Handpumps: where now?
A synthesis of online discussions
(2012-2014)
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Handpumps: a synthesis of online discussions (2012-2014)

Sustainable Groundwater Development: Handpump Technologies

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In 2012, RWSN established Dgroups.org as its online electronic platform for membership and discussion. The groundwater and handpump groups have been among the most active communities. The number and depth of contributions has been rich, and several members have asked for a synthesis of the discussions. Among the most active members of the group have been key staff of the original World Bank/UNDP handpump project of the 1980s and staff who have played a direct role in the development and uptake of pumps such as the India Mark II/III, Afridev, Tara, Vergnet and Blue Pump.

The key text for understanding this topic remains “Community Water Supply: the handpump option” (Arlosoroff et al. 1987). More documents on handpumps can be found on the RWSN website using the handpump filter. Further details about specific pumps can be found in the Implementation Section of the RWSN website. Also linked to this work is a handpump online survey answered by RWSN members in 2013.

The following topics have been pulled from discussions that have taken place between August 2012 and August 2014. RWSN would like to thank those RWSN members who contributed so much of their time and experience for the benefit of others. Particular thanks to Raj Kumar Daw for sharing numerous useful reports and documents and also to Tony Beers, Vincent Casey, Saul Arlosoroff, Jim Anscombe and Rowan Frederick-Matthews for numerous detailed responses.

The purpose of this synthesis is to extract the valuable insights and experiences from the discussions and present them in a way that is useful to other practitioners who are facing similar challenges. Along with the 2013 handpump survey and the forthcoming field note on handpump standardisation, it is also an opportunity to reflect and prioritise where RWSN should be focusing efforts to improve handpump services for rural people. In this summary the clear priorities that emerge are:

- The number one issue is water quality, in particular high iron levels in the water and corrosion of pump parts. Therefore, what is needed is:
  - Better testing and monitoring of groundwater quality so that GI pump components are not installed, leading to rust, build-up of iron and rejection of the water by users;
  - Clearer understanding of when high iron levels are caused by natural conditions and when they are caused by pump corrosion;
  - Replacement of GI pipes and pump rods in all existing pumps in aggressive groundwater – and to stop rehabilitation projects repeating the same mistakes;
  - Clear guidance and training for designing and operating iron filters, where they are needed;
- Greater care and supervision of contracts, procurement and installation to stop handpumps being bought and installed that do not meet the RWSN and Bureau of Indian Standards (for India Mark II) quality standards. In particular to prevent GI being installed in aggressive groundwater;
- The lifetime of a handpump can be more than 20 years if it is well made, well installed and well maintained, but often not all those conditions are met. Reinforcing this message is essential.
- There is no clear agreement on the need to improve the design of public domain handpumps, despite their limitations and known faults. However, a clear process of testing and evaluating new designs, or design modifications is needed.
- Advocacy is needed that any organisation developing a new type of pump really needs to examine its own motives: is a new pump going to reduce poverty on a large scale or is it being used as a fundraising tool because it is more tangible than tackling deeper causes of rural poverty? It also needs to be remembered that this is an old
technology and that many pumps have been invented and reinvented by many people and organisations around the world and very few have made an impact on people’s lives.

One of the areas that got relatively little attention was the concept of Village Level Operation & Maintenance (VLOM), which was a strong concept emerging from the World Bank handpump project of the 1980s. This is probably because the concept of community management itself has evolved and the need for external support (from government and/or the private sector) is increasingly recognised. In addition, the growth of globalisation means that need, or desirability, of local manufacture is not as strong as it was. Of more importance is the viability of the supply chains, the skills of the technicians and the quality control throughout the whole process. There are still major problems with handpump supplies; many of them are not new. Some may never be resolved fully due to the limitations of the service that they can deliver and the social, political, environmental and economic contexts in which they are used. There is a growing emphasis on piped schemes and the use of technologies such as solar pumping, which can provide a higher level of service but have their own costs and uncertainties. However, what is clear from the discussions from the very knowledgeable members is that handpump are important, they are used by millions of people in dozens of countries and that the priorities outlined above have the potential to make an important impact.

Disclaimer: In producing this synthesis, care has been taken to check facts and references, however we urge the reader to realise that much of what is reproduced here are opinions based on varying levels experience across many different contexts in Africa and Asia. RWSN, its partners and the contributors accept no liability for any damage caused by application, or misapplication, of the advice in this document. If you disagree with any aspects, add your experiences or ask a question then please join the RWSN community at: www.dgroups.org/rwsn
Glossary

Terms and abbreviations

- **Aggressive groundwater** – a description applied to groundwater that has a particular low (acidic) pH value and is therefore associated with corrosion of well casing pipes and pump components.
- **Aquifer** – any underground layer of water bearing rock from which groundwater can be usefully abstracted.
- **Basement Complex/Crystalline Basement** – any rock below sedimentary rocks or sedimentary basins that are igneous and metamorphic in origin.
- **Borehole** – a hole in the ground that has been drilled by mechanical or manual means for the purpose of abstracting water.
- **Direct Action / Lever Action handpump** – Lever action handpumps create a mechanical advantage for the user so are better suited to deeper boreholes. Direct action handpumps are where the user pushes the pump rod directly and though they have the advantage of simplicity (fewer parts to break) they are less ergonomic.
- **EC – Electrical Conductivity**. In context of this document: a measure of how easily electricity passes through water. It is affected by factors like Total Dissolved Solids (TDS) and salinity. Measured in millisiemens per metre (mS/m) ².
- **Flange** – a metal plate welded to the main cylinder of the India Mark II body that allows the sections to be bolted together.
- **GI – Galvanised Iron / Galvanised Steel**. A common material used for handpump parts, pipes and borehole casing. The iron or mild steel is dipped in zinc to inhibit corrosion; however, over time most GI components do rust, especially if in contact with saline or acidic water. Rust can also occur through wear or damage to the galvanised zinc layer that exposes the iron or mild steel beneath. It is cheaper than stainless steel. GI components should not be used if the pH is lower than 6.5 (page 12)
- **HDPE – High-density polyethylene**. A common plastic, often used for pipes, but less commonly available than PVC in some countries. It is rigid and corrosion resistant.
- **Iron (Fe)** – an abundant metallic element that is not harmful to human health but in high concentrations causes taste and discoloration problems. It makes water undesirable for domestic use above 0.3 mg/l but there is no WHO health-related guideline. It generally occurs in two oxidised states: Fe²⁺ (or FeII), known as Ferrous Iron, which is relatively soluble in water; Fe³⁺ (or FeIII) known as Ferric Iron, which is insoluble in an aerobic environment and causes orange discoloration in laundry and cooking.
- **Laterite** – soil layer that is rich in iron oxide and derived from a wide variety of rocks weathering under strongly oxidising and leaching conditions. It forms in tropical and subtropical regions where the climate is humid.
- **mg/l** – Milligrams per Litre (also can be expressed as mg ¹)
- **pH** - a measure of the relative acidity or alkalinity of a solution related to the hydrogen-ion concentration of the solution on a scale between 1 (Acidic) - 7 (Neutral) – 14 (Alkaline). Very acidic or alkaline substances are often highly corrosive and damage some materials. Pure water has a pH of 7, but dissolved ions can alter this.
- **PVC – Poly Vinyl Chloride**. A common plastic used for water pipes and components. It doesn’t corrode, but can weaken and become brittle if exposed to direct ultra-violet (UV) radiation in sunlight.
- **Rising Pipe, Riser Pipe** – the pipe up which water flows from the aquifer. On an India Mark II, it is the pipe that connects the pump cylinder to the water tank on the above-ground mechanism. The pump rod moves up and down within the riser pipe.
- **SS – Stainless Steel**. This highly resistant form of steel (which is itself an alloy of iron and carbon) is an alloy with at least 10.5% chromium. A major advantage over galvanisation is that the chromium is not applied as a layer, it is part of the alloy, and therefore stainless steel pipes and components aren’t subject to the same corrosion as galvanised iron (GI). Its main drawbacks for handpump are cost and availability. There are two main grades: 304 and 316. 316 contains molybdenum and has greater corrosion resistance that 304.
- **Stoichiometry** - The process or art of calculating or determining the equivalent and atomic weights of the elements participating in any chemical reaction.
- **uPVC** is a variant that is UV-resistant, stronger but is less common and more expensive.

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1 Water Quality

1.1 Summary

The number one issue discussed in both the handpump and groundwater community was water quality – in particular the issues around corrosion and high iron levels. This is a major factor affecting the quality and reliability of the service provided to water users. The anecdotal evidence from our members is that the problem is widespread and not improving. The use of Galvanised Iron (GI) pipes, pump rods, pistons and other components in aquifers with aggressive groundwater appears to be major failing by many implementers. Figure 1 shows some of the areas of the world known to be affected.

