It is time for the problem of pump corrosion and consequent failure to be eliminated

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Authors

Jacinta Nekesa
Head of Programmes
WaterAid Uganda
+256 41 4505795
jacintanekesa@wateraid.org

Vincent Casey
Senior WASH Advisor
Programme Support Unit
WaterAid
47-49 Durham Street, London, SE11 5JD (UK)
+44 207 7934932
VincentCasey@wateraid.org

Lawrence Brown
Senior Hydrogeologist
Hafren Water
Barkers Chambers, Barker Street, Shrewsbury, SY1 1SB (UK)
lawrence.brown@hafrenwater.com

Jacob D. Carpenter
Independent WASH Consultant
1891 Flat Shoals Road, Atlanta, GA 30316 (USA)
jcarpenter@mail.usf.edu

Abstract/Summary

Handpump corrosion has been known about for over 30 years following a number of significant research projects undertaken in the late 1980s. Nevertheless, aid organisations and governments have continued to install pumps manufactured with unsuitable materials, leading to high maintenance costs, pump failure and rejection of water sources due to poor water quality. The WASH sector has so far failed to address this recurrent problem which threatens to hamper progress towards achievement of SDG 6. WaterAid has undertaken field research in northeastern Uganda to highlight the issue again and to provide data to support changing procedures. The results of the research have been presented to stakeholders in local government and a number of actions implemented by WaterAid's partners in Uganda.

Introduction

The problem of high concentrations of iron in rural water supplies is well known across many countries in Africa and elsewhere. Although elevated concentrations of iron are not considered a particular health problem, aesthetic issues may result in a reluctance to use a water point and in severe cases, abandonment of the water point for an alternative, and potentially unsafe, source. Typical problems include metallic taste, discoloured and turbid water, discolouration of water following pumping and discolouration of food and clothing. The World Health Organisation has given an advisory limit of 0.3 mg/l for drinking water supply (WHO, 2011), which is considered the limit at which taste become apparent. However, less stringent limits are often used in national standards for untreated rural water supplies, for example, in Uganda a value of 1 mg/l is specified (UNBS, 2008).

Iron is present in soils and rock formations in two forms: reduced soluble ferrous iron (Fe^{+2}), or oxidised insoluble ferric ion (Fe^{+3}). The highly soluble nature of the ferrous iron can mean that, if conditions are right, groundwater can hold significant concentrations of iron yet appear clear and colourless because the iron is in solution. When such groundwater is pumped out and exposed to the atmosphere, oxygen will convert the ferrous iron to ferric iron, which reacts with other components in the water to form insoluble iron hydroxides. These precipitate out to cause red/brown cloudiness in the water and staining. This oxidation process can take some time, so apparently clear water can be produced at the pump, but then discolours later, once the water has been standing.

Two sources of high iron concentrations are possible in pumped groundwater: a natural (geogenic) source in the aquifer, or as the result of the corrosion of susceptible pump components. In some circumstances a combination of both is possible. It is important to distinguish which of these is the source in any particular case as this will point to potential solution(s). For example, where a natural origin is identified, implementers may install iron removal plants on handpumps. In other circumstances, it may be the handpump itself which is causing, or significantly adding to, the problem. This has been observed particularly the case where India Mark II handpumps are deployed, but other models of handpump may also be affected.

The corrosion of susceptible pump components can be significantly enhanced by the action of iron bacteria. Although not a health hazard in themselves, they can have a significant detrimental impact on water quality, as well as resulting in clogging of pumps and borehole screens.

Perhaps the most surprising aspect of handpump corrosion in rural water supply is that it has been thoroughly documented and specific preventative guidelines have been available for 30 years. There appears to be a general awareness of the problem, although this has not been translated into action. A survey of online discussions Furey, 2014) on handpump technologies among rural water supply specialists and practitioners between 2012 and 2014 concluded that water quality, particularly related to high iron, aggressive groundwater, and corrosion, was the main issue. Particular needs identified from the discussions were:

- better testing and monitoring of groundwater quality so that galvanised steel (GI) pump components are not installed;
- a clearer understanding of whether high iron levels are caused by natural conditions or by pump corrosion, and,
- the replacement of GI pipes and pump rods in all existing pumps in aggressive groundwater.

Despite this knowledge, it is apparent that the corrosion of handpump components continues to be a significant problem in some places, where it impairs water quality, handpump performance, and functional sustainability. In these places, communities are burdened with a handpump that is costly to maintain and produces water that is undesirable.

This paper sets out to briefly describe some of the background to the issues, research work that WaterAid has been undertaking in Uganda to highlight the issue, feed back from this work and recommendations to improve the situation and prevent continuation of this problem which is helping to prevent the provision of rural water supplies becoming truly sustainable.

Description of the Case Study – Approach or technology

Background

Identification of the problem and still the most significant research into the issue, dates back to the 1980s and a World Bank / UNDP Project: 'Laboratory and Field Testing and Technological Development of Community Water Supply Handpumps', UNDP-INT/81/026 (the 'Handpumps Project'). The final project report (Arlosoroff et al, 1987) included a significant emphasis on the corrosive effects of aggressive groundwater, which it characterised as 'much more widespread and much more damaging than previously suspected in both Africa and Asia'. The report highlighted the importance of corrosion-resistant materials and concluded that, while assessment of corrosivity of groundwater is a complex matter, pH is a 'valuable indicator of aggressivity'; pH below 6 is likely to be "highly aggressive" while pH above 7 is unlikely to contribute to corrosion.

In a subsequent report, Langenegger (1987) recognised the complexity of corrosion, its dependence on a number of parameters and the lack of a universal index for predicting corrosion in all water quality conditions. Based on data collected during the Handpumps Project, Langenegger considered that pH, which is easily measured in the field, was a useful corrosion indicator and he developed a set of guidelines for the use of galvanised steel riser pipes and pump rods, reproduced as Table 1.

Table 1. pH-based index for applicability of galvanised downhole components

pH	Application of galvanised material	Aggressivity of water
pH> 7	Suitable	Negligible
6.5 < pH ≤ 7	Limited	Little to medium
6 < pH ≤ 6.5	Not recommended	Medium to heavy
pH ≤ 6	Not recommended	heavy

Source: Langenegger, 1987

In 1994 the World Bank published one of the most extensive and complete research-based resources on handpump corrosion. The report (Langenegger, 1994) was based on field and laboratory experience in the Handpumps Project gained in West Africa (Burkina Faso, Ivory Coast, Ghana, Mali and Niger). It provides details of the characteristics of corrosion and the various geological, chemical, electrochemical, and biological factors associated with it. Some key conclusions included:

- natural iron concentrations in groundwater in the region was rarely greater than 1 mg/L,
- High iron concentrations in handpump wells was usually caused by handpump corrosion. To confirm this, Langenegger (1994) suggested performing a pumping test with periodic sampling to measure iron concentration. If the major source of iron is corrosion, then the iron concentrations will drop rapidly after pumping continuously for a few minutes,
- galvanization does not protect riser pipes and pump rods from corrosion where pH < 6.5 and provides limited protection for pH of 6.5 – 7,
- lower handpump usage results in more serious high-iron problems,
- the internal surface of immersed pipes are less corroded than the external surfaces, while the external surface of pipes above the water level have negligible corrosion,
- stainless steel pump rods had corrosion rates an order of magnitude less than galvanized pump rods.
- A simple pH index (Table 1) was sufficient to determine the potential for electrochemical corrosion, which is the type of corrosion that is primarily responsible for the elevated iron levels found in many wells

Another important issue is the role of bacteria in the geochemical cycle of iron in respect of pump corrosion and production of poor quality water from handpumps. Iron bacteria are a well-known cause of problems in water supplies around the world, both in abstraction boreholes and water distribution systems. These bacteria can grow in either aerobic (oxygen present), or anaerobic (oxygen absent) conditions. In aerobic conditions, the specialised bacteria that influence the geochemical cycle of iron are termed iron bacteria, or iron-related bacteria (IRB). Anaerobic corrosion is commonly the result of the presence of sulphate-reducing bacteria (SRB). Both these types of bacteria are reported to be present naturally in most aquifers (Houben and Treskatis, 2007, P 68).

Iron bacteria use the oxidation of ferrous iron to insoluble ferric hydroxides as an energy source. The ferrous iron can originate either naturally in the aquifer, or as a consequence of the electrochemical corrosion of pump components. According to Cullimore and McCann (1978), iron bacteria have been found in waters with iron concentrations as low as 0.02 mg/l, but generally require higher concentrations to thrive. In flowing water, such as an abstraction borehole, they reported that growth of iron bacteria may be expected if iron concentrations exceed 0.2 to 0.5 mg/l. The rate of bacterial growth is controlled by a number of factors including temperature, groundwater flow rate and pH.

The activity of IRB results in the deposition of thick ferric hydroxide ochre and the development of a characteristic orange slime coating that is often noted in affected wells (Fader, 2011). The mobilisation of these products when pumping, results in the rejection of the water by users.

Sulphate-reducing bacteria are considered to be the most common cause of microbially induced corrosion (MIC). As part of their life-cycle the bacteria produce hydrogen sulphide which reacts with ferrous iron to produce sulphuric acid which causes further corrosion. One of the solid products is a characteristic black deposit comprised of iron oxides and sulphides, which can be recognised by a 'rotten eggs' (hydrogen sulphide) smell if a few drops of dilute acid are placed on a sample. The bacteria can sometimes be found beneath oxygen tolerant bacteria where oxygen is absent. SRB-induced corrosion rates can be very high and Houben and Treskatis (2007, P 58) quote rates of several millimetres per year. Fader (2011) noted the typical products of SRB bacteria in boreholes in Uganda which had black slime of the riser pipes and a smell of rotten eggs. Evidence of significant corrosion through the wall of riser pipes was also apparent.

WaterAid Uganda's experience

WaterAid Uganda (WAU) currently operates in a number of districts in North East Uganda working closely with the District Local Governments and through two local implementing partners, Church of Uganda-Teso Dioceses Planning and Development Office (CoU-TEDDO) and Wera Development Agency (WEDA). In two of these districts, Amuria and Katakwi, there had been increasing concerns over problems with poor water quality in groundwater sources due to high iron concentrations.

Increasing concerns with the quality of water sampling being undertaken by drilling contractors led in 2012 to WAU deciding to use staff from the Government Laboratory in Mbale to carry out on-site pH measurements at boreholes before handpump installation rather than including testing in the drilling contract. Subsequent analysis of these pH measurements in Amuria and Katakwi districts indicated that the pH of the groundwater was much lower than was previously suspected. Out of 34 samples, 91% were below pH 6.5 and 38% below pH 6. This reinforced the suspicion that corrosion was likely to be contributing to the high iron concentrations reported in groundwater sources.

Diagnosis of the origin of high iron in rural water supplies

In August 2014 WaterAid Uganda undertook a field testing programme on a number of recently installed boreholes where high iron concentrations had been reported by communities; in one case this had resulted in the abandonment of a newly constructed supply. The objