In addition a small amount of chlorine is added to prevent membrane fouling. Both Lifestraws effectively remove 99.9999% of waterborne bacteria and 99.9% of waterborne protozoan parasites, and the Lifestraw Family removes 99.99% of viruses and all turbidity. Over their lifetimes they can filter 1000L and 18000L water respectively. These results have been confirmed by independent laboratory studies, for example tests carried out at the University of Arizona (Vestergaard Frandsen, 2011).

A Lifestraw costs $3.50 and will last around one year (BBC, 2006). Starr (2011) estimates a Lifestraw Family can cost up to $70 and will last three years.

Application
Vestergaard Frandsen was inspired to create the Lifestraw following the Cochrane report (Clasen et al, 2006) which claimed that household level interventions were more effective than source interventions at preventing diarrhoea. The Lifestraw was created in 2006 and followed by the Lifestraw Family in 2008.

Lifestraws have been distributed in at least 24 countries across Africa. Mostly they have been delivered in batches of hundreds or thousands – the exception is the 500 000 distributed in Kenya – covering 90% of all households in the Western Province (see case study) (Vestergaard Frandsen, 2011). Lifestraws are always free to users – in fact the company believes that when a country's economy has developed such that the users can afford to buy their own Lifestraws, the entire population will be connected to a safe water system anyway. This approach builds on Vestergaard Frandsen's experience of selling anti-malarial bed nets where they found there was no private market. As such, Lifestraws are always donated, primarily through either Corporate Social Responsibility initiatives or charity fundraising, and more recently through carbon credits (see case study). They have so far struggled to attract donor funding (Lunde, 2011) although this is starting to change with more NGOs, UN agencies and government development agencies taking interest (van Beek, 2011).

Case Study: Kenya

A new financing mechanism for Lifestraws is the Carbon for Water programme whereby Vestergaard Frandsen gain carbon credits for the distribution of Lifestraws in Kenya as carbon is saved because water treatment by boiling is unnecessary. They can sell these carbon credits to buyers who want to improve their environmental stewardship (Vestergaard Frandsen, 2011). This scheme is criticised by Starr (2011) who cites an unpublished study by Jeff Albert of Aquaya that only 100 out of 400 households that they surveyed actually treat water by boiling, and even this figure is probably inflated.

Technical success

Elsanousi et al (2009) reported a reduction in diarrhoea from 15% to 2% after Lifestraws were distributed in El-Masarf settlement camp in southern Gezira, Sudan. However Boisson et al, (2009) found no significant difference in diarrhoea prevalence between households who had been supplied with Lifestraws and those who had not in Robe Gabia in rural Ethiopia, although the water quality in people’s homes was found to be better in the houses with Lifestraws.

Lifestraws are effective in water treatment although the Lifestraw Personal does not remove viruses and turbidity. Their health impact is still under debate and a detailed discussion of the role of household water treatment in development is beyond the scope of this review.

Financial success

For users they would be unaffordable (BBC, 2006), however, they are an inspirational solution that has attracting a massive amount of funding from a variety of sources making them free to end users. This funding mechanism needs to be maintained as the lifespan of a Lifestraw is a maximum of 3 years under normal usage.

Social success

There have been no studies testing use rates but there are no reports of families not using donated Lifestraws.

Institutional success

Despite receiving numerous rigorous tests, some countries have demanded tests on local water before the technology is approved for import. These tests are usually simple tests on bacteria removal rather than checking capacity or flow rate. In other countries the regulations are more relaxed, whilst some counties accept tests done by their neighbours, for example Liberia accepted the approval of Guinea’s Food and Drug Administration. Approval can mean Lifestraws are exempted from import tax which can range from 10% to 30% (van Beek, 2011). There are no reports of Lifestraw approval being refused.

2.9 Jerry cans

Literature

Unlike the other technologies, the majority of references on jerry cans are academic papers. None of the references could be accused of having any bias, as none of the authors are financially or ideologically linked to the technology, indeed almost all talk of jerry cans being only part of a water system. Appendix 1 only refers to jerry cans being promoted or distributed in development situations, not emergencies. All searches were dominated by references to emergency situations, so Appendix 1 is somewhat brief and probably not comprehensive. In fact, many references talked about jerry cans in a negative way, as they imply that water is still being collected and transported home rather than being accessed in or near the home. While of course the latter is the most desirable, the reality is that water collection and storage is a reality for the imminent future. As such, perhaps they are not an intervention that all NGOs want to be associated with.

Description

The criteria for safe water storage are described in Box 1. Plastic jerry cans meet all of these criteria except having a spigot or tap. If they have not been produced specifically for household water storage they will not have illustrations on safe water storage and treatment. New or recycled jerry cans are available from $4.50 to $7.25, depending on place of manufacture and transport costs. A container made of high density polyethylene may last up to 20 years, depending on the thickness of the material (Mintz et al, 1995). It is recommended that separate containers should be used for drinking water, washing clothes, washing pots and personal hygiene to avoid cross contamination (Oxfam, 2008).

Box 1: Criteria for safe water storage

A water storage vessel that will adequately protect water should:

- have an opening that is large enough to facilitate filling but too small to allow hands to enter, and a lid (Mintz et al, 199;, Clasen and Bastable, 2003; CDC and USAID, 2009) or have a cover which can be removed for cleaning but which users do not extract water through (Oxfam, 2008)
- be constructed from a material that is easy to clean, inexpensive and enables it to be locally produced (Mintz et al, 1995)
- be of a size, shape, weight and durability that renders it suitable to be taken to and filled at the pump (Clasen and Bastable, 2003; Oxfam, 2008)
- have a spigot or tap for access without inserting cups or other utensils (Mintz et al, 1995; Roberts et al, 2001: Clasen and Bastable, 2003; Oxfam, 2008; CDC and USAID, 2009)
- hold an appropriate standard volume (Mintz et al, 1995)
- have a stable base and a sturdy comfortable handle (Mintz et al, 1995)
- allow air to enter as water is extracted (Mintz et al, 1995)
- have volume indicators and illustrations of safe water handling on the outside (Mintz et al, 1995; Oxfam, 2008)
- be of a size appropriate for household water treatment, with permanently attached instructions for using the treatment method and for cleaning the container (CDC and USAID , 2009).

Application

Jerry cans were introduced to Africa during World War II, but it was not possible to confirm when the use of jerry cans as water containers became so ubiquitous. In Southern Africa (for example Zambia and Mozambique), they were rare or non-existent in the poorer areas in the early 1990s, but were common by the time Sutton wrote in 2000. In Kenya, between 1972 and 2002, jerry cans have become the most popular vessel for water collection, displacing the tin debe and traditional gourd (Curtis, 1987; Sutton, 2000; Kutui Katua, 2002). Now jerry cans previously used to transport vegetable cooking oils are widely used in Africa, costing $1 to $5 on the open market (Sutton, 2000; CDC and USAID, 2009), approximately one-third the cost of a reasonably strong 15L metal bucket (Sutton, 2000). In eastern Uganda the jerry cans used in households used to be recycled from cans that originally contained paraffin, which brings its own water quality concerns (Sugita, 2005). However more recently cans are being bought new at markets. Jerry cans have taken on the role of vessels for both storage and collection (Sutton, 2000). There were no countries in Africa where searchers suggested that jerry cans did not exist, but Heath et al (2010) observed in urban Madagascar that there were no jerry cans of a suitable size for both children and adults to use so 15L buckets were the most common water collection vessel.

Although jerry cans are very commonly distributed by NGOs in emergency situations, there were only four documented examples of them being distributed to aid development (see Appendix 1). It seems that families purchase their own jerry cans. In Ethiopia, Coulter (undated) found that poorer households are unlikely to be able to afford more than one or two jerry cans, and in eastern Uganda purchasing a recycled jerry can is an investment for most households and does not occur very often (Sugita, 2005).

Case Study: Madagascar

Foldable jerry cans and disinfectant were distributed to households in Madagascar following Cyclone Hudah. Of 123 households surveyed, 76% reported they were using the jerry cans but only 43% were observed using them. This disparity could be due to the difficulty of emptying water from the flexible jerry can. The simultaneous promotion of water treatment items makes it hard to separate out the effects of the improved storage, but it was found that E coli counts were significantly lower in jerry cans than in buckets (Mong et al, 2001).

Technical success

Jerry cans meet almost all of the criteria described in Box 1 apart from having a spigot. If old vegetable oil cans are used, they are cheaper than purpose designed water storage vessels, though care should be taken to avoid containers previously used for toxic products like fuel or pesticides (CDC and USAID, 2009).

Studies in emergency situations have found greater incidences of either cholera or diarrhoea or higher faecal coliforms in stored water in groups using wide necked or lid-less water storage containers (Deb et al, 1986;, Mintz et al, 1995;, Ogutu et al, 2001; Roberts et a, 2001; Quick et al, 2002), although Roberts et al (2001) did not find a reduction in diarrhoea in adults, only in under-fives.
Both Sutton (2000) and Sugita (2005) found that per capita water use could be increased with more jerry cans. This would be a simple and cheap intervention.

Indigenous pots earthenware or tin vessels are advocated by Oxfam (2008), although they recognise that these may not be as durable, cheap, lightweight or hygienic as jerry cans (Mintz et al, 1995). Crampton (2005) stated there was a balance between a jerry can which is hard to clean versus a bucket where hands can easily contaminate the water.

Financial success

Cost is probably the main barrier to uptake of jerry cans, even though Mintz et al (1995) argues that the savings in medicals costs of safe water storage outweigh the investment in suitable vessels. If vessels are constructed locally, market forces might promote their success. Quick et al (2002) also found in peri-urban communities in Zambia that the cost of advanced water storage vessels was the main barrier to uptake.

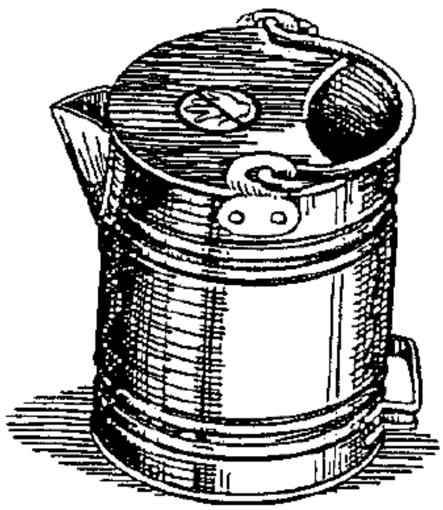

Figure 7: Improved bucket with lid, from Roberts et al, 2001

Social success

Roberts et al (2001) did a trial in a refugee camp in Malawi which involved families trading their standard issue bucket for an improved bucket with a lid (see Figure 7). At the end of the trial only 8% of households wanted the standard issue buckets returned, even though the buckets could not be used for washing clothes, dishes or children or for construction activities (Roberts et al, 2001). Conversely Makutsa (2001) found that clay vessels were preferred to jerry cans by 91% of households surveyed in Western Kenya.

Institutional success

There were no reports on institutional attitudes to jerry cans.

2.10 Bio-additives (to pit latrines)

Literature

Bio-additives are a new technology and as such there is not much literature on them. For example, there are no Practice Notes, which have been a key source of information for other technologies in this review. The literature that exists is polarised between the distributors who are trying to market the products, and other authors, speaking at conferences and even publishing peer reviewed literature on laboratory and field trials which show the technology does not do what the distributors claim. Some of the distributors, particularly those working in South Africa, asked to remain anonymous as they had already received threats for being white professionals working in black areas.

Description

Manufacturers claim that pit latrine additives are combinations of microbes, enzymes, nutrients and chemicals that accelerate the rate that the naturally present microbial communities consume faeces. This reduces the occupied volume in pit latrines by up to 30%. The additives are also claimed to reduce unpleasant odours (Woods, 2010; Bio-Systems SA, 2011; Eco-Logical Technology, 2011). One product also claims to stop larvae turning into flies, hence reducing flies in pit latrines (Sannitree, 2011).

Application

The first recorded use of bio-additives in pit latrines was by the company Avantu in South Africa in 1996. They have subsequently been used in sixteen countries across Africa, but always on a very small scale. Pit latrine additives are currently being marketed by companies based in Kenya (AfriCote, 2010; Africa BioProducts Ltd, 2011) and South Africa (for example Avantu, 2011; Bio-Systems SA, 2011; Eco-Logical Technology, 2011; Sannitree International, 2011). There seemed to be a common desire to at least initially distribute products to countries bordering the original manufacturers, and in fact this may become the principal market for small white South African companies who cannot do business in black areas (Anon, 2011; Hadley, 2011). A further barrier to scale up in new countries is finding a distributor with the financial capacity to buy in bulk (Thimba, 2011).

Technical success

There is only anecdotal evidence that pit latrine additives do indeed reduce sludge volumes. When undertaking independent trials it is important to ensure there is adequate control for the effects of the method of treatment which includes adding water and stirring the waste. During field trials in South Africa there needs to be a reliable method of assessing changes in pit volumes. Simple height measurements have been found to be subjective (WRC, 2007). Such trials in both the field and laboratory have shown that the additives have no effect on pit latrine sludge volume under anaerobic conditions (WRC, 2007; Foxon et al, 2009; Bakare et al, 2010; Nkomo, 2011;, Still and Foxon, 2011). A trial by Oxfam (undated) in Intenrlaly Displaced Person (IDP) camps in Sierra Leone found no effect on sludge volumes, but observed a reduction in flies and odour (although it is not clear how this was measured).

The Gates Foundation (2011) is funding research into additives to pit latrines at the London School of Hygiene and Tropical Medicine (LSHTM), but they have not reported any results yet.

Financial success
Despite the claims of the manufacturers, the cost of emptying a pit every five years may be substantially less than regular treatment with a pit latrine additive (WRC, 2007).

Social success
There are no reports on the social side of bio-additives.

Institutional success
It is claimed that "Avantu" is recognised by African governments, WHO and UNICEF (AfriCot,e 2011). Letters from the Department for Water Affairs and Forestry confirm this is the case in South Africa (Kempster, 2007). "Pit King" is approved by the Kenya Bureau of Standards and the Ministry of Public Health and Sanitation (Thimba, 2011). Another company claimed they had not sought any government approval for the product in South Africa because this process would be costly and customers were satisfied that the product worked. In Lesotho their product received an 87% rating by the Department of Health, although the rating criteria were unknown to the company despite enquiries. In other countries it had been approved on the basis of the Material Safety Data Sheet provided by the company (Anon, 2011).

2.11 VIP Latrines
Literature
Both grey and academic literature was used to construct this section of the review. There were fewer examples reported than initially expected and Dumpert et al (2009) explains that there were few evaluations completed beyond Zimbabwe's neighbours. Also many of the recorded interventions were before the advent of the internet, so it may be that reports generated from them have never been published online.

Description
The VIP latrine is a development of a conventional pit latrine that resolves the two issues of flies (minimized by means of using a mesh filter) and odour (by means of a vent pipe to divert smells), (IRC, 1983). These developments can be seen in Figure 8.

In Kumasi during the 1970s, there was a high dependency on public toilets. Hence the Kumasi Ventilated Improved Pit Latrine (KVIP) was developed. This has two pits so that the contents of one pit can decompose whilst the other is in use (Saywell & Hunt, 1999).

Another variation is in the Volta Region in Ghana where there is a high water table. People rely on shallow hand-dug wells for domestic purposes, and hence unlined latrines pose an unacceptable risk to water quality. The response was to adapt the VIP latrine which resulted in the creation of the "Volta Watertight VIP Latrine (VVIP)" (Dadie-Amoah, 2000). Which is what??

According to Brikke & Bredero, (2003) indicative initial costs, which include materials (60-80%), transportation (5-30%) and local labour (10-25%), vary from $70-400 for a single pit VIP family latrine to US$200-600 for a double-pit version.

Application
The Ventilated Improved Pit Latrine (VIP latrine) was developed by the Blair Research Laboratories in Harare, Zimbabwe between 1973 and 1976 (IRC, 1983). Its first application was in Zimbabwe (UN, undated.), and this is one of only two countries where it has gone to scale, the other being Lesotho (Dondo & Scott, 2006; Black and Fawcett, 2008; IRC, undated). Both of these cases are described in more detail below. VIPs have been constructed in at least five other countries in Africa, though there is no evidence of scale. With the exception of Ghana, every country with VIPs is geographically close to Zimbabwe

where it was originally developed, an observation supported by Dumpert et al (2009). In every country with VIPs they have been supported by the government, both in terms of promotion and financing. This support may even have been to the detriment of improved sanitation access, for example, in Zimbabwe NGOs lobbied the government to relax the high standards for sanitation technologies which were unaffordable to the poor (UN, undated). This also proved to be the failure of the VIP latrine introduction to Mozambique, where in addition people do not like the idea of emptying latrines and defecating in a roofed house (IWA, 2007).

Case Study: Zimbabwe

The Ministry of Health initially identified the VIP latrine as a key technology, but rural households did not share their enthusiasm and uptake was limited. A network of health workers was mobilised to promote and build Blair latrines on commercial farms and at government offices, health clinics and small towns around the country. As a result, between 1975 and 1980 tens of thousands of Blair latrines were constructed and many government staff became familiar with this new sanitation technology (Dondo and Scott, 2006). However, despite the success of the VIP latrines, only 31% of the rural population has access to adequate sanitation. This low coverage is probably related to the relatively high cost of the standard brick VIP design. The government's subsidy system was neither sustainable nor capable of achieving universal sanitation coverage. Both the size of the individual subsidies and the overall cost of the subsidy programme have been too high (Morgan, 2011).

NGOs in Zimbabwe have developed lower-cost VIP latrine designs, without sacrificing the durability of previous models. They are also experimenting with smaller subsidies. The Mvuramanzi Trust, for instance, has promoted a cheaper design, which requires one less bag of cement, and asked the household to provide one bag of cement and some other materials previously provided in the subsidy. This approach has managed to reduce the latrine subsidy by as much as 50% (Morgan, 2011).

In 2010 the Government of Zimbabwe relaxed its technical policy guideline for family toilets (the spiral brick Blair VIP) to include an additional design called an Upgradeable BVIP (uBVIP). In this version the basic requirement is for a brick lined pit and covering concrete slab, which allows the owner to upgrade in a sequence of steps to attain the final brick built Blair VIP (Morgan, 2011).

Case Study: Lesotho

UNDP, UNICEF and the government initiated a small-scale pilot project in 1983 which became a national programme by 1986 (Dondo and Scott, 2006). The government finances the training of toilet artisans, but households fully cover the costs of construction (Black and Fawcett, 2008). The project has been successfully scaled up because communities and women have been fully involved in planning, construction and maintenance and there has been long-term planning and improved collaboration among donors. Credit schemes were available and the private sector was supported (Dondo & Scott, 2006).

Technical success

VIP latrines are classed as improved sanitation (JMP, 2010). However, the typical mud-brick superstructure generally has a relatively short design life and frequently has collapsed by the end of the rainy season. Whilst the structures can be rebuilt during the dry season this is not always the case, especially when the PVC ventilation pipe has broken as it is expensive and hard to source (Dumpert et al, 2009). VIP latrines are also technically infeasible in high density population areas (Iwugo, 1981)

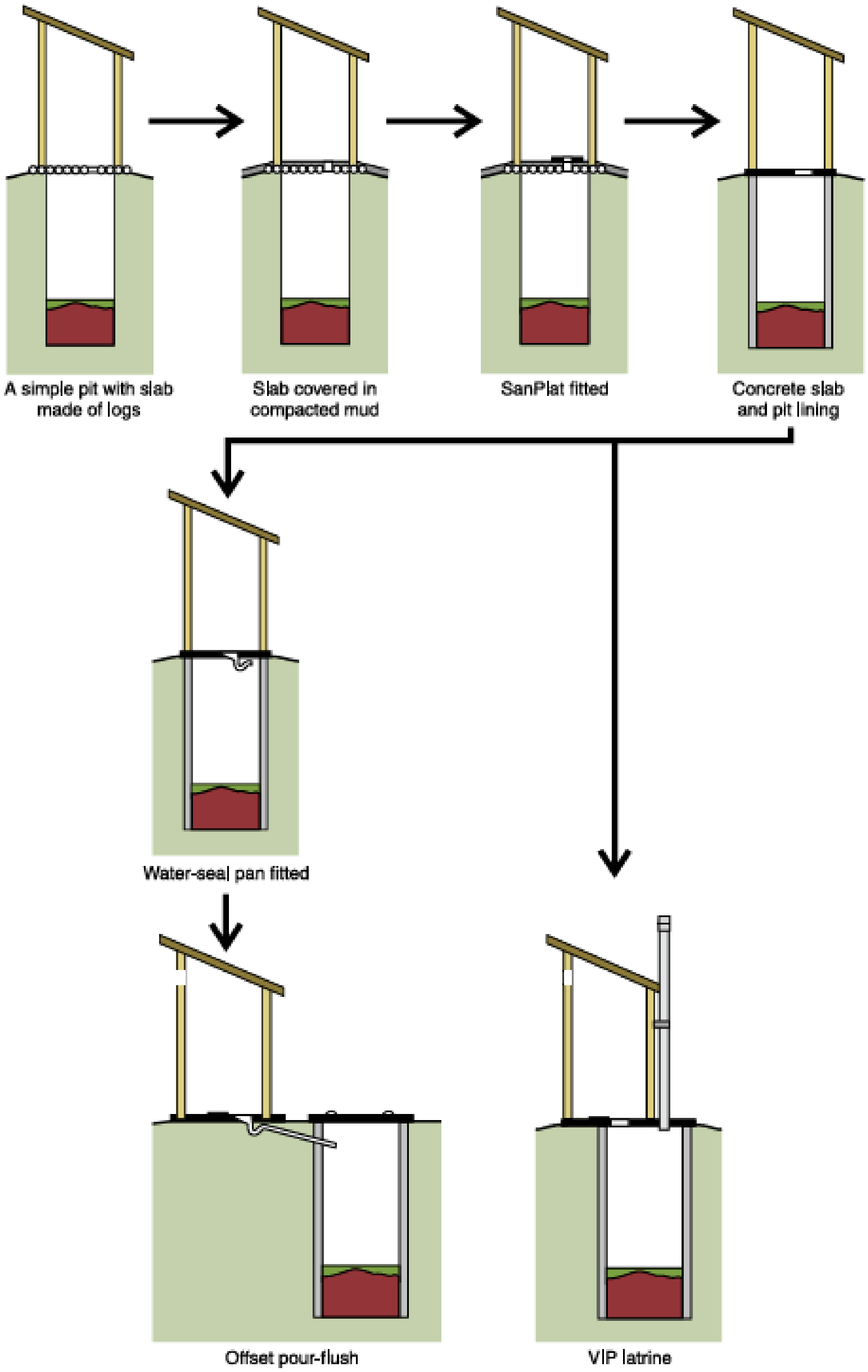

Figure 8. Incremental improvement to sanitation facilities, resulting in the VIP latrine, (WELL, 1998)

Financial success
VIP latrines are unaffordable to poorer communities as the materials are expensive and hard to source (UN, undated). Detailed cost analyses reveal that VIP latrines are more expensive than simplified sewerage in high density areas (Sinnatamby, 1986; Mara, 2005).

Social success
The design of most VIPs makes them inaccessible to disabled people (WELL, 2006); however, there is no evidence that they are not accepted by the majority of users.

Institutional success
VIPs have been promoted and financed by several southern African national governments.

2.12 Urine Diverting Dry Toilets
Literature
Urine Diverting Dry Toilets (UDDTs) were widely described in a variety of sources. However, the case studies on the website of the Sustainable Sanitation Alliance (SuSanA) were an excellent resource, describing and evaluating the introduction approaches in detail. There was more detail than could be included here. The SuSanA website also gave reasonably comprehensive details on programmes of UDDT introduction as few examples were found that were not documented here. The journal “Sustainable Sanitation Practise” provided more summarised material appropriate for this review.

Description
Urine diverting dry toilets collect urine separately from faeces and water. The urine is collected in a bowl in the front of the toilet pedestal or squatting pan, and drained into a storage container. Urine is a quick acting fertiliser, which can be applied to fields as long as good hygiene practices are used by the applicator (washing hands after use, etc). It should not be applied directly on to the plant as it can burn the leaves (GTZ, 2009).

For faeces there is a straight drop into a vault or bin. A vent pipe removes odour and speeds up the drying process (GTZ, 2009). Ash, lime, sawdust or earth may be added to lower the moisture content and raise the pH. If the UDDT is specified correctly for the number of users, it should take about one year for the vault to fill up. If it is a double vault latrine, at this point the vault is sealed and left for a further year to dry and for pathogens to decrease. Faeces collection can then be done using the other vault. If it is a single vault latrine the material must be removed and further dried elsewhere. Then it is possible to use the dried faeces as a solid fertiliser. Urine can be used immediately as fertiliser (Wafler and Spuhler, 2011)

Meinzinger et al. (2009) found in Ethiopia that UDDT costs are favourable in comparison to pit latrines, both for the initial investment and operation and maintenance costs. Their analysis assumed there was no income from selling fertiliser or increasing crop production. However other authors (for example Nyambe et al, 2010) using data from surveys, found UDDTs to be much more expensive than conventional pit latrines and hence unaffordable to households.

Application
The first UDDTs to be introduced to Africa were in 2000, simultaneously by GTZ, EEPCO and Ecosan Club (Shayo, 2007; Muellgger et al, 2009; Werner et al, 2009) and they now exist in at least 14 countries. GTZ and the EU have been key drivers of UDDT introduction; NGOs have only played a small role. Interestingly, no new installations have been documented since 2008. In most countries, they are still limited to tens or hundreds of installations, financed by external donors, with users contributing only in kind. Many are

billed as pilot or demonstration units, and are often in schools with the rationale that they are then used by large numbers of school children who may encourage their family to invest in the technology. The key exceptions are Namibia, where in addition to 1200 installed units, 100 self build kits have been sold to private users (Kleeman, 2011) and South Africa, where there are 75000 UDDTs installed in eThekwini (Roma et al, 2011). Interestingly, scale-up has been achieved here not through the private sector or self-supply as is often cited, but through municipality investment, as water and sanitation are free services in South Africa under post-apartheid policy.

Technical success

UDDTs attempt to address the problem of emptying pit latrines in peri-urban areas – a problem for which there are few proven solutions. It prevents uncontrolled discharge of wastewater which can pollute water bodies and impact ecosystems and human health. It also prevents the loss of valuable nutrients and trace elements contained in excrement and minimises the use of chemical fertilisers. There is the potential for small businesses to develop to provide ecosan services. Ecosan is a holistic, interdisciplinary approach incorporating hygiene, water supply, sanitation, resource conservation, environmental protection, urban planning, agriculture, irrigation, food security (Werner et al, 2009). It also requires no water to flush toilets and is odourless (if used correctly) so it can be used indoors (GTZ, 2009).

However, the removal, treatment and transportation of the waste are still issues which need careful consideration particularly in peri-urban environments which may be some distance from agricultural areas (Cross, 2002; GTZ, 2009). Space is also required to construct the toilets.

Financial success

There is still some debate about whether UDDTs are more expensive or the same price as improved pit latrines, however there is still a high cost barrier to uptake and the potential to offset costs with waste reuse has not yet been realised. Other ecological sanitation options may be cheaper.

Social success

Users need to change their behaviour in order to use ecosan toilets. For example, men need to sit down to urinate in pedestal urine diversion toilets and all users need to sit further back to ensure anal cleansing water can be collected separately from faeces where dry ecosan technology is promoted. Finally there needs to be social acceptance of the use of human waste in agriculture (GTZ, 2009), which can be a problem in cultures that believe toilet shelters and waste are homes to supernatural beings (Camara, 2009).

The UDDTs that have been installed are still used, with only one case (Mali) where they had been abandoned entirely (Werner et al, 2009). However, reuse is non-existent or limited in nine of the fourteen countries, including both of the large scale examples (Namibia and South Africa) mentioned above.

Institutional success

Ecosan principles have been integrated in national sanitation policies in Senegal (Camara, 20009), South Africa (Roma at a,l 2011) and Ethiopia (Meinzinger et al, 2009). Policies in other countries are unknown, but reuse of waste is specifically banned in Zambia (Nyambe et al, 2010), although WSUP and IESTO are working to change the policy.

2.13 Gulper

Literature

Despite the fact that there are only two places where the gulper is being used, both on a very small scale, there is a surprising amount of literature about it. The gulper certainly has the potential to fill a gap in the sanitation chain, and as such it has been written about with great excitement. However, as yet there are no evaluations of its performance technically, socially or institutionally.

Description

The gulper was originally designed by Stephen Sugden in Tanzania (Tilley et al, 2008; WaterAid, 2009). The gulper is a simple hand pump comprising of a stainless steel puller rod and valves and PVC pipes and fittings for the main body. Operated by either one or two workers remaining at the surface, the pump is lowered into a pit latrine until the footrest is at ground-level. The worker(s) pump the handle causing the sludge to rise through the base of the pump, through a pipe and into the collection point, which can be a bucket, bag, barrel or cart. Three litres of sludge can be extracted with every stroke. The waste can then be disposed of with little mess or danger to the worker (AKVO, 2007).

Application

Gulpers are currently in use in Tanzania (SHARE, 2011) and Malawi (Magoya, 2011). The original design has been further developed and ten have been manufactured in Kenya, however they cannot be used until other components of the system have bene completed, namely the sludge reception tanks at the transfer station (Wilson, undated).

Case study: Tanzania

The Gulper has been used successfully in the informal settlements of Dar es Salaam, Tanzania. A small business operated by a team of two has the capacity to empty 3 pits daily using a gulper in combination with a motor tricycle. Overall the initiative has been low-cost and effective, but over 2000 gulper teams will be required to serve all of Dar es Salaam (SHARE, 2011).

Technical success

This technology has significant advantages in densely populated urban areas where the practice of covering a full latrine and relocating the superstructure is often not possible. Alternatives (for example the vacutug) cannot access dense settlements and are expensive (Tilley et al, 2008; WaterAid, 2009). The gulper can also be used in remote locations where mechanical methods are not available (Water Aid, 2009).The gulper reduces health risks compared to other manual pit emptying systems. It is also a quicker solution (Ideas at Work, 2007).

However, the gulper is not able to empty the pit latrine or septic tank completely, and is not totally spill-poof, so the gulper teams need to wear protective equipment including plastic suits that cover the entire body and head, goggles, and heavy duty gloves. They should also line latrines, work area and floor outside latrines with plastic to prevent waste from dirtying the latrines and the ground outside (Kent, 2011). Oxfam have stopped their trials on the gulper as they found a cheaper alternative (Bastable, 2010). The gulper cannot transport the sludge as well so a separate technology has to be used.

Financial success

The gulper has not yet been used at sufficient scale to test its financial success.

Social success

The gulper has not yet been used at sufficient scale to test its social success, but there is a lot of social stigma surrounding pit emptying in general.

Institutional success
The gulper has not yet been used at sufficient scale to seek government approval.

2.14 Tippy tap
Literature
Mainly grey literature was used for this review and there is little information available on this topic in the academic library. Information on how to build a tippy tap is abundant, but there are few details on where they have been introduced and at what scale. In addition, they are often not branded "tippy taps" – they are simply described in a similar way to below, making it hard for references to be picked out using standard searching techniques. As such, Appendix 1 should not be treated as comprehensive.

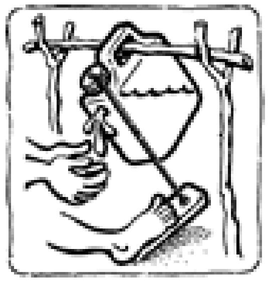

Figure 9: A tippy tap from Tippy Tap (2011)

Description
The tippy tap (also known as Mukombe) is a simple device for hand-washing with minimal use of water. It is essentially a suspended water container (e.g. a jerry can) with a small hole to let water out and a rope or foot pedal to enable tipping (see Figure 9). It provides a cheap and potentially convenient means of washing hands after latrine use with no need for running water. The water container does not need to be touched, which prevents disease transmission (Biran, 2011), and the soap bar can be conveniently hung from a rope.

Application
The tippy tap was designed in the 1980s by Dr. Jim Watt of the Salvation Army in Zimbabwe (Biran, 2011). Tippy taps are documented in six other countries in Africa. Tippy taps have usually been promoted alongside other health messages, and even alongside bigger sanitation projects (Kenya Water for Health Organisation, 2008; Blume, 2009). There is no evidence of them going to scale, or being incorporated into government policy.

Case study: Uganda
In Uganda health workers and village-level volunteers provided health education and carried out household inspections which provided information on use of tippy-taps. The key findings of Biran (2011) regarding adoption and sustained use of tippy taps are as follows:

- The acquisition of tippy taps seems largely driven by the combination of educational messages and instructions from the Health Assistants and the possibility of inspection.
- Dissemination of information about the tippy-tap between villages and even between households within villages is limited. In villages where tippy taps have not been promoted most respondents are unaware of the tippy-tap.
- Awareness of the tippy-tap does not necessarily translate into immediate action to obtain one. Some households were aware of the tippy-tap but had never owned one.
- The tippy tap situated near the latrine is mostly used. It is believed that householders' post-latrine hand-washing rates had increased as a result. It seems likely that tippy-taps provide both convenient water and soap and a salient cue to wash hands although health workers found empty bottles during household inspection.
- After a decade of educating villagers of the health benefits of the tippy tap; progress has been slow. The design of the tippy tap is basic but extremely effective. The response of the villagers has been mixed towards the tippy tap.

Technical success
Tippy taps will only have a health impact if individuals are motivated to use it, and indeed to use it out of habit (Verplanken and Wood, 2006; Coombes and Devine, 2009). Research

shows that low hand-washing rates (e.g. 10% after cleaning up a child in rural Nigeria) is caused by a lack of habit (PPPHW, undated.). The tippy tap itself acts as a reminder to wash hands (Curtis *et al*, 2005; Devine, 2010; USAID HIP, 2009), although it always needs to be there and working, with water in and soap available (Verplanken and Wood, 2006).

Research shows that a person washing hands under a tippy tap uses less than 10 times the amount of water than when water is accessed by other means (WaterAid Australia et al,, 2010; Biran, 2011).

Financial success

Tippy-taps are made of locally available materials (USAID HIP, 2009). Due to wear and tear, tippy taps need to be replaced yearly (Biran, 2011). It is simple and cheap to construct a new one and it can be fun for children (e.g. Zhang, 2010). Akvo (2011a) estimate that the maximum a tippy tap would cost if it was constructed from new materials is $4.

Social success

Children like using tippy taps. They may waste water playing (e.g., USAID HIP, 2008; Biran, 2011), but the tippy tap can have an important role in nurturing the hand-washing habit in children (Biran, 2011).

Tippy taps were found to be preferred in rural areas because in urban areas there may not be space inside or outside the houses and vandalism and theft may occur (USAID HIP, 2008; Biran, 2011). In the poorer rural areas, soap may be hard to get hold of or unaffordable (Coombes and Devine, 2009) but there are alternatives as presented by Bloomfield and Nath (2009) such as using mud, soil or ash (USAID HIP, 2008; WaterAid Australia et al, 2010).

The need for regular replacement may lead to a decrease in the number of users if households lack the motivation to carry this out after visits by health workers and village health committee members cease (Biran, 2011).

Institutional success

There is no evidence they have been incorporated into government policy anywhere.

3 Reflections and Recommendations for the WASHTech Consortium

There seemed to be no pattern for technology adoption across the different technologies – technologies are introduced by different organisations, with different funding mechanisms and different reasons for either successfully scaling up or remaining at the pilot stage. This may be due to the wide range of technologies that were selected for the review. However, there are some general observations:

- **Commercial Interest**: All the technologies that are produced commercially and imported (India Mark II, Playpump, Lifestraw and bio-additives) got government approval. This may be due to the fact that they have the resources and the contacts to complete the approval process. However, their scale-up relied on government funding as well, and this was only achieved by the India Mark II. However there are further examples of imported technologies that have not received approval from governments.

- **Appealing to naive donors:** The market for Playpumps and Lifestraws is really people and organisations in the developed world who donate to charity. They are captivated by a technology that could “solve” Africa’s water “problems” and are inspired to donate money to distribute a particular technology, rather to support a more generic water and sanitation programme. Their opinions are consolidated by the numerous awards that these technologies have received, as well as praise in the media. This mismatch between appropriateness and popular appeal is a core issue to be explored by the WASHTech consortium.

- **Capital Cost and Investment Model**: Two of the sanitation technologies (VIP latrines and UDDTs) were promoted and funded by both government and NGOs but neither went to scale, in both cases because they were too expensive to be invested in by users. This is a particular problem for sanitation where intervention is required at a household rather than a community level. A few technologies relied on investment by users (hand dug wells and jerry cans). These technologies had no clear advocates but are almost ubiquitous across Africa.

- **Local Manufacture and Quality:** Technologies that are manufactured locally and are specifically designed to be low cost (rope pumps, biosand filters, constructed rainwater harvesting jars, water jetting and tippy taps) struggled to get government approval and funding and relied on the efforts of NGOs, hence they have not gone to scale. Their local manufacture helps keep costs down, but can also lead to variable quality and hence performance. Exploring how these technologies can get government approval is a key issue for the WASHTech consortium.

- **Timescales of Technology Introduction:** Even with a more globalised society where in theory technologies can be disseminated rapidly, new technologies like the gulper still only exist in small numbers, and have not yet proved their scalability. There seems to be a time lag between what is happening in the field and what is documented.

There were only a few examples of any geographical bias is the distribution of the technologies. Biosand filters were primarily found in Anglophone countries due to the policy of CAWST. Bio-additives were usually distributed in neighbouring countries to the manufacturers (Kenya and South Africa). VIP latrines are most common in countries bordering their inventor’s country of Zimbabwe.

Only two technologies met all four success criteria: hand dug wells and the India Mark II pump, and the latter only with the caveat that there was a functional maintenance system. The least successful technology was the Playpump, which was only institutionally successful, and even that was only after significant pressure was put on governments by non-conventional donors. Jerry cans and the gulper only met one success criteria (technical success); they may meet other success criteria but further research is required.

Most technologies were technically successful – the only failures were bio-additives and Playpumps. The other success criteria were met by roughly half of the technologies.

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Appendix 1 – Technology distribution by country

Rope pumps					
Country	**Year introduced**	**Organisation introduced**	**Approach**	**Most recent update**	**References**
Burkina Faso 1	1976	Demotech			Sutton and Gomme, 2009
Ghana 1	1988		Rope pump existed, further details unknown		WaterAid 2004
Mauritania	1995	Peace Corps	Production and installation commenced		Technology Transfer Division, 2011
Senegal	Mid-nineties	Geewu Jaakaar Ji/EWV	Local manufacture of adapted design with inconsistent quality, mainly for private market	2009: >400 pumps	Sutton and Gomme, 2009, Technology Transfer Division, 2011
Zimbabwe	1996	PumpAid, Mvuramanzi Trust	Incremental introduction and local manufacture, with a focus on community participation.	2009: 4000 pumps produced	Alberts 2004, Vertesy 2006, Holtslag and Mgina 2009, Technology Transfer Division, 2011
Kenya	1998	Christian Community Services	Pilot trials using pumps provided by Nicaraguan manufacturers. Subsequently 30 local artisans trained	2009: >500 pumps	Alberts 2004 Technology Transfer Division, 2011
Madagascar 1	1998	TARATRA/SK AT-HTN	Three rope pumps installed and evaluated. Then local manufacture (in south Madgascar) was started, on a design adapted for locally available materials and previous user comments. However, the standard is variable due to the lack of jigs and fixtures in the workshop.	2009: 1000 pumps installed	Vertesy 2006, Sutton and Gomme 2009, Technology Transfer Division, 2011
Tanzania 1	1998	Christian Community Services	Local artisans trained		Technology Transfer Division, 2011

Angola 1	1999	Acción Contra el Hambre	Pilot trials using pumps provided by Nicaraguan manufacturers	Initiative halted by war	Alberts 2004, Technology Transfer Division, 2011
Ghana 2	1999	World Bank	Workshops suitable for rope pump production identified. Some materials supplied locally, some from Nicaragua.	Initially 70% repairs done by community. However 80% not functioning after one year. Government acceptance low (date unknown)	Holtslag and Mgina (2009) Technology Transfer Division, 2011
Zambia 1	2000	DFID/ Research Into Improvement of Traditional Sources	Imported pumps installed. Materials available locally but technical capacity lacking.		Alberts 2004, Technology Transfer Division, 2011
Mozambique 1	2000	PumpAid	Ten demonstration pumps built, but a different social context required a different design.		Technology Transfer Division, 2011
Mozambique 2	2001	UNICEF	Government visit to Nicaragua	Government officials unimpressed by frequent breakdowns, they were also looking for a pump for communities, not families.,	Sutton and Gomme, 2009
Mozambique 3	2002	WaterAid/CFPAS/CARE/UNICEF/DAPP/ADPP	Five producers supported	2009: 540 pumps installed 2011: National Department for Water authorised use of rope pumps	Alberts 2004, Sutton and Gomme 2009 Technology Transfer Division, 2011 WaterAid, 2011b
The Gambia	2002	Concern Universal		2003: 40 pumps produced	Technology Transfer Division, 2011
Uganda	2003	Directorate of	Small scale piloting and initial production	2009: <20 pumps	Alberts 2004, Sutton

		Water Development/ SIDA			and Gomme, 2009 Technology Transfer Division, 2011
Angola 2	2003				Technology Transfer Division, 2011
Ghana 3	2003	Rural Aid/WaterAid/ Janamese Enterprises	Provision of a market for rope pumps, training of pump members and quality control of production	2009: 1600 pumps installed 2011: 2000 pumps produced	WaterAid 2004, Sutton and Gomme 2009, Smit 2011
South Africa	2003	Ubombo Family Wells Project		2009: >200 pumps	Sutton and Gomme, 2009
Ethiopia	2005	PRACTICA/JICA/ World Vision/IRC/Selam TVC	Local artisans trained in manufacture, local water office trained in repairs. Installed at well-owner's cost. Marketing done poorly.	2009: >2000 pumps Approved by government	Sutton and Gomme, 2009, Sutton 2010a, Butterworth, 2011, Smit 2011, Sutton and Hailu, 2011, Technology Transfer Division, 2011
Zambia 2	2006	Connect International/DAPP/WaterAid	NGOs and local workshops trained in production and installation. Families given pump on credit, then pay back investment by selling vegetables in the local market.	2009: >600 pumps	Holtslag and Mgina 2009, Sutton and Gomme, 2009
Congo	2006	Solidarities/UNICEF	Initiated local manufacture	2008: Workshop now operating independently, other NGOs starting to encourage installation	Jadot 2008
Madagascar 2	2007	PRACTICA Foundation	Trained four local companies in rope pump manufacture	2009: "small number" installed	Voahary Salama 2010
Madagascar 3	2008	Centre of Renewable Energy	Training in maintenance and repair for areas not covered by water utility.	40 pumps erected and working (date unknown)	Alberts 2004, Centre of Renewable Energy, undated

Tanzania 2	2008	SHIPO	Training technicians	400 pumps installed (date unknown)	Akvo 2011b
Tanzania 3	2009	MSABI	Other enterprises offer reapir services for $3/month	2011: 150 rope pumps installed	MSABI 2011, Smit 2011
Niger 1	2010	Coca-Cola Africa Foundation	Local manufacture	2010: 53 pumps installed	The Coca Cola Company, 2010
Burkina Faso 2	2004	WaterAid	Trained manufacturers and mechanics. Also two small businesses are marketing to farmers.	2009: <100 pumps 2011: sales <50/year	Sutton and Gomme, 2009, WaterAid, 2011b, Smit 2011
Malawi		WaterAid/Pump Aid/DAPP		2009: >400 pumps	Sutton and Gomme, 2009, WaterAid, 2011b
Mali		WaterAid/Oxfam	Pilot with government approval	2009: <50 pumps	Sutton and Gomme, 2009, WaterAid, 2011b
Nigeria		WaterAid			WaterAid, 2011b
Niger 2		EWV/UNICEF	Two local manufacturers	2007: 50 pumps	Danert, 2007, Sutton and Gomme, 2009
India Mark II					
Country	**Year introduced**	**Organisation introduced**	**Approach**	**Most recent update**	**References**
Benin	1970s	UNICEF	Installed pumps manufactured in Mali		Beyer 1987,
Sudan 1	1976	UNICEF	Imported handpumps installed as part of post-conflict development scheme.	1985: 850 India Mark IIs installed, programme since stopped due to escalating crisis elsewhere	Beyer 1987,
Gambia	1983	UNICEF	Pumps supplied to Department of Water Resources		Sonko and Jallow 2002
Sudan 2	1989	UNICEF	Donors agreed to write off Sudanese government debt in they invested in safe water project	1993: 6500 hand dug wells capped with India mark II handpumps	UNICEF 1993, Baumann 2000

				2000: Included in national standardisation programme	
Nigeria			Manufacture in country	2000: Included in national standardisation programme	Baumann 2000
Ghana				2000: Included in national standardisation programme	Baumann 2000
Mali			Manufacture in country	2000: Included in national standardisation programme	Baumann 2000
Togo			Manufacture in country		Baumann 2000
Uganda			Manufacture in country	2000: Included in national standardisation programme	Baumann 2000
Zambia		AusAid	Standard hand pump installed by AusAid		ZEA 2005
Playpumps					
Country	**Year introduced**	**Organisation introduced**	**Approach**	**Most recent update**	**References**
South Africa	1990s		1999: Roundabout Outdoor won a contract to supply water to all of South Africa by 2008	2011: 1106 pumps installed	Purkayastha 2009 Hayes 2011
Mozambique	2005	IFC		2010: Where villagers requested, conventional handpumps were reinstalled in place of PlayPumps 2011: 103 pumps	Obiols and Erpf 2008, Purkayastha 2009 Campana, 2010, Freschi 2010, Hayes 2011

				installed Installation programme halted.	
Swaziland	2005	UNICEF/MTN		2011: 46 pumps installed	Purkayastha 2009, Freschi 2010, Hayes 2011
Zambia	2007		Government subjected to non-traditional donor pressure to sign an MoU with PlayPumps International. Some pumps installed without consulting local governments	2011: 29 pumps installed Installation programme halted.	UNICEF 2007, Purkayastha 2009, Freschi 2010, Hayes 2011
Lesotho	2008			2011: 315 pumps installed	Purkayastha 2009, Freschi 2010, Hayes 2011
Malawi	2008		Government subjected to non-traditional donor pressure to sign an MoU with PlayPumps International, to replace Afridev pumps. No capacity for maintenance in District Water Offices; relationships with communities negatively impacted.	2011: 288 pumps installed, at least 2 have been abandoned and 2 uprooted by communities. Government ordered NGOs not to install any more pumps.	UNICEF 2007, Purkayastha 2009, Freschi 2010, Hayes 2011, Phiri and Molaro 2011, Songola and Byrns 2011
Biosand filters					
Country	**Year introduced**	**Organisation introduced**	**Approach**	**Most recent update**	**References**
Ethiopia	1999	Samaritan's Purse/ Kale Heywet Church/Oxfam	Households had to provide transport and labour for the biosand filter, and received training in its operation and maintenance.	2006: No government support for biosand filters yet 2011: >14156 filters	Earwaker 2006, Ngai 2011, Samaritan's Purse 2011
Kenya	1999	Aqua Clara International/ Bushproof/Medair/Friendly	Filter mould supplied to local NGO. Two technicians trained and established business after Medair withdrew.	2011: >6857 filters	Grassroots Wiki 2009, Ngai 2011, Samaritan's Purse 2011

		Water for the World/Running Water International/ Samaritan's Purse and others			
Sudan	2003	Medair/IRC/Tearfund and others	Model filter installed in compound of village chief. Filters then constructed even when situation was too dangerous for ex-patriot staff.	2011: >2024 filters	Biosandfilter.org 2004 Ngai 2011
Ivory Coast	2005	MAP International	Provided 800 biosand filters	2011: Thousands of filters	Ngai 2011, MAP International 2011
Niger	2006	Samaritan's Purse	Project includes health and hygiene education	2011: 1000 filters	Samaritan's Purse (undated), Samaritan's Purse 2011
Ghana	2008	Hydraid	Plastic biosand filters	2008: 115 filters, achieving 97% E Coli removal	Hydraid (undated)
Cameroon		College Agricole Bullier/Thirst Relief/Livlieho od/ Life and Water Development group and others	Thirst Relief: Built 500 filters, teaching households how to build and maintain them, with three full time technicians	2011: 3219 filters	Ngai 2011, Thirst Relief International (undated)
Nigeria		Nappan Project/Rural Africa Water Development Project		2011: >1760 filters	Ngai 2011
Mozambique		Bushproof/ Samaritan's	Filter mould supplied to local NGO		Grassroots Wiki 2009, Ngai 2011

		Purse/Medair			
Angola		Development workshop		2011: Hundreds of filters	Ngai 2011
Namibia		COSDEF		2011: Hundreds of filters	Ngai 2011
Malawi		Samaritan's Purse/South Lunzu Anglican Church/St John the Evangelist Anglican Church		2011: >125 filters	Ngai 2011, Samaritan's Purse 2011
Zambia		SHIP/National Housing Authority	Initial programme recently expanded to build a factory with the potential to produce 5000 filters per year, removing previous bottleneck of sand washing.	2011: >6691 filters	CAWST 2010, SHIP 2011
Tanzania		Serving our Neighbour International/ Maisha na Maji and others		2011: 3868 filters	Ngai 2011
Madagascar		Bushproof/Medair	Filter mould supplied to local NGO		Grassroots Wiki 2009, CAWST 2010, Ngai 2011
Uganda 1		Bushproof/Divine Waters/Connect Africa/Samaritan's Purse/Water God's Way and others	Filter mould supplied to local NGO. Villagers prepared own filter media, but this was not successful	2011: >9523 filters	Grassroots Wiki 2009, CAWST 2010, Ngai 2011

Congo		Bushproof	Filter mould supplied to local NGO		Grassroots Wiki 2009
South Sudan		Bushproof	Filter mould supplied to local NGO		Grassroots Wiki 2009
Sierra Leone		Goal/World Vision	Evaluation found more follow up required	2011: 394 filters	CAWST 2010, Ngai 2011
Zimbabwe	2010	ActionAid/One Way Ministry/Single Paretns and Widow(ers) Support Network		2011: >2185 filters	ActionAid 2011, Ngai 2011
Uganda 2		Technology for Tomorrow	Commercial company	2010: 200 filters sold	Juuko 2010
Burundi		Quakers	Entrepreneurship workshop	2011: orders for 30 filters received	Henrysson 2011
Equatorial Guinea		UNICEF		2011: Tens of filters	Ngai 2011
Mali		Hands Across the Nations		2011: Tens of filters	Ngai 2011
Rwanda		Life and Water Development Ministries/ Rwandese Health Environment Project Initiative/ The Emmanuel Foundation		2011: >334 filters	Ngai 2011
DRC		Heaven's Family			Ngai 2011
Burkina Faso		Samaritan's Purse		2011: 296 filters	Samaritan's Purse 2011
Hand dug wells					
Country	**Year**	**Organisation**	**Approach**	**Most recent update**	**References**

	introduced	introduced			
Ghana	1920	Various government departments	1920: Geological Survey Department offered advice on where to site wells. 1970: Communities below 500 inhabitants are helped to construct hand dug wells by the government.	1999: 50000 hand dug wells (66% used for drinking) 2006: Dug wells are a permissible source of water	Gyau-Boakye and Dpaah-Siakwan 1999, Ghana Districts 2006
Tanzania - Morogoro	1978	Ministry of Water and Energy/DHV consulting engineers		1984: 811 wells constructed	DHV Consulting Engineers 1984
Zimbabwe	1980	Ministry of Health + NGOs		2005: Protected wells are a legitimate technical water supply option	Dyer, (undated), Watabe (undated), Magrath 2006
Sierra Leone	1980	CARE	Provided assistance to communities to construct hand dug wells, VIP latrines and provided community-based environmental health education. Wells not in use were in villages where health education received a low priority	1991: 42% wells not in use 2006: Hand dug wells included in the policy of the Sierra Leone Water Company and the Water Supply Division of the Ministry of Energy and Power	CARE 2004, Magrath 2006
Somalia				1984: 17000 hand dug wells	Louis Berger International 1986
The Gambia	1988	UNDP	Wells constructed, however, they are more suitable for agriculture than drinking because of their location.	1992: 150 wells constructed. Only 4 of 20 wells tested met WHO standards.	PPEU 1992
Sudan	1989	UNICEF	Donors agreed to write off Sudanese	1993: 6500 hand	UNICEF 1993,

			government debt in they invested in safe water project	dug wells capped with India mark II handpumps Hand dug wells Technical Guidelines published	UNICEF 2009
Liberia	1990	International relief agencies, including Tearfund	Communities participate in well siting, Tearfund or their partners provide oversight to construction. Communities manage completed wells.	1995: 300 dug wells complete with handpumps. 37% ran dry or had reduced yield during dry season 2009: Protected dug wells included in Liberia's Water and Sanitation Policy 2010: 285 wells constructed, 92% functional, used and regularly maintained by the communities 2010: 796 hand dug wells fitted with hand pumps constructed	Gehrels et al 1995 Liberia's Water and Sanitation Policy 2009, Burt 2010, Myers 2010, Greaves 2011
Malawi			Malawi Social Action Fund disburses funds directly to Community Project Committees, who engage local contractors. The District Water Office provides training and technical supervision.	1990: 3500 protected hand dug wells with pumps installed 2005: Protected wells are a legitimate technical water supply option	Chingoli 1998, Vezina 2002, Magrath 2006
Kenya -Kanduyi		Ministry for		1994: 130 hand dug	Ligale 1994

		Land Reclamation, Regional and Water Development		wells	
Uganda - Kabarole		Water for Survival	Decisions made in collaboration with the community, local labour used.	1995: 105 wells completed	La Roche (undated)
Nigeria	1996	Nigerian Guinea Worm Eradiation Program	As part of a guinea worm eradication programme, villagers were encouraged to dig their own wells with NIGEP providing sand and cement.	1998: 400 hand dug wells constructed 2007: 2280 dug wells in Abeokuta, Nigeria, 10% with handpump 2011: National Code of Practice for Water Well Construction in Nigeria in place, but needs to be implemented and enforced.	Miri et al 2010, Bamgboye 2011, Oluwasanya et al 2011
Malawi – Salima	1999	WaterAid		2011: 203 hand dug wells constructed	WaterAid 2011c
Mozambique	2000	WaterAid	Finance provided	2003: 146 protected wells constructed, only 2 in disrepair 2001-5: Protected wells not longer permitted in government Implementation Manual.	Magrath 2006
Ethiopia	2001	Government, WSP, UNICEF, RWSN	Government implemented the National Water Resources Management Policy, Water Sector Strategy, and Water Sector Development Programme. The wells	2006: 90 000 new hand dug wells in Oromia (although not all successful)	Vezina 2000, ODA 2009, Ayenew 2010, Sutton 2010a

			are constructed by contractors, although in smaller communities they would dig to the water table. Around 1000 wells were funded by Ethiopian Social Rehabilitation and Development Fund. 600 were funded by A Glimmer of Hope Foundation working in partnership with Oromia Development Association.	2010: Government to focus on low-cost technologies including hand dug wells to meet universal access target by 2012.	
Kenya - Bumala		Kenya Finland Community Supply and Sanitation Programme/Water Resources Management and Development Ministry		2004: 163 hand-dug wells	Karua 2004
Mali			Self supply. Payment for well digging is increasingly common. Some government financed wells.	2005: 4498 wells constructed with government funds 2010: 200 000 unlined traditional wells. 42% dried up at least once in the previous year, 21% had been redeepeened. Large diameter lined wells with pulleys are considered by the government for isolated communities and	WaterAid 2005, Sutton 2010b

				pastoralists	
Zambia		Africare, Care International and World Vision International, UNHCR	UNHCR initiative to invest in refugee host communities, including digging wells with local labour.	2005: Protected wells are a legitimate technical water supply option for scattered households 2007: 7000 wells in Mansa District 2008: 5000+ wells in Chilombo	Dyer, (undated), .Magrath 2006, ICLEI 2008, Sutton 2010c
South Africa				2005: Protected wells are a legitimate technical water supply option	Magrath 2006
Niger				2006: 13000 cement lined wells	Danert 2006
Burkina Faso - Pissy		Self supply	Residents dig wells because they cannot afford the connection fee of the water utility. but they are poor quality.	2007: 1000 wells dug	Guienguere 2007
Uganda		Governments and NGOs	Wells managed through Community Based Maintenance Strategy. 3% privately financed. Government researching ways to encourage self supply.	2010: 16000 improved hand dug wells	Danert and Sutton 2010
Angola		Development workshop	In collaboration with water utility	2010: 700 hand dug wells	IRC 2010
DRC		The Hunger Strike		2011: 314 wells constructed	Hutchinson 2011
Constructed rainwater harvesting jars					
Country	**Year introduced**	**Organisation introduced**	**Approach**	**Most recent update**	**References**
Kenya 1	1970s	UNICEF and ActionAid	Construction of jars that use basketwork frame made from sticks plastered with mortar	Designs have been abandoned as they turned out to lack	Nissen-Petersen, 1999

				durability due to rotting or termite attack of the organic frame.	
Kenya 2		Roman Catholic Church and other developed agencies	Cement jars have been constructed by the hundred in Kitui district. Analysis of water quality in 13 roof catchment tanks indicated zero faecal coliform count and total coliform count which indicated that the water presented no health risk.	Failed to produce durable tanks.	McPherson and Gould 1985, Gould and Nissen-Petersen, 1999
Uganda 1	1996	Kigezi Diocese	Masons are hosted in communities to build tanks		Cruddas 2007
Uganda 2	2005	WEDA	Started constructing 200L jars, Warwick University encouraged construction of 1500L jars in 2006. Jars donated to vulnerable families.		Cruddas 2007
Uganda 3			A local women's group was trained in tank making by a Kenyan women's group and have made a large number of small (700 litre) jars to supplement their water use, particularly in the wet season when they provide the bulk of water needs. The sub $70 cost of the systems are financed by a self sustaining revolving fund.		UN-HABITAT, 2005
Uganda 4	2007	World Bank	Train masons in 1500L jar construction and business management. First few jars are fully funded by World Bank and given to AIDS and TB patients.	2007: Still trying to develop community demand	Cruddas 2007
Uganda 5		WaterAid	Local masons have been trained in the construction of rainwater harvesting jars made of locally available materials with a capacity of 1500 litres.		WaterAid, undatedb
Water jetting					
Country	**Year**	**Organisation**	**Approach**	**Most recent update**	**References**

	introduced	**introduced**			
Chad 1	1965	Peace Corps/CARE	Manual drilling, but with inadequate attention to well design, siting and construction. Despite failures, private sector has continued to jet wells as there is still a demand for cheap boreholes.	Most wells failed, so government and donors did not accept manual drilling 2009: Most common manual drilling method	PRACTICA Foundation et al (2009)
Niger	1983			1997: 1000 wells	Sonou 1997, RWSN, 2011a, PRACTICA Foundation (undated)
Nigeria	1983	World Bank/SWS	Richard Cansdale taught jetting to local teams from an agricultural project. Private drilling contractors subsequently established	2006: 75,000 wells (10 000 for irrigation)	Sonou 1997, Grimm & Richter 2006, Adekile & Olabode 2009 Cansdale 2011, RWSN, 2011a
Ghana			Agricultural Sector Investment Project	1995: >2,000 shallow wells and some 100 deep wells.	Sonou 1997
Burkina Faso				1997: 100 new wells	Sonou 1997
Madagascar	2004	Bushproof/Medair	Technique introduced from Senegal. Approximately 80% of materials were prepared by the community. Wells were constructed at a rate of 50 per week. Jetting had never previously been attempted at such a scale and speed in Madagascar.	204 new wells 2006: Jetting included as an approved drilling technique in “manuel de prodecures”	Erpf & Gomme 2005 Mol et al., 2005, Robinson et al., 2006, RWSN, 2009, 2011a, Cansdale 2011,
Sudan	2004	BushProof	Modest scale programme		Mol et al., 2005,