Figure 1 – Countries where RWSN members have reported problems with corrosion and/or high iron levels

It should be noted that the spread of countries is perhaps a better reflection of the spread of active members of the Groundwater and Handpump communities, where there is a strong Sub-Saharan bias, however it is clear that the problem is widespread.

The situation appears to be a combination of pump and groundwater factors. It is a serious problem because high iron levels often lead to a rejection of the water source and the users going back to less safe water sources for domestic use. If the cause is naturally high iron levels then water treatment is needed, which increases the cost and management complexity of the service, while if the cause is corrosion then the premature replacement of GI pipes and rods will be a major financial burden on the users. The problem is not new, it was encountered by the World Bank/UNDP project in the 1980s and there was no clear answer, however the consensus is best strategy for aggressive groundwater is to use PVC (or uPVC) for the riser pipe and stainless steel for the pump rods. This is the arrangement used by other pumps, notably the Agrid, U3M and Blue Pump.

1.2 Problems

Throughout 2012-14 a number of problems relating to corrosion and high levels of iron or manganese were reported by RWSN members, often sparking detailed discussions. In Northern Uganda, water pumped out of boreholes is clear, but after being stored for a few hours (covered or uncovered), the water develops yellowish-brown deposits. This happens quicker when the water is left in an open container. The water discourts food and laundry. At the time of drilling, water quality tests did not show high iron levels [Ocaya Santos Rembos, Uganda]. The consensus was that this behaviour was due to high iron (orange/brown) and perhaps Manganese (yellow) [Krischan Makowka, Uganda; Ihsan Ullah, Pakistan; Yaya Ganou, Burkina Faso; Robin Hazell, UK; Richard Carter, UK]. Dissolved minerals in the groundwater can cause corrosion or encrustation and the problem is common in boreholes drilled into crystalline basement formations throughout the world [Vishwas Joshi, India].

In Uganda and South Sudan, the corrosion of GI components on India Mark II has been a longstanding problem for both water quality and the cost of the operations and maintenance [Titus Draleke, Uganda]. WaterAid have observed corrosion problems with India Mark II (U2) pumps in Katakwi and Amuria districts in the north east of Uganda. Readings of pH taken on-site at recently drilled boreholes have been largely on the acidic side, almost always below
6.5. Before pump installation iron concentrations were well below 1 mg/l. However, routine follow up water quality surveillance highlighted elevated iron concentrations in these same boreholes, even just a few weeks after pump installation. People would complain about brown water in the morning and after periods of pump dormancy. Left unattended, pipes would begin to leak [Vincent Casey, UK].

Iron problems are reported in Sierra Leone where recorded pH levels have been as low as 4.8 [Keith Norris, USA; Andrew, USA]. In Chad, groundwater pH levels are often found to be less than 6.5 and with a median value 5.6. Most of the pumps found are India Mark II with galvanized steel pipes and rods. There is a very significant failure rate. Most pumps fail after a year, and the quality of water is almost always poor: it is red in colour, smells foul and has an awful taste. More recent India Mark II installations using stainless steel pipes and rods do not seem to have this water quality problem [Philippe Lacour-Gayet, France/Chad].

Similar aggressive groundwater has been encountered in Chad, Senegal and Ghana since the 1980s. A 1992 evaluation for CARE in Southern Chad found that over 400 wells had been equipped with galvanised (GI) components and that within four years of installation many pumps were breaking, with the riser pipes and pump rods falling to the bottom of the borehole [Jon Naugle, USA]. The "Ministère de l’Hydraulique" in Ndjamena, Chad are apparently aware of this however it seems that many organisations continue to install pumps with GI components. [Philippe Lacour-Gayet, France/Chad].

In Zambia, where the underlying rock is mudstone and/or shale of the Kundulungu Formation (pre-Cambrian), iron levels as high as 26 mg/l have been recorded during drilling, development and yield test. It has been observed that iron is often high where there is surface laterite (often with a pan or depression nearby), where yield is low and where users pump the borehole water level down to the level of the pump intake – so the cone of depression is narrow and steep [Jim Anscombe, Zambia]. In Northern Zambia, hundreds of India Mark II pumps with GI pipes have been observed being installed in the last year. Varying degrees of complaints about rust and taste have been reported by users and sometimes within four months of installation the pumps are not being used. Similar complaints have not been observed with other pumps that are less vulnerable to corrosion (Afridev, Malda, Access 1.2) [Carmen Brubacher, Zambia]. However, in a recent sustainability check for UNICEF in Nchelenge and Mansa Districts of Luapula Province, Zambia, high iron was observed in borehole that appears to be coming from the aquifer rather than the pump components [Jim Anscombe, Zambia]. The situation therefore appears to be a combination of pump and groundwater factors.

Figure 2: (a) Afridev pump rods (b) PVC riser pipe, Zambia coated in iron deposits (Jim Anscombe, Zambia)

In Cameroon, two boreholes with India Mark II pumps (with GI pipes) were installed in a village called Modeka. The water from the pumps turned reddish-brown, while the water from nearby rope-and-bucket wells did not. The boreholes have since been abandoned and the community continue to use rope-and-bucket until something is done [Fidelis Folifac, Canada].

Problems have also been reported in Kenya. An 84 m borehole was drilled and an Afridev handpump installed with about 29 m of PVC rising main and mild-steel pump rods (hook & eye connections). It was commissioned in January 2010. The pump test showed a yield ~ 3.5 m³/hour and the water quality showed moderately high pH, moderate alkalinity, low iron and low manganese. By mid-2010, users reported an “oily sheen” and precipitate formation after

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1 There is no WHO health guideline for iron, but the water becomes undesirable above 0.3 mg/l (WHO 2011)
exposure to air. In July 2011 at site visit in July 2011, it was observed that the pumped water was initially clear and then brown precipitation occurred after exposure to air. Users complained of poor taste, stained laundry and spoiled food and tea. Subsequent off-site testing confirmed high iron levels in the 3 to 7 mg/l range. The pH had changed and was now low, around 6 or so; thus the water quality was very different than indicated by the initial Nov 2009 testing. The users of the water speculated that the cause of the corrosion was the steel borehole casing and pump rods, which seemed unlikely but plausible. In January 2012 further testing that confirmed very high iron levels, and based on iron levels as a function of extensive pumping time, with some initial levels as high as 30 mg/l, but never decreasing below 4 to 10 mg/l. [John Tobison, USA].

In Zimbabwe, the Bush Pump has used GI rods and pipes since it was first developed in 1933. There have been problems with poor manufacturing standards (both domestic and imported) with sub-standard galvanising. However the government has become stricter. There has been experimentation with PVC and HDPE but the trend by installers has been to stick to what is known: GI. Despite successful tests there has been a challenge in getting more widespread uptake beyond the experimental stage. The issue of the iron taste in the water reportedly varies considerably but overall is not considered a major problem. [Peter Morgan, Zimbabwe].

Iron is also a problem outside Africa: In Bolivia, groundwater is rejected by households because food boils brown and the laundry get stains [Wolfgang Buchner, Bolivia]. In Bihar State, India groundwater was found to have iron levels up to 15 mg/l and needed treatment before domestic use. [Shiva Narain Singh, Kenya]. In West Bengal State, India, there are problems with both arsenic and high iron level in groundwater [Dave Shyam, India]. In Orissa State, India, there were many problems associated with corrosion and high iron levels where India Mark II pumps had been installed [Raj Kumar Daw, India] however the situation is complex and there was some disagreement on whether the groundwater quality in a borehole can change radically overtime, unless it was due to corrosion of pump components [Christophe Leger, France]. In the Danida Orissa project of 1985-94, four hydrochemists were working full time conducting on-site water quality analysis on 16 parameters. Even when the GI was replaced by PVC riser pipes and stainless steel pump rods, water quality deterioration was still observed, albeit more slowly [Raj Kumar Daw, India].

Jim Anscombe reported that iron levels changed significantly over time and between boreholes in Malawi:

“I recently replaced a high iron borehole at Kitchwe RHC in Solwezi District. The replacement was 30m away but has no iron. I think we drilled and screened deeper and this may explain this but the replacement was also next to a termite mound and maybe the churning of the sediments by the termites has oxidised the local water table and this has precipitated out into the ferricretes observed between the two boreholes.”

[Jim Anscombe, Zambia].

It was suggested that this difference may be due to the presence/absence of bacteria, probably fed by organic matter. [Bob Hather, USA]

1.3 Causes

From the discussion there are clear, interrelated, causes of corrosion and high iron levels water from handpumps:

- **Groundwater quality** which may have naturally high levels of iron,
- **Corrosion of the down-hole components** of the handpump (casing, riser pipe, pump cylinder\(^4\), pump rods), which releases iron into the supplied water and is associated with a number of natural chemical factors, most notably low pH.
- **Bacteria-induced** corrosion, which was less discussed.

1.3.1 Natural Groundwater Quality

Where iron and manganese levels are naturally high then there may be no alternative to treatment, or finding an alternative water source.

1.3.2 Corrosion of GI pump parts

Low pH (Acidic) groundwater is one factor causing corrosion of rods and pipes. However, it has been found that if the water has very low Electrical Conductivity (EC), e.g. less than 100 mS/m then less corrosion occurs. Factors affecting the corrosion of GI components include low pH, high EC, high dissolved oxygen, high chloride [Jim

\(^4\) On the India Mark II the pump cylinder and components are generally brass
Saline water (i.e. with high levels of Na\(^+\) and Cl\(^-\) ions) leads to faster sacrifice of the zinc so that eventually the iron/steel beneath will be exposed [Gachai Bernard, Kenya]

In the 1980’s the World Bank did a large study in West Africa\(^5\) that found iron levels in the groundwater were generally less than 0.3 mg/l and yet the water that was pumped from the wells had levels of 10, 20, 50 or 60 mg/l and was higher in the early morning. The problem was identified as the corrosion of the GI pipes and pump rods by the slightly acidic groundwater [Richard Carter, UK]

The problem for many users with GI pipes and pump rods is that corroded iron builds up in the borehole water overnight and when pumped up in the morning, the aeration that happens in the handpump water tank and spouts oxidises the dissolved iron from Fe\(^{2+}\) to Fe\(^{3+}\), causing it to precipitate as reddish-orange-brown ferric oxides. [Richard Carter, UK]

One of the reasons that GI is unsuitable is that galvanised zinc is just a coating over the iron or mild steel and that layer can be damaged or removed during installation (where pipes are threaded to screw together) and during use or routine maintenance by physical damage or wear. [Jon Naugle, USA; Gachai Bernard, Kenya, Sampath Kumar, India]. Where corrosion is rapid, communities often lack funds to replace the pipes, often within two years of construction [Julie Truelove, Canada]

In conclusion, the most commonly reported cause of problems is the installation of India Mark II pumps with GI riser pipes and pump rods. This is not an inherent fault in India Mark II design because the RWSN and BIS standards also encourage the use of stainless steel in aggressive groundwater. However, very aggressive groundwater can cause corrosion on all metal fittings between borehole and container [Robin Hazell, UK], which would affect the other pumps with above ground components, e.g. the Afridev.

Figure 3: Recent examples of corroded GI riser pipes in Chad, with heavy orange ferric oxide (Fe\(^{3+}\)) deposits (Philippe Lacour-Gayet, IDO)

Figure 4: Corrosion of the threads on a GI pipe in Chad (white paper inserted to show holes) (Philippe Lacour-Gayet, IDO)

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1.3.3 Bacteria-induced corrosion.

Iron (Fe) in steel and GI pipe is mostly in a very reduced form, e.g., Fe(0). To be released to water, it must be oxidized, to Fe^{2+} or Fe^{3+}. Sulphate-reducing bacteria can reduce SO_{4}^{2-} to sulphide (S^{2-}), with Fe^{0} as a potential electron donor, yielding Fe^{2+}, which can then create the black FeS precipitate [John Tobiason, USA].

Analysis and options for dealing with bacteria-related iron problems are found in (Fader 2011) [Krischan Makowka, Uganda]

1.4 Testing, measuring and monitoring

"But, how do we recognize aggressive groundwater? Unfortunately there is no simple answer to this question."

"Assessment of the corrosivity of water is a complex matter, involving a number of inter-related water quality indicators. The pH is a valuable indicator of the aggressivity and thus corrosion potential. As a rough guide, water with a pH below 6 is likely to be highly aggressive; while above 7 there should be little or no corrosion. It must be stressed however that these are only guideline figures, as other factors, such as conductivity, CO_{2}, chloride and sulfate content, as well as the presence of bacteria, also influence corrosivity." p.54 of Arlosoroff et al. (1987)

Referencing Arlosoroff et al. (1987) above it was asked if there were any guidelines of the aquifer properties [Jake Carpenter, Uganda]

It was confirmed that a solution to aggressive groundwater was not found by the 1980s Handpump Programme and that it was hard to accept that a solution did not exist. From the current discussion it appears that the situation has not changed [Raj Kumar Daw, India]

Water samples should be tested on site. Samples sent to the lab will not give accurate or reliable iron concentrations because in transit the iron will oxidize in the sample bottle and precipitate. The first thing the lab does is to filter the sample rendering the iron determination useless. Acid may be added but this puts iron in the water and iron held in colloidal particles into solution and again renders the analysis useless (much higher than the actually problem is). To measure iron content when suspected it is best to get a fresh sample from the yield test or from the hand pump spout and use - on site - an Iron Checker Disc (Hanna Instruments) or a Photometer - both with the necessary reagents. Once you know how much iron is in the water you can consider an water treatment options [Vincent Casey, UK].

WaterAid’s testing procedure (Figure below) to determine the origin of the high iron. It will allow you to distinguish between iron emanating from corrosion of GI rods/risers/iron bacteria or iron emanating from the aquifer. The test is useful if you wish to examine a number of boreholes and will save you pulling the pipes to investigate. If you are only looking at one or two boreholes then you might as well just pull the pipes and have a look at them. GI rods and riser pipes are not supposed to be used in situations where groundwater pH is lower than 6.5. There isn’t much point in
getting a laboratory reading of pH as the value will drift between the site and the lab. You really have to take a reading on-site if you are going to get something representative. This presents challenges in the field because although pH meters are straightforward to operate, they need calibration solutions and the probes can get damaged if not handled properly. You can hazard a well-informed guess of pH by using groundwater quality information for your district. In Uganda, the Directorate of Water Resource Management (DWRM) have produced detailed groundwater quality maps and reports for each district. You can get a good idea of prevailing pH and iron conditions from these [Vincent Casey, UK].

**Figure 6: WaterAid test for origin of iron in borehole water**

"To identify if corrosion of pump components is the cause of high iron concentrations, a simple pumping test can be carried out with periodic measurements of iron content. If iron concentrations fall rapidly after a few minutes (see graph below), corrosion is likely to be the major source of iron. The objective of the pumping is to replace the well water with fresh water from the aquifer so that iron concentrations are representative of the aquifer water. The test should be undertaken first thing in the morning, before any pumping has taken place. Most of the solid corrosion products will be removed once the water within the rising main has been removed, volume V1 on the graph."

BROWN, L. (2013) *Water quality testing to establish whether high iron originates from corrosion of pump components or the aquifer*, Method Sheet, WaterAid, London, UK


### 1.5 Prevention

#### 1.5.1 Why are GI pump parts installed where the groundwater is unsuitable?

- Despite tender documents, in Zambia, specifying a plastic pumps, India Mark IIs with GI pipes end up being installed due to the lack of availability of alternatives. It is not practical or sustainable for every organisation to import their own pumps [Carmen Brubacher, Zambia].

- Organisations hire drillers who handle the handpump procurement as part of the larger borehole contract. Poor contract management and supervision can lead to the donor or implementation organisation not knowing (or perhaps even caring) what is being installed in their name [Raj Kumar Daw].

- Some traders are importing pump rods made from mild steel (for India Mark II/III and Afridev) or buying pipes from pipe brokers rather than handpump manufacturers and in such cases the GI pipes can be 5kg instead of the heavier duty 8.8kg set out in the RWSN/Skat Specifications, so the thinner walls corrode faster [Jim Anscombe, Zambia].

- The India Mark II was developed before the advent of PVC pipes. There was one project where PVC pipes and fibre glass rods with an India Mark II was carefully monitored but despite its success, it never took on. [Raj Kumar Daw].

- The thickness of the pipe will determine the relative life. In Uganda, India Mark II/U2 failed handpump components have been marked according to the ISO standard from their country of origin but they generally do not conform to that standard. Elsewhere, unscrupulous traders pass off cheaper pipe by changing the colour coding or markings on the pipe. This lack of checking and enforcement of these standards means that the cheap components find their way onto the market that do not have the lifespan that they should [Enangu Moses, Uganda; Gachai Bernard, Kenya].
In Sierra Leone it is difficult to find riser pipes that are strong and won’t corrode and the cost of importing PVC is prohibitive [John Campbell, Water4]. Further background on the use of GI for handpumps was provided by Raj Kumar Daw (See Annex 6.3)

1.5.2 PVC / uPVC

The main argument against the use of PVC is the availability of PVC pipes of sufficiently high quality. Care needs to be taken: blue or yellow PVC pipes are usually new, while black or grey is recycled and therefore weaker. Below 40m, PVC pipes often break or split due the fatigue from the horizontal swing or the vertical ‘dancing’. Therefore, below 40m bottom-support to the rising main is needed. [Paul van Beers, Netherlands].

In Uganda, a company called GENTEX has recently started production of square-threaded uPVC pipes that can be screwed directly into India Mark II (U2) water tanks, and can be used to a depth of 30m [Vincent Casey, UK/Jake Carpenter, USA]. This type of pipe could be used to rehabilitate India Mark/U2 pumps that were installed with GI pipes.

References were provided on the performance and use of PVC with India Mark II pumps [Raj Kumar Daw, India]

- Performance of PVC riser pipes with India Mark II hand pumps
- India Mark II hand pumps with open top cylinders in low lift application
- Performance of India Mark II solid link suction pumps in Danida assisted water supply project in coastal Orissa

It is important that the right grade if PVC is installed. A paper by Boode Waterwell Systems (undated) highlights that whilst appropriate specifications and standards exist for materials used in borehole construction in the UK, the reality on the ground in the UK is that drillers can use sub-standard, lower quality alternatives when actually drilling and installing a hole if the supervision is weak. In parts of the country, Northern Ireland for example, the drilling sector is completely unregulated. There is the real possibility that supervisors may not be completely savvy on what materials to look for. [Vincent Casey, UK]

1.5.3 Stainless Steel

The main arguments against stainless steel are cost and availability.

Some care still needs to be taken with the grade of stainless steel because of the electrical potential where there are two different types of metal – stainless steel 304 will rust in the presence of stainless steel 316. [Paul van Beers, Netherlands]. Vergnet pumps use stainless steel 304 and plastic parts [Christophe Leger].

Electrical submersible pumps use stainless steel and those manufacturers have a lot of experience dealing with corrosion issues [Saul Arlosoroff, Israel].

1.5.4 GI, PVC or Stainless Steel?

In the opinion of Paul van Beers, stainless steel can still rust over time and the threaded coupling can cause problems. PVC pipes are cheaper and better. The Blue Pump uses quality-controlled PVC from the Netherlands. [Paul van Beers, Netherlands]. Vergnet also use quality controlled parts (from France) but use HDPE rather than PVC.

Brad Saltzman prefers stainless steel pipes and connecting rods because concerns of PVC: “be very careful of PVC pipe and the joints. Even if high quality PVC pipe is used, cutting the threads into it weakens it tremendously and the tensile strength of the threads is very limited. It will often snap off at the reservoir, even if centralizers are used. In addition PVC couplers can fail if not formed from extruded pipe.” [Brad Saltzman, USA]

Ashok Kumar recommended stainless steel (304) where pH is below 6.5 but that they (Ajay Industrial Corporation) do also supply uPVC pipes which are generally used with submersible pumps, but can be used for handpump as well. The use of uPVC for bottom-supported deepwells should reduce rather than increase costs, compared to GI [Ashok Kumar, India].

In Sierra Leone, World Hope International only use stainless steel risers, because of the corrosive groundwater [Keith Norris, USA]

In southern Senegal (Ziguinchor), the USAID/PEPAM project at first installed India Mark IIs with galvanised pipes but encountered iron problems, which have been resolved by replacing with PVC pipes and stainless steel pump rods. [Ibrahim Mamadou, Senegal]

In the opinion of Tim Journey, pump rods should be stainless steel (and should be a tube rather than a solid bar to have neutral buoyancy) and expressed concern about the strength of PVC for deep wells quoting a report by
Consumer Research Laboratory. Draft report A 9141, dated 11 March 1988, titled “Rising main and pump rod breakages”, page 55, under the heading “conclusions”.

"The fatigue life appears to be the limiting factor for uPVC rising main. There is no data available for the type and levels of stress imposed on uPVC pipe installed as a rising main, but it is interesting to note that a section of pressure pipe supporting a continuous load of 36 MN/m² will last one month until failure occurs. If the 36 MN/m² is applied as a cycling load at a frequency of 0.5 Hz, the sample will only last three hours to failure. The continuous load sample lasts 240 times longer. This is an indication of how varying the loads imposed can drastically reduce the useful life of a component."

[Tim Journey]

Another option is to use uPVC pipes with stainless steel couplings. These are very difficult to get hold of in some countries. There have been some reported problems with response of the joints to stress [Vincent Casey, UK].

1.5.5 Pump alternatives

In Uganda, the Afridev (and other PVC-piped pumps) are not permitted by the standardisation policy of the Government. The U3M (developed by Skat and the Ministry of Water & Environment), which uses uPVC riser pipes and stainless steel rods, is permitted but not widely used. WaterAid is now using the U3M on new boreholes to monitor how they perform over time. It is not intended to use them where the groundwater is deeper than 35m [Vincent Casey, UK]. Elsewhere, proprietary pump designs, such as the Vergnet and Blue Pump may be better but there will still be issues around national standardisation (if any) and availability of the necessary spare parts and handpump mechanic skills (and willingness to adopt a new design).

1.5.6 Well cleaning and rehabilitation

In some cases, such as in Orissa, India, water quality is not static – the act of drilling a well and installing a handpump can change the aerobic conditions in the borehole water that led to microbiological activity and corrosion that led to the water users rejecting the water. Water quality was restored after well cleaning, rehabilitation using PVC pipes and stainless steel pump rods. However, the water quality deterioration could not be stopped, only slowed. The conclusion was that the scope of the handpump maintenance needed to be extended to include maintenance of the water source by periodic rehabilitation. It may be possible to estimate the rate the water quality deterioration to work out the optimal well cleaning timetable:

- Make an accurate inventory of your wells.
- Territorially do a saturation-rehabilitation of ALL the wells.
- After rehabilitation, record water quality AT SITE for all rehabilitated wells, especially for unstable parameters like Iron.
- Convert a good number of the pumps to 50 mm PVC risers with 3-piece couplers, stainless steel or fibre glass pump rods, brass lined PVC cylinders with Universal Cylinder components.
- If you want to prove the obvious, keep a small number of wells as a “control” group with new GI Pipes, GI Rods, cast iron cylinder.
- Then start a water quality monitoring programme, with monthly observations initially, then bi-weekly after 6 months, and even more frequently after that as the WQ deteriorates.
- Match this with community usage information.
- With time and some number crunching, you will have enough information to give you your thumb rule of when re-rehabilitation will be necessary. [Raj Kumar Daw, India]

1.6 Treatment

Iron filtration is not recommended as a first step because of the cost and because they are not easily managed at the community level [Mubiana Muyangwa, Zambia]. However, if problems still persist after GI components have been replaced with more corrosion-resistant alternatives, then the following treatment methods have been recommended:

1.6.1 Chlorination

It was suggested that where the problem is caused by bacteria, boreholes can be successfully treated by adding chlorine with a gallon of bleach as shock treatment and continued treatment with a handful of chlorine tablets [Bob Hather, USA]. However, in another thread it was argued that chlorination is only a temporary solution and that the
real solution is only to replace any GI down-hole parts with PVC riser pipes and stainless steel pump rods [Krischen Makowka, Uganda]

1.6.2 Chemical oxidation
Another method is to raise the pH of the water, and the iron will immediately be precipitated as Fe₂O₃. The simplest solution is to pass the water upwards through a cylinder or closed tank containing calcium carbonate (limestone) or a close relative. Depending on which level of technology is appropriate to your environment, you can install a cylinder in line containing a proprietary brand of pellets; or a cheaper option is to make a closed tank and fill it with limestone or marble chips. The carbonate slowly dissolves and the iron oxide coats the pellets, chips or granules; so you need to back flush the container regularly for a few hours, about once a week and discard the brown water; and top up the container every six months or year (depending on how aggressive the water is) [Robin Hazell, UK]

1.6.3 Four-chamber aeration and filtration
The National RWSS Program in Zambia adopted an iron filter developed on a KfW-funded project in northern Zambia. It is connected directly to a raised India Mark II handpump and has four chambers one after the other. The water is pushed under a baffle plate between the 1st and 2nd chambers, over another baffle plate between chambers 2 and 3 and under yet another baffle between chambers 3 and 4 before exiting from an open pipe at bucket level. The 1st chamber is a splash chamber which aerates the water, the 2nd collects any precipitating Fe₂O₃, the 3rd is full of washed, rounded quartz gravel about 2-5mm and the 4th has some coarser material. Iron-reduction bacteria proliferate in the gravel in the 3rd chamber and when water pushes through a 20-30cm thickness of it - all iron is removed. The iron concentrations at the inlet can be 3-8 mg/l of iron and outlet 0.1 to 0.5mg/l. The purpose of the coarse gravel in the 4th chamber is to stop the finer material being washed out the outlet pipe. No charcoal, no lime is needed, only basic gravel. However, the design suffers from the following:

a) through flow is about 0.1 l/sec;

b) needs frequent back-washing and a motivated group of users to do it, which can be a challenge [also reported by: John Tobiason, USA, Shiva Narain Singh, Kenya];

c) it’s expensive;

d) the contractors don’t understand the hydraulic principal and get the levels and baffle positions wrong; and

e) users like to bung the open outlet pipe with a maize cob. This makes the water bank up inside and nullify the hydraulic gradient which drives the water through the filter.

The bacteria are not added but seem to be universally present in groundwater. [Jim Anscombe, Zambia]. In Bangladesh, gravel is not easy to obtain but brick chips are available [Jess MacArthur, Bangladesh] which should work fine [Jim Anscombe, Zambia]

**Figure 7: Four-chamber iron filter (Jim Anscombe)**
1.6.4 Two-chamber batch chlorination/sedimentation
An example was completed in Kenya in January 2014 [John Tobiason, USA]. It comprises two 1500 litre tanks. Oxidation of the iron is done by adding chlorine and overnight precipitation of the iron. The treated water is used during the day, drawing water from a tap about 8 inches (20cm) off the tank bottom, and the tank is drained from a bottom tap, flushing out the iron solids to an infiltration/drying bed. The second tank is pumped full of water during the day for subsequent treatment and use the following day.

One technical challenge was to raise the water up into the tanks, which was not possible with the existing hand pump head. Two options were explored. One would be to add a vertical section to the pump stand to raise the pump head by a meter or so but this would have required building stairs and a safe platform. Instead, the pump head was changed from the Afridev to an India Force Lift pump head, which is the India Mark II with the “third plate” converted to a simple water lubricated seal and the spigot supplied straight with a threaded end. The pump stand flanges of the Afridev and the India Mark II (at the water tank base level) have the exact same dimensions, making the conversion possible. From a corrosion perspective, it was decided to keep the PVC riser pipe and stainless steel pump rods. However, this required that enlargement of the hole in the base of the India water tank, removing the threaded pipe connection. A stainless steel adapter was machined to attach the India top pump rod (stainless steel, 12 mm, threaded) to the Afridev pump rod string (stainless steel, cut off, 10 mm).

Two technical problems occurred: One was that the Afridev string of pump rods, centralizer bushings and new plunger seal in the pump cylinder initially did not have enough free weight to allow the string to drop when the India pump handle was raised, resulting in a slack chain (the rigid connection of the Afridev pump head does not have this issue). This was solved by removing the crude rubber bushings, reaming them out a bit, and replacing them. The resulting seal leaks more than one might wish, but the pump rods drop freely. The other unanticipated change was that the vertical throw (movement) of the Afridev pump rods is longer (maybe 9 inches (23cm) or so) than that of the India (which is maybe 4 to 5 inches (10-12cm)), decreasing the 10 to 12 l/min Afridev flow rate to only 7 to 10 l/min. Replacing the rising main and pump cylinder with India components (which has a larger diameter cylinder than the Afridev), the pumping rate would have been higher, but would have created a questionable installation of a GI rising main, which was clearly not a good choice for the borehole. [John Tobiason, USA].

1.6.5 Figure 8: Two-chamber batch chlorination/sedimentation with Force Lift India Mark II, in Kenya [John Tobiason, USA]

1.6.6 EMAS iron filter
Details presented in an online video: https://vimeo.com/20835173 [Wolfgang Buchner, Bolivia]

1.6.7 Household Treatment
The simplest method is to aerate the water, store it for 12 hours and filter it in the house. [Jim Anscombe, Zambia]. Two plastic drums, or ferro-cement tanks, can be used to store the water and used alternately. Over 12-24 hours, the iron oxidises and can be removed with a simple textile filter. Iron precipitates more easily when the pH is higher, which can be done by adding lime (burnt limestone) [Wolfgang Buchner, Bolivia].
In West Bengal state, India, there is a locally made filter that consists of a cheap 20 litre capacity ferro-cement tank (INR 350.00/USD6.00) with two chambers. In the upper chamber is a ‘candle’ made of sand, clay and rice husks in the proportion 1:1:0.25 by volume. The candle is made by puddling the mixture to bring the plastic consistency and then it is kept untouched for two days. Next it is put into cone-shaped mould (150 mm upper diameter, 163 mm lower diameter and 163 mm height). The candle is sun dried for 15-20 days and kiln-fired for 10-12 hours after which it is ready to be installed in the tank. The candle needs periodical cleaning to remove the deposited ferric hydroxide particles which gradually clog the water flow through the candle and arrangements are in-built for manual backwashing. This candle essentially functions on the principle of oxidation of iron to insoluble ferric hydroxide precipitates and their removal by the candle. The candle (Tripura type) itself was found to be very effective in removing both iron and arsenic. It purifies about 3 litres of water per hour. [Dave Shyam, West Bengal]
2 Procurement, Quality Control and Installation

2.1 Costs & Prices

There was some disagreement about the relative cost of GI to stainless steel, but it appears to vary a lot between countries, from 3-4 times more expensive to 10 times more expensive in Uganda [Ashok Kumar, India; Vincent Casey, UK; Eric Miller, USA].

The WaterAid observations in Uganda have been that good quality GI produced by Ajay Industrial retails in Kampala for around UGX 45,000 (US$18) per metre and stainless steel is about 3-4 times more. However, much lower quality and price GI is available in local markets for around UGX 20,000-25,000 (US$8-10) per metre. Furthermore, GI pipes from decommissioned boreholes are being re-threaded and sold for even less, perhaps UGX 10,000 – 15,000 (US$4-6) per metre. The wide availability means that it is widely used and the problem may be getting worse through an influx of cheap, poor quality material. [Vincent Casey, UK]

2.2 Quality Control, Inspection and Installation Supervision

There are third party companies who can be contracted to perform reliable third-party inspection to ensure conformity to whichever standards are required. The cost of the inspection is almost negligible compared to the value of a container full of pumps and riser pipes. Eric Miller (IPA, Inc.) vouches for the reliability of such inspections that they have done from very order from India and has not had any surprises contradicting the inspection reports.

Beyond donor-projects there are often many private local drillers who carry out their own procurement to Bill of Quantities (BOQ) provided by the client and it is therefore essential that the agency/partner commissioning their services implements adequate supervision to ensure that the materials going down the hole meet with acceptable quality standards. [Vincent Casey, UK]. However, even certifications can be faked by unscrupulous traders so vigilance is essential [Paul van Beers, Netherlands].

Sometimes water quality reports may not be available for many weeks after drilling if the contractor is tasked with commissioning the water quality analysis. If water quality does not inform the procurement decisions then the wrong decisions are likely to be made. For this reason, in Uganda, WaterAid work with a government laboratory, in Mbale, to carry out stringent water quality analysis on all new holes. Because of this, the U3M is now the favoured pump type as a precaution against corrosion [Vincent Casey, UK].

Boode B.V. (Netherlands) Vergnet (France), Sovema (France) are manufacturers that maintain control of their supply chains and Vergnet offer a 10-year guarantee. [Paul van Beers, Christophe Leger, Ibrahim Mamadou]
3 Sustaining handpumps - what is the average lifespan of a handpump?

- 30 years [Divya Prasad, India]
- 10 years is a good enough assumption. There are, of course, exceptions, plus and minus. [Raj Kumar Daw, India]
- “In my experience 7-10 years for a handpump and 25 years for a borehole (on average) would be good going. [Richard Carter, UK]
- In Guinea, where standardisation and rural water policy is strong, functionality is above 90% with half the pumps older than 10 years and quarter older than 16 years. [Etienne Decherf, France]
- The lifetime largely depends on the maintenance cycle, it could be as little as 5 years, and it is a vague definition anyway: “if you replace in time all the worn parts of a car, for example, it will run for hundreds of years”. [Ken Gibbs, UK; Saul Arlosoroff, Israel]
- India Mark II and Afridev pedestals and pump heads are robust and could easily last 20+ years. It is the fast wearing parts (rubbers, bearings, chains, bushes, pivots, pins) that need 2-5 year replacement and the medium wearing parts (pipes and rods) that need 5-10 year replacement [Jim Anscombe, Zambia].

A series of factors for handpump sustainability were discussed:

A. Getting the borehole sited on a sustainable pocket of ground water (e.g. on a fracture trace rather than merely on the seepage at the overburden/bedrock interface) [Jim Anscombe, Zambia].

B. Getting the borehole drilled straight and through the aquifer, with screens in the right place, gravel installed, developed and yield tested (involves the contract specification the supervision and the supervision back-up by the Client where the contractor fails to follow specification) [Jim Anscombe, Zambia].

C. Sourcing the appropriate hand pump with the correct materials for observed ground water chemistry – from a decent factory – and then installing it correctly in the borehole [Jim Anscombe, Zambia].

D. Standardization of the type of pumps per country is also a key issue in order to reach high operating rates as it simplifies all after sales services organization. To be efficient, standardization shall not only be a list of types of pumps but should precise technical specifications (especially for generic type of pump) and authorized manufacturers [Etienne Decherf, France].

E. Any pump can work for as long as someone will keep the "maintenance" work done on the pump in questions. All pumps need some maintenance work. I do not believe there is a "maintenance free" pump made by man. Electric, solar, hand pump or rope pump along with everything in between takes some maintenance. If it is not the actual pump (electric) it is the power source for that pump [Jim Hocking, USA].

F. With proper maintenance done by qualified people it is not hard to experience hand pumps even, India Mark II and other models lasting 15 to 20 years. [Jim Hocking, USA].

G. After Sales Services: the best pumps ever will wear out eventually and without parts - and skilled technician - near the users will remain broken. Authorities or contractors should find a way to make suppliers to commit themselves towards after sales services, and even to enforce it:

   a. Asking 3 or 5 years full warranty on the most expensive parts of pumps, a 10 years warranty on any breakdown due to corrosion (to avoid approximate qualities of stainless steel for example).

   b. Pumps suppliers may also be asked to take care of maintenance for 5 years period, through simplified DBO programs, allowing every financial countermeasure possible (bank bond to be alleviated at the end of the contract only if conditions for after sales services are fulfilled) [Etienne Decherf, France].

H. The supply chain for the parts, transportation to the villages, accountability of the maintenance actually being done and the ownership (skin in the game) of the villages are involved in the program. [Jim Hocking, USA].

I. Social mobilization (marketing) around the pump is also crucial, especially when alternatives water sources are available, assuming the pump delivers a better water than those sources [Etienne Decherf, France].
“Put a shoddy borehole on a smidgen of groundwater and install a hand pump that weighs less and is made from inferior quality materials then you have the recipe for a non-sustainable water point.” [Jim Anscombe, Zambia]

“The key point in all of this is that this is a development process not something that just happens...especially for countries and communities who have ALWAYS received hand outs on a regular un-ending stream.” [Jim Hocking, USA]

“After sales service: the main idea should be to get rid of suppliers not willing to involve themselves in long term commitments.” [Etienne Decherf, France]

There are risks from programs that replace entire pumps regardless of what is wrong with them: like many manufactured products there is the “bathtub” shaped curve that describes the failure rate of a population of pumps installed at the same time. At initial installation of a group of pumps there is an abnormally high rate of failure (the weak parts are being removed and replaced with strong ones) once all the pumps have a complete set of strong components, through replacement of early failures, then the pumps should have few failures for several years and wear and hazards becomes the main factor for failure. At some point at the end of the life of the pump fatigue and corrosion damage will take over and the group will die out. Since the forces involved on the major welds of the pumps are small in relation to the resistance of the material, fatigue failure of the stand and pump heads is unlikely. [Tony Beers, USA]. Other field observations, from Sudan, suggest that pump stands and flanges do commonly suffer from early fatigue and not always caused by loose bolts. [Rowan Matthews-Frederick, Sudan/Australia]

“I cringe when I see organizations pulling up entire pumps to put in all new pumps, essentially they are removing tested parts for untested ones and paying for a whole pump when replacing bearings or a set of valve seals would likely solve the problem.... it is a bit like replacing an engine in a car when all that is needed is a new sparkplug.” [Tony Beers, USA]

This is why the World Bank handpump project came to the conclusion that a good handpump needed to have a riser pipe that allowed replacement of the easily worn parts as easily and cheaply as possible, and this was the philosophy that drove the design of the Afridev and India Mark III [Saul Arlosoroff, Israel].

If India Mark II/III and Afridev pumps are made to the stated specifications and if they are installed properly and if preventative maintenance is practice serious then many of the problems that are seen would not occur. [Raj Kumar Daw]. Recent work in Niger and Mali shows that the standards have not kept up with advances in manufacturing materials. Most of the India Mark II deep well pumps repaired as part of a failed parts collection and redesign study in Niger use only stainless steel and Nitrile rubber components below ground. The pumps were fitted with ~60 m of rising main. The stainless steel assemblies for the valves were of good quality except for the upper valve (I’m working on a redesign). The stainless steel riser pipes often break at the welds (weld-on couplers are used with sch20 ss pipes) it appears to be poor QC/no weld penetration as the weld calculations for the pipes show safety factors of 8:1 for standard operation and 3:1 in bending if maintenance is carried out poorly. All of the pump rods were made from stainless steel. [Tony Beers, USA].

The lack of maintenance observed in Niger, Mali, Mozambique and Burkina meant that worn out bearings led to other components, such as the pump stands, getting damaged. Getting hold of spares in these countries is challenging.

“If the pump repair techs do not know where to get the parts we have a problem.” [Tony Beers, USA]

Are we, however, asking the wrong questions and the Myths of Rural Water Supply should be remembered and considered (RWSN Executive Steering Committee (2010):

“But in a system in which those who take decisions are not responsible for the outcome it would be difficult to establish effective quality control, or make sure that only drillers and handpump mechanics who know their business are operating or have manufacturers who are proud of their product when they know the next tender is lost because a competitor is a few shilling cheaper or pays a little more into the buyer’s account. Rupert’s idea of establishing a system of comprehensive review of hand pump manufacture, installation and drilling with emphasis on quality control could work if there were a market that awards quality work with a the possibility of making a living in the future. At the moment it is better to make the quick buck.”

[Erich Baumann, Ireland]
4 Handpump component failures and the need to redesign public domain designs

4.1 Process of changing standards

The India Mark II, III and Tara are public domain designs available from RWSN, however, the governing body to which the majority of manufacturers work to is the Bureau of India Standards because India probably remains the largest market and the where the majority of manufacturers are based.

In the Bureau of Indian Standards Handpump Committee, changes to the design of the IM II were considered only after providing results of field trials. This usually involved monitoring of the performance of the innovation for a long period and for a relatively large number of pumps, of the order of 6 months to a year and between 30 to 50 pumps or more [Raj Kumar Daw, India]

“The original standard, IS 9301 for the IM II, underwent many revisions at the BIS thereafter. The designs did not come out of thin air” [Raj Kumar Daw, India]

It was recommended that RWSN specifications should continue to evolve but with the following provisos:

1. A process for validation is necessary to protect the public (especially pump users who may fall ill or lose valuable time in the event pump failures, but also NGOs, state agencies, and donors who are also pump customers.)
2. Redesigns should retrofit to old pumps and old pump parts should fit in new designs (there are millions of dollars of pump equipment in the field that must be supported)
3. Redesigns should prove a cost savings on the total cost of ownership of the pump or a greater level of reliability resulting in economic benefits to the community.
4. Redesigns should be subjected to a standardized field trial to ensure statistical accuracy of claims.
5. If a process for proposing and evaluating pump design changes were available then those working on pump sustainability could perform the required tests and field trials and compare designs to predefined requirements. [Tony Beers, USA]

“It seems at the moment we have a debate and good people doing good work identifying failures and working on solutions, but we don’t know quite what to do with them.” [Tony Beers, USA]

4.2 Changing context

The public domain designs were developed on the basis of sound engineering theory and testing, however, since the 1970s and 1980s a number of design and manufacturing tools have appeared, improved and/or become significantly cheaper:

1. Laser cutting has made intricate shapes in steel plates possible with good accuracy, repeatability, and low cost.
2. CNC (Computer Numerical Control) machining is ubiquitous and is bringing down the price of high volume machined parts. (these are more consistent than castings).
3. The cost of different manufacturing processes is always in flux relative to each other as new disruptive technologies emerge.
4. FEA (Finite Element Analysis) software packages are lower cost with more features and computing has become cheap and powerful.
5. Pumps are being put on deeper and deeper wells as we try to bring water access to the difficult areas.
6. There is 30 years’ worth of field experience with what is doing well and what is not doing so well in the field.
7. Design for manufacture, design for life cycle sustainability, lean design and manufacturing, and six sigma movements have changed design thinking in subtle ways.
However, data seems sparse because:

1. Maintenance is the community's responsibility it seems no one is tracking early failures and linking them to lot numbers, pump depth, etc.
2. Manufacturers are not being held accountable for poor quality parts as often as they should. (How will a rural community in Niger approach a manufacturer in Europe or India that they do not have a relationship with over a $35 part?)
3. Nobody has yet said 11.2% of flanges break in the first 9 months of installations from brand x and 1.4 percent fail from brand y, because we probably do not have the data.
4. Data is expensive especially in remote areas. Are there ways to share data that we do collect? How do we collect more data in a cost effective manner?
5. When someone has a design idea a common attitude is "we have always done it this way" (and 30% of handpumps in Africa do not work for various reasons.)

If we can estimate the cost of installation and the total cost of ownership on each part we can start to agree on what needs improvement.

4.3 Priorities for design changes

Varying experiences and opinions exist on the frequency and causes of several pump component failures, most notably the flanges on India Mark IIs, particularly in Sudan on boreholes where the static water level is below 40m. [Rowan Matthews-Frederick, Sudan]. Possible causes include:

- A design flaw that could be addressed by adding more supporting gussets to spread the load and the extra cost will be minimal. Stress fractures start in the weld area and propagate until complete flange failure. This can happen on a brand new pump. [Rowan Frederick-Matthews, Sudan; Sandy Polak, UK].
- Increase the flange thickness from 6mm to 10mm [Sandy Polak, UK].
- Caused by loose bolts due to lack of maintenance.
- Improper use certainly causes flange failures [Rowan Frederick-Matthews, Sudan].
- Use of substandard materials and/or poor installation [Sampath Kumar, India].
- The mild steel plate used by the manufacturers may have been recycled (because it is 15% cheaper) but with more hardness than specified and hence more brittle. [Ashok Kumar, India]  
- Installing the pump too deep into concrete in any way shape or form will accelerate flange failure [Rowan Frederick-Matthews, Sudan].

An analysis is presented in (MATTHEWS-FREDERICK, 2012) [http://www.rural-water-supply.net/en/resources/details/603]

Figure 9: India Mark II cracked flanges in Sudan (Rowan Frederick-Matthews)
Rather than just improve one or two components, an alternative is to use modern computerised design methods to develop a new or improved design particular suited to deep wells (below 40 metres) where the India Mark II/III and Afridev struggle. However, the Vergnet HPV and Blue Pump already do this, and others are already in development (Poldaw, LifePump).

In addition, trying to introduce a universal design is a complete technical contradiction. What works for the range 50 to 100m lift will certainly be a total failure if used where the water level is at 5m [Ken Gibbs, UK].
5 The politics of new pump designs: the Squirrel Cage Pump

“A water well drilling contractor called me and said he was working on the design for a pump powered by a human (or animal, even) walking or running in a wheel similar in design to one in a squirrel cage. It seems to me I have heard about these so I am unsure if the concept is new, at least as far as borehole pumps are concerned.

“He was specifically wondering if such a device would find utility in the developing world. I’m not sure people would want to run in a wheel, but that is why I’m asking those of you who have far more experience than I. He does not have a prototype or a cost estimate. I told him about the PlayPump fiasco, stakeholder buy-in, cost, etc” [Michael E. Campana, USA]

A play pump has developed by Ajay Industrial Corporation has been running in Madhya Pradesh, India and lift water to 3-4 meter above ground. The only problem faced is that the above ground merry-go-round is approximately 3 metres in diameter and 600 mm high so it is difficult and expensive to transport because it is very bulky. [Ashok Kumar, India]

There are good experiences with Horse powered Rope pumps in Nicaragua. It was developed with support from Practica Foundation and is based on the Noria pump. These so called Bometran pumps are installed on wells of 5 to 65 metres deep. The oldest pumps are over 16 years and still working, cost around US$ 800 and they can be produced with local materials. For information see www.ropepumps.org [Henk Holtslag, Netherlands]

Concern was expressed about the need and dignity of this “squirrel cage” concept [Rupert Talbot, Prof. Isiorho, Prof. Richard Carter, Paul van Beers, Tesfaye Hailu]. Tackling the wider issue of NGO motives and practices in developing and promoting new pump types:

“It was noted that there is more money to be made in fundraising for problems that are easy to understand for the general public, than in really solving the underlying problems and showing the good results of what you have been doing. Focus on a problem is very good for fundraising, showing sustainable results does not count, is not sexy. On the other hand, (also confirmed in several RWSN publications) most water NGOs don’t have lasting results to show anyway, so they have no option to continue in focusing on campaigning for the problems to secure their own existence.

“As a result of selling the water problems, we have now in the water sector over 100,000 alien expat people working worldwide in “solving water problems” funded by these marketing principles, while the key problems (how to make water sustainable available at very low cost for the poor) are not really fundamentally addressed by the local governments, as it should be of course. Handpumps still break down, rust and fail every day and often poor people spend a fortune to maintain them, travelling long distances to source spare parts and it seems that this will never end, as long as the fundraising campaigns are so successful and NGOs have no interest to focus on sustainable results and providing handpump that last at low cost.”

“For instance, the good old NGO marketing phrase “every 20 seconds a child dies from unsafe water”, so donate to us and “we will give a child water if you donate 2,50 euro” is very effective and the NGO will have its overhead covered for another year until the next campaign. What really happens with the money remains unclear for ever. So maybe the idea of a treadmill is not so bad in that respect? It is a catcher!

“To honest, I was mainly triggered by the word “dignity” in your mail. I feel that it is also not respectful and also violating people’s dignity to hand out rusting pumps and at campaigning for saving lives at the same time. We all know very well that rusting pumps don’t last, but NGOs continue to do so and only few organizations practise what they preach.” [Paul van Beers, Netherlands]

Saul Arlosoroff reflected on the history of this issue:

“I was struck by Paul’s recent message - it took me back to the 1970s as if we are again at the same spot, he phrased and he touched and has the courage to say it clearly. It raises many issues and will touch here only on few of them.
“These were the thoughts and the realization when we started the WSP Program of the water decade - we listened and realized that the common concepts of piped networks and the Regional water office with trucks travelling hundreds of kilometres and lifting a handpump to replace a seal - will not be the answer for the hundreds of millions rural poor - we therefore reached the conclusions a that the hand (pump) is a reasonable tool for marketing, for Donors to concentrate and we must develop a pump that will survive longer periods and when broken will enable repairs by the trained village staff and or a local bicycle rider.

“We did not think it will last for many years but we felt that the Afridev + IMIII [India Mark III], after long testing and design, will last longer that the hundreds of thousands or millions of other pumps that littered the rural scene all over the world.

“It was clear that these were marketable for donors who looked for real options to improve the sad situation, costs wise and a solution that will not be universal but will open a window for improvement and changes to be adopted in different countries and conditions.

Indeed, 30 years passed and many communities are still being served by these pumps and I meet donors that are still proud of their efforts and investments.”

[Saul Arlosoroff, Israel]

Others were concerned about the reinvention of old ideas and the need for such an invention: millions of treadle pumps are used throughout India and Bangladesh. They have their limitations, but better than a squirrel cage. [Erich Baumann, Ireland; Vincent Casey, UK; Saul Arlosoroff, Israel] Meanwhile, many ideas for pumping water have made fine demonstration projects but are not used at a large scale (see example below). [Sampath Kumar, India].

Figure 10: Demonstration Play Pump in India (Sampath Kumar)
6 Annexes

6.1 Contributors

With thanks to the following people who took part in the online handpump discussions. It was not possible to include everyone’s contributions in this synthesis:

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6.2 Pump types mentioned in the discussions

- **Access 1.2** – a direct action pump made largely from standard PVC pipes. Developed by Water4 Foundation over the last five years and similar to the EMAS Flexi-Pump.

- **Afridev** – a conventional lever action handpump developed in Malawi in the 1980s (as the Maldev). It is designed for heavy-duty use, serving communities of 300 people. The maximum recommended lift is 45 m. The Afridev Pump is a public domain pump defined by RWSN specifications. The Afridev Pump is fully corrosion resistant, easy to install and has excellent potential for community-based maintenance. For more, including the standards, see Afridev on the RWSN website.

- **Blue Pump** - a lever-action reciprocating handpump that is intended to be a more rugged alternative or replacement for an Afridev or India Mark II/III. It can reportedly pump from a deep as 100m. The Blue Pump was developed by Fairwater Foundation (Netherlands) and is manufactured by Boode B.V. (Netherlands)

- **Duba Tropic** - a heavy-duty reciprocating rotary action pump developed and manufactured by Duba (Belgium).

- **EMAS Flexi Pump** - a low cost self-supply household pump for drinking water and limited use for irrigating gardens. The EMAS Flexi-pump is a direct action pump initially developed by EMAS in Bolivia. It uses a simple pumping principle. It consists of two pipes (diameter approx. 5 cm) put into one another, one slightly larger than the other. At the bottom of each pipe is a non-return valve (glass ball). For more information see EMAS Flexi Pump on the RWSN website.

- **India Mark II** - a robust conventional lever action handpump developed in India in the mid-1970s and is now the most common handpump worldwide. It is designed for heavy-duty use, serving communities of 300 people. The maximum recommended lift is 50 m. The India Mark II is a public domain pump defined by Indian Standards and RWSN specifications. The India Mark II pump is not corrosion resistant. For more information see India Mark II on the RWSN website.

- **India Mark III** - The India Mark III Pump is a robust conventional lever action handpump for shallow to medium deep wells. It is designed for heavy-duty use, serving communities of 300 people. The maximum recommended lift is 30 m. It is a public domain pump defined by Indian Standards and RWSN specifications. This pump requires special skills for installation but has good potential for community based maintenance. For more information see India Mark III on the RWSN website.

- **Malda** - The Malda Pump is a direct action pump for Low Lift Wells. It uses a buoyant pump rod that helps to reduce the forces on the handle. It is designed for heavy-duty use, serving communities of 300 people. The maximum recommended lift is 15 m. It is a public domain pump defined by RWSN specifications. The Malda Pump is fully corrosion resistant. It is easy to install and has excellent potential for community-based maintenance.

- **Poldaw Ultra Deepwell** – in development by Poldaw Designs (UK) to meet the need for handpump that is reliable and usable at depths of 60–100m.

- **Rope Pump** - The Rope Pump features a design in which small plastic pistons are lined up on a rope. The distance between the pistons is approximately 1 m. The drive wheel is crank operated and pulls the rope through a plastic rising pipe. The drive wheel consists of cut old tires. A concrete guide box with a glass bottle at the well ground leads the rope with the pistons into the riser pipe. For more information see Rope Pump on the RWSN website.

- **Tara Pump** - is a direct action pump for low lift wells. It uses a buoyant pump rod that helps to reduce the forces on the handle. It is not designed for heavy-duty use, and can serve small communities of 100 people. The maximum recommended lift is 15 m. The Tara Pump is a public domain pump defined by RWSN specifications and Indian Standards. It is fully corrosion resistant and is easy to install and has excellent potential for community-based. For more information see Tara Pump on the RWSN website.

- **Treadle Pump** - A pump for small scale irrigation and only limited use for drinking water. The treadle pump was developed as a simple foot operated pump for small scale irrigation. For more information see Treadle Pump on the RWSN website.

- **U2, U3, U3M**: These versions of the India Mark II (U2) and India Mark III (U3) specified by the Government of Uganda. The U3M is a corrosion-resistant variant defined by RWSN specifications. For more information see U3M Pump on the RWSN website.

- **Vergnet Hydro HPV60 / HPV100**: a pump operated by foot with a pedal. The piston movement is hydraulically transmitted via a flexible hose to a rubber diaphragm down in the pumping element. It is designed for heavy-duty use, serving communities of 300 people. The maximum recommended lift is 60 m. The Vergnet pumps are fully corrosion resistant and installation of the pump is easy. Maintenance requirements are simple; above ground...
components allow interventions by the village caretaker, but below ground components are difficult to repair. Designed and manufactured by Vergnet-Hydro (France).

- **Zimbabwe ‘B’ Bush Pump** - is a robust conventional lever action handpump, first developed in 1932 and standardised in Zimbabwe (SAZ 881:2004). It is designed for heavy-duty use, serving communities of 300 persons. Three different cylinders are available, the smallest one extend the range to a maximum recommended lift of 80 m. The Bush Pump is not corrosion resistant. It requires special skills for installation as well as for the maintenance; it is not a VLOM pump. For more, including the standards, see [Bush Pump](#) on the RWSN website.

### 6.3 Note on Galvanised Iron for handpumps, Raj Kumar Daw

1. The Afridev handpump does not use Galvanised Iron (GI) pipes.
2. The India Mark II uses 1 ¼" (32 mm ND) B (or Medium) Class GI pipes, with heavy-duty couplings (or sockets) in 3 m lengths.
3. The India Mark III uses 2 ½" (65 mm ND) B (or Medium) Class GI pipes, with heavy-duty couplings in 3 m lengths.

The detailed specifications of GI pipes used in IM II and IM III pumps are provided in Clause 8.1, IS 15500 (see box) published by the Bureau of Indian Standards.

**Figure 11: Extract from Deepwell Handpump Standard 15000 (BIS 2004)**

> 8.1 Riser pipes shall be hot dipped galvanized, screwed and socketed pipe conforming to IS 1239 (Part 1) medium class with special emphasis on the requirements given in 6.4. Pipe ends shall have smooth finish and shall be free of burrs or sharp machining chip. Internal surface of pipes shall not have any lump of zinc. One end of each riser pipe shall be fitted with a hot dipped galvanized socket and the other end with a thread protector. The nominal bore and length of each pipe for different handpumps shall be as given in Table 2.

Under normal circumstances GI pipes should last for an indefinite period, easily over 5 years and sometimes they lasted for 10 years. Problems come up with each of the above GI pipes for different reasons. Lack of adherence to specifications of pipe manufacturing is one reason. This has caused more problems for 2 ½" pipes than for 1 ¼" pipes. GI pipes are manufactured in 6 m lengths and so need to be cut to 3 m lengths for use on handpumps. Being smaller in diameter, lighter and easier to handle, 1 ¼" pipes are easier to cut and thread manually or on a simple lathe. This is not so easy for 2 ½' pipes. As a result, the thread quality on 2 ½" pipes has, in the past, been a serious problem. Moreover, 1 ¼" pipes is a much more commonly used pipe (and therefore manufactured in larger quantities and remained more consistent in quality – wall thickness, galvanising and treading) that 2 1/2" pipe. Then, the 2 ½" being much heavier than the 1 ¼" pipe, creates much heavier load on the pump's Water Tank coupling.

Conclusion: The use of 2 ½" pipes raises a number of difficulties. Its higher cost is a major inhibiting factor. Being heavier, it is more difficult to install manually and even more difficult remove. Pipe failures (dropped connections), leaking joints (due to poor threading), non-verticality (again poor threading) were some of the other reasons why the IM III was never as popular as the IM II.

With 1 ¼" pipes, the problems of manufacturing quality were never serious, but sometimes short supply, and simple avariciousness led to the use of A (Light) Class pipes instead of B (Medium) Class pipes. A Class pipe was significantly cheaper. In the A Class pipe, with a thin wall thickness, threads would either be insufficient in depth or would cut into
the inner pipe wall if they were made deep enough. The use of A Class pipe was never reported to be a widespread problem, but it did come up occasionally in the past (1980s in India).

The quality of pipe sockets for 1 ¼" pipes posed a serious and persistent problem for quite some time. They were of uncertain quality in wall thickness and threading. They cracked. Dropped pipe connections resulted fairly regularly, especially post 1980s when cylinder installations began to go deeper, up to 45 m and more. Heavy duty couplings had to be specially mentioned in the specifications.

An unexpected problem area began to emerge around the late 1980s, when groundwater quality began to show up as a problem in some areas. This included high Iron content, which caused rust-like scaling on pipes, slime formation on pipe walls, rapid corrosion of the galvanising, pitting and pipe perforation. In more general terms, the occurrence of aggressive water became a recognised problem in coastal Orissa (in India), scaling was seen in pipes coming out wells in Rajasthan with similar corrosive effects. Internationally, the corrosion problem began to be reported from Sri Lanka and Uganda (both Danida projects of the 1980s-90s).

In the early 1990s, very little was understood about aggressive waters, except for the fact that GI pipes did not last very long. In coastal Orissa they lasted for 3 years and threw the project completely out of its cycle. Trial and error led to alternatives. The Danida assisted project in Sri Lanka used 40 mm ND PVC pipes on large scale, made in Germany, around 1986-88, on around 3000 installations. An Indian equivalent emerged soon for application in Orissa. The experience with PVC pipes on the Tara pump in Bangladesh was also adapted for deep well application in India.

That is the GI pipe story in short. I am open to correction.

The Afridev used with PVC right from the start. It had the obvious advantages of cost, weight, ease of installation and non-corrodibility. Problems emerged with PVC pipes too, some were solved, some not.

Raj Kumar Daw
Pune, India, rajda1@gmail.com
August 2013

6.4 References and further resources

- BIS (2004) IS 15500-1 to 8 (2004): Deepwell handpumps components and special tools (amalgamation of IS 9301, 13056, 13287,14101, 14102, 14103, 14104, 14105 and 14107) [MED 27:Handpumps], Bureau of Indian Standards, New Delhi, India

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6 In 2012, in South Sudan, I came across stocks of A Class pipe that had been given by an international NGO to the Govt. as a gift. The Govt. were fully aware that the pipe was unsuitable, but one officer actually told me – beggars can’t be choosers. I have photographs of the pipes and pipe sockets and have made high levels of the Govt. aware of this problem.
Handpumps: a synthesis of online discussions (2012-2014)

S G Furey, Skat Foundation