					Cansdale 2011, RWSN 2011a
Chad 2	2005	PRACTICA/UNICEF	Large scale capacity building programme to increase the quality of manual drilling enterprises and quality control, creating a professional manual drilling sector.	208 boreholes manually drilled	PRACTICA Foundation et al 2009, RWSN, 2011a
Senegal	1991	ATI	Hand dug wells were failing because of collapse below the water table. Richard Cansdale did 2 weeks' of demonstration. Local suit fabric used instead of geotextile.	2007: Technique still in use. <10000 wells drilled.	Grimm & Richter, 2006, Cansdale 2011, RWSN, 2011a
Uganda		Bushproof	NGOs trained		UNHABITAT, 2007
Benin					PRACTICA Foundation (undated)
Cameroon					RWSN, 2011a
Zimbabwe			Modest scale programme		Cansdale 2011, RWSN, 2011a
Tanzania			Modest scale programme		Cansdale 2011,
Kenya			Modest scale programme		Cansdale 2011,
Lifestraws					
Country	**Year introduced**	**Organisation introduced**	**Approach**	**Most recent update**	**References**
Sudan 1	2007		Lifestraws distributed and training provided in their use	2007: 647 Lifestraw Personals provided	Elsanousi et al., 2009
Ghana	2008			2008: LifeStraw family launched by Minister of Women and Children's Affairs	Ghanazone 2008, Lunde 2011, Van Beek 2011, Vestergaard Frandsen (undated),
Ethiopia			LifeStraws distributed as part of controlled trial	2009: 731 Lifestraw Personals	Boisson et al., 2009

				distributed	
Sudan 2	2008	Revel Consulting/Save the Children	Donation	2008: Lifestraws provided to 3200 hosueholds	Save the Children 2008
South Africa	2009	Ulusaba, Water For All	Distributed through Health Centre	2009: 500 Lifestraws donated	Water For All 2009, Van Beek 2011
Zimbabwe 1	2009	UMCOR		300 Lifestraws distributed	Scott 2009, Van Beek 2011,
Tanzania 1	2009	Fishingcross/Dusty Feet	Donation	2009: 1000 Lifestraws delivered	Bratcher 2010
Tanzania 2		World Serve/Rotary	Donation	10 000 LifeStraw personals	WorldServe 2010
Kenya 1	2010	CocaCola, Water For All	Donation, funded by a levy on Coca Cola products	2010: 50 000 lifestraws donated	Vestergaard Frandsen 2010,
Kenya 2	2011	Vestergaard Frandsen	Use of carbon credits to fund Lifestraw distribution	2011: 900 000 Lifestraw Families donated	Vestergaard Frandsen 2011
Zimbabwe 2		Rotary	Donation	1000 Lifestraws distributed	Rotary Club of West Fife 2011, Van Beek 2011
Liberia				Accept Guinea's government's approval	Van Beek 2011
Guinea				Approved by Food and Drug Administration	Van Beek 2011
Uganda					Vestergaard Frandsen (undated)
Nigeria					Vestergaard Frandsen (undated) Lunde 2011. Van Beek 2011
Togo					Vestergaard Frandsen (undated)
Mali					Vestergaard Frandsen

					(undated), Lunde 2011, Van Beek 2011
Burkina Faso					Vestergaard Frandsen (undated)
Niger					Vestergaard Frandsen (undated)
Cote d'Ivoire					Vestergaard Frandsen (undated)
Mauritania					Vestergaard Frandsen (undated)
Senegal					(Lunde 2011), Van Beek 2011
Angola					Van Beek 2011
Mozambique					Van Beek 2011
Jerry cans					
Country	**Year introduced**	**Organisation introduced**	**Approach**	**Most recent update**	**References**
Kenya	1972			2002: Most popular vessel for water collection	Curtis 1987, Kutui Katua 2002
Angola			Global Handwashing Day kits distributed to 700 schools		Global Handwashing Day 2011
Ethiopia	2009	Help Age International		Provided jerry cans to 60,000 pastoralists	Help Age International 2011
Senegal	2008	RAIN	Training for DRWH system beneficiaries promoted jerry cans		RAIN 2011
Liberia	2010	Solidarities	Jerry cans distributed in 11 schools		Solidarities International 2011
Bio-additives					
Country	**Year introduced**	**Organisation introduced**	**Approach**	**Most recent update**	**References**
South Africa 1	1996	Avantu	Avantu added to school pit latrines,	Project did not go	Anon 2011, Avantu

			reducing desludging costs.	well. 2011: Acknowledged by Department of Water Affairs and Forestry	2011,
Lesotho 1	1996	Avantu		1996: Avantu eradicated a cholera outbreak which resulted from pit latrines at a school	Avantu 2011
Zambia 1	1997			1997: Desludged 5200 pit latrines	Avantu 2011
Uganda 1	1998		Dosing programme implemented		Avantu 2011, Thimba 2011
South Africa 2			Website advertising, distribution by agents		Anon 2011
Kenya 1	2007	Africa Bio Products Ltd, Kenya Red Cross, Oxfam	Pit King marketed through local radio and agricultural shows.	2011: Over 50 000 pits treated Products approved by Kenya Bureau of Standards and Ministry of public Health and Sanitation.	Thimba 2011
Sudan			Struggling to find a distributor with financial capacity		Thimba 2011
Uganda 2			Struggling to find a distributor with financial capacity		Thimba 2011
Zambia 2			Website advertising, distribution by agents		Anon 2011
Zambia 3				2011: 10kg additive ordered	Hadley 2011
DRC			Website advertising, distribution by agents		Anon 2011

Congo			Website advertising, distribution by agents		Anon 2011
Gabon			Website advertising, distribution by agents		Anon 2011
Lesotho 2			Website advertising, distribution by agents	Product given an 87% rating by Department of Health, criteria unknown	Anon 2011
Namibia				2011: 10kg additive ordered	Hadley 2011
Botswana				2011: 10kg additive ordered	Hadley 2011
Madagascar				2011: 10kg additive ordered	Hadley 2011
Lesotho 2				2011: 10kg additive ordered	Hadley 2011
Kenya 2				2011: 10kg additive ordered	Hadley 2011
Cameroon					Anon 2011
Swaziland					Anon 2011
Malawi					Anon 2011
Sierra Leone					Oxfam (undated)
VIP latrines					
Country	**Year introduced**	**Organisation introduced**	**Approach**	**Most recent update**	**References**
Zimbabwe	1975	Ministry of Health	Health workers built latrines in public places to a government standard. Rural households could receive a subsidy to build a latrine, but the subsidy scheme was not large enough. NGOs introduced cheaper designs.	2010: Technical standards relaxed to include an upgradeable BVIP. 2011: More than 500,000 VIP latrines built	UN, (undated)
Botswana		UNDP/World Bank		1983: Construction Manual published by	Van Nostrand and Wilson 1983

				the government	
Tanzania				1982: 10 VIPs surveyed	Curtis and Hawkins 1982, Mara 1984
Lesotho	1983	UNDP, UNICEF Government	Pilot project to build 400 VIP latrines. 1986: Translated into a national programme, with artisans trained, private sector supported and credit available to households who cover construction costs.	1986: 600 VIP built initially, but many more constructed since	Dondo & Scott 2006, IRC (undated)
Ghana	1989	UNDP & Government of Ghana	Kumasi Strategic Sanitation Project driven by the Government of Ghana: 8 VIP demonstration toilets were built by UNDP. Households paid 20% and were loaned the rest, with an estimated recovery rate of 50-70%.	1994: 256 latrines in 3 pilot locations 2009: VIPs in poor condition	Saywell & Hunt 1999, Dumpert et al 2009
South Africa	1994	Department of Water Affairs and Forestry	Government and donor investment supported a subsidy for each household latrine as part of the government's Free Basic Services policy.	1994: VIP identified as a a basic adequate service of sanitation	Dondo & Scott 2006
Malawi		Ministry of Local Government	Sanitation Centres built to inform and demonstrate latrines. However, only 3% respondents got information from them.	2000: 5 of 100 households surveyed in Ndirande township had a VIP latrine	Grimason et al 2000
Zambia	2003	Zambia Social Investment Fund	Community contributed 25% in kind (labour, sand and crushed stones)	40 VIPs	IRC, 2004
Urine diversion dry toilets					
Country	**Year introduced**	**Organisation introduced**	**Approach**	**Most recent update**	**References**
Mali	2000	GTZ	UDDT pilot started, but aborted after non-cop-operation form municipality. Reuse was planned but there is no longer demand.	2009: 11 constructed, mostly abandoned	Werner et al 2009

Tanzania	2000	EEPCO	Pilot project. Little reuse in peri-urban area	2007: 95 UDDTs	Shayo 2007
Uganda	2000	EcoSan Club	Donor funded. Urine and faces used in local plantations	2009: 45 UDDTs in a school	Muellegger et al 2009
Mozambique	2002	UNICEF/ADA	UDDTs implemented in a resettled area following flooding. Sensitisation by radio. theatre and activities. Products not reused. 25% cost contributed in kind by owners. Toilets deliberately built to a high standard to encourage replication.	2011: 575 family UDDTs, to public toilets	Fogde et al 2011
Botswana	2002	GTZ	Households contributed superstructure. Urine and faces reused in gardens, especially after demonstration of increased productivity (control vs treated garden), however, reuse decreased with time.	2009: 42 UDDTs constructed	Werner et al 2010
Senegal	2002	CREPA	Sensitisation programme. Users contributed 10% cost in kind. Reuse is low.	2009: 232 UDDTs Ecosan integrated into Manual of the Millennium Water and Sanitation Programme	Camara 2009
Namibia	2003	GIZ, EU municipality	Donor funded installations, municipality funded installations plus some privately funded. Urine infiltrates into the ground, composted faeces can be used as fertiliser but some users are reluctant	2010: 1200 "Otji toilets" installed + 100 self build kits sold	Kleeman 2011
South Africa	2003	eThekwini Municipality	Programme implemented by municipality, no charge to users (financed by a government grant). Nutrients are not reused. Users are trained to manually empty and bury the faecal matter, or pay a private contractor. Urine is diverted to a soakaway. With such a large number of units manufacturers were able to	2011: 75000 UDDTs constructed	Roma et al 2011

			adapt designs to users' needs.		
Burkina Faso	2006	EU, CREPA, GTZ	107 local masons and 800 gardeners trained. Subsidies provided and topped up to ensure completion targets met. Gardeners now pay for urine, reuse of faces is less because of the timescales involved.	2011: 922 household UDDTs, 11 public UDDTs	Fall and Coulibaly 2011
Rwanda	2006	GTZ	Donor funded. One school reused both urine and faeces, the other only reused fertiliser.	2010: 24 UDDTs in 2 schools	Dusingizumuremyi 2010
Zambia	2006	CARE	Pilot scheme	2010: 28 household UDDTs, 2 public UDDTs Government policy only support disposal of waste, not reuse	Nyambe et al 2010
Ethiopia	2008	EU	First few toilets built for demonstration in schools and households, fully funded by the EU, remainder 75% cost met by owners. Farmers starting to demand urine.	2009: National policy and strategy including ecosan 2010: 16 UDDTs constructed	Meinzinger at al 2009, Shewa et al 2010
Kenya 1	2008	EU	Units constructed in schools. Composted faeces used in school gardens or in research.	2010: 14 UDDTs constructed	Gachwiya and Mutua 2010
Kenya 2	2008	EU, SIDA, GTZ	Toilets installed in clusters of up to 20 near to a school. Urine and faeces used in school gardens, though gardens are poorly managed.	2010: 263 UDDTs constructed in schools, 600 in households	Kraft and Rieck 2011
Tanzania	2008	EU	One unit constructed in an exhibition centre garden. Visitors considered it to be more appropriate for rural settings	2010: 1 UDDT constructed	Tendwa and Kimaro 2010
Gulper					
Country	**Year introduced**	**Organisation introduced**	**Approach**	**Most recent update**	**References**

Tanzania		WaterAid	One business developed		SHARE 2011
Kenya	2009	WSUP	Model of Gulper Mark 1 taken to Kenya workshops.	2011: Ten Gulper Mark 2s have been constructed, not in operation yet as sludge reception tanks are not yet constructed	Wilson (undated)
Malawi	2010	Water For People	Set up businesses using the gulper		Magoya 2011
Tippy taps					
Country	**Year introduced**	**Organisation introduced**	**Approach**	**Most recent update**	**References**
Zimbabwe				1988: One school installed a line of tippy taps outside its latrines.	Watt, 1988
Uganda 1	2004	Plan Uganda/USAID	Community based care providers promoted monitored and supervised tippy taps.	2008: 12 rural families and 3 urban families adopted tippy taps.	USAID HIP, 2008
Ethiopia	2004	USAID	Tippy taps provided to people living with HIV/AIDS.		Federal Democratic Republic of Ethiopia Ministry of Health, 2005, WaterAid Australia et al 2011
Kenya 1	2007	GTZ	Tippy taps promoted alongside UDDTs.		Blume, 2009
Uganda 2	2007	District Health Authority/ Agency for Cooperation and Research in Development (ACORD)	Health Assistants working with village level volunteers promoted tippy taps. The intention was that model villages would serve as examples.		Biran, 2011

Uganda 3	2009	Uganda Village Project	Materials for primary school students to build tippy taps near latrines at their schools were provided.		Zhang, 2010
Zambia	2008	Oxfam	Hygiene promoters helped the community to build tippy taps.		Woodward, 2011
Madagascar	2010	Scouts			Rakotojoelimaria *et al*, 2010
Burkina Faso	2011		Tippy tap built at community watershed workshop to wash hands before eating lunch!		Jared, 2011
Kenya 2		KWAHO	Tippy taps installed as part of bigger water and sanitation projects		Kenya Water for Health Organisation, 2008

Appendix 2A – Cited literature types

- Programme evaluation reports – if an independent evaluator is selected and permitted to report honestly then these can provide excellent critiques of the technology. However, organisations may be selective about which reports they publish, and the organisation publishing the report may have a particular motivation to promote or critique a technology.
- Resource centre websites, newsletters and reports (Akvo, IRC, RWSN) – these typically describe a range of technologies rather than focussing on one in particular. Their quality and bias depends on the contributor and to what extent contributions are reviewed.
- Instruction manuals, factsheets, guidelines, training handouts and technical briefs (Appropriate Design Choice, Community Empowerment Collective, Oxfam, WaterAid, WELL, WHO) – these present information accurately in general but typically have little discussion of whether the technology is appropriate for the particular application. Their bias depends on the motivation of the publishing organisation.
- Donor grant lists – these provide factual information about funded research or implementation programmes. They can give insight into the development strategies of promising technologies but do not report the results of the research or implementation.
- Books and book chapters – normally only academics or experienced and reputable practitioners are asked to be authors, and it is usually clear exactly who the authors are, hence it is possible to consider their motivation on a case by case basis.
- Magazine, newspaper and non-reviewed journal articles – the motivation of the authors should be considered on a case by case basis.
- Government policies – these should be an accurate statement of the policy.
- Parliamentary proceedings – the politician may be trying to put across a particular set of facts in order to win votes
- Management case studies – these are written by individuals not directly involved in the company, and as such can provide a good explanation of the company's development.
- Conference presentations – if the conference has some sort or review process then extremely biased articles may be rejected. However, conferences are excellent opportunities for self promotion which organisations and individuals may want to capitalise on.
- MSc and PhD theses – students at an early stage in their career may be open minded and unbiased. However, they may still want to report positively for their research sponsor, and the review by the examiners may not be very thorough.
- Practice notes or other reports (NGOs, World Bank, GTZ, WRC) – these tend to report examples where technologies have been taken up successfully, rather than lessons learnt from technology failure. They should be accurate, but may not report the whole story.
- Blog and forum posts – for someone to be motivated to make a blog post suggests there is an issue they care passionately about, hence there is probably significant bias. However, they are a very easy way to put information and opinion in the public domain, so can present a useful critique as long as they are considered alongside more positive information.
- Websites, papers and newsletters from Special Interest Groups (EcoSanRes, Ropepumps.org, SHARE) – if a special interest group is set up to explore a particular technology they may be biased towards it as they will be receiving funding to implement or research it – and they will want to continue to do so in the future.

- Innovation organisation websites (Ideas at Work) – whilst they will be initially open minded to ideas, they will ultimately be biased towards technologies that they are associated with.
- Personal communications, letters and interviews – these typically (but not always) criticised rather than promoted technologies. They are valuable as they can provide critique where there is otherwise none, but they may be based on personal feelings and a limited perspective rather than hard evidence. Note that these are cited as references rather than being referred to in the text as personal communications; it would be misleading to distinguish them from other sources in the text.
- NGO and UN agency websites and press releases – these typically present interventions in a positive light as they are trying to attract donations.
- Foundation websites - these typically present interventions in a positive light as they are trying to increase the Corporate Social Responsibility image of their associated company.
- NGO Grant Completion Reports - these typically present interventions in a positive light as they are trying to obtain follow on funding.
- Manufacturer or distributor websites and brochures – these present technologies very positively as they want to sell more products

Appendix 2B – Cited literature by type

Literature type	Rope Pumps		India Mark II		Play pumps		Household bio-sand filters		Hand dug wells		Constructed rainwater harvesting jars		Water jetting		Lifestraw		Jerrycans		Bio-additives		VIP Latrines		Urine Diversion Dry Toilets		Gulper		Tippy tap	
Number referred to in….	Text	Appendix	Text	Appendix	Text	Appendix	Text	Appendix	Text	Appendix	Text	Appendix	Text	Appendix	Text	Appendix	Text	Appendix	Text	Appendix	Text	Appendix	Text	Appendix	Text	Appendix	Text	Appendix
Conference presentations	2	1	1		2	2							2	2					3				1	1				
Academic paper	3	2					3		2	1	3		1		3	2	11		1		4	2	1	6			3	1
Practice notes or other reports	2	3	4	2	1		1		7	9			5	5			4	1			3	2	5	8	2	1		3
NGO press releases and websites	1	2			1		2	10	2	5	5	3				6							1	1	1		7	6
Special Interest Group websites	2	1																					1				4	3
Technical briefs and training handouts	2								2		4	1					2				4	2			1			
Evaluation reports	1	1		2	2	1			1	1				1									1	1				
MSc and PhD thesis		2					3	1																				
NGO Grant completion reports		1						1		1																		
Resource centre websites and reports		2	1				1	1		2		1	2	3					1		3	3	1		2	1		
Foundation websites		1																									1	
Blogs					2	2			1	1																		
Management case studies					1	1																						
Newspaper articles					1			1		1																		
Personal communications					2				1	1					2	2			5	5								

Literature type	Rope Pumps		India Mark II		Play pumps		Household bio-sand filters		Hand dug wells		Constructed rainwater harvesting jars		Water jetting		Lifestraw		Jerrycans		Bio-additives		VIP Latrines		Urine Diversion Dry Toilets		Gulper		Tippy tap	
Number referred to in….	Text	Appendix	Text	Appendix	Text	Appendix	Text	Appendix	Text	Appendix	Text	Appendix	Text	Appendix	Text	Appendix	Text	Appendix	Text	Appendix	Text	Appendix	Text	Appendix	Text	Appendix	Text	Appendix
Books							1				2	1	2				1	1			1							
Magazine and review articles									1	3					1											1		
Government policies and parliamentary proceedings									1	3																		
Interviews and parliamentary questions									1	3																		
Manufacturer and distributor website													1		1	2			6	6								
NGO / UN websites													1	1				3										
News media articles															1	1												
Donor grant lists																			1									
Forum posts																			1						1			
Special interest group websites																												
Innovation websites																									1			

Who is involved in WASHTech?

WASHTech is a consortium research project comprising national and international NGOs, academic institutes and training centres in Africa and Europe.

WASHTech in Africa is spearheaded by the following institutions:
In Burkina Faso:

- Centre Régional pour l'Eau Potable et l'Assainissement à faible coût (CREPA), Burkina Faso
- WaterAid Burkina Faso

In Ghana:

- Training, Research and Networking for Development (TREND), Ghana
- Kwame Nkrumah University of Science and Technology (KNUST), Ghana
- WaterAid Ghana

In Uganda:

- Network for Water and Sanitation (NETWAS), Uganda
- WaterAid Uganda

European partners include:

- IRC International Water and Sanitation Centre (The Netherlands)
- Cranfield University (United Kingdom)
- Skat Foundation (Switzerland)
- WaterAid (United Kingdom)

WASHTech is coordinated by IRC International Water and Sanitation Centre in The Hague.

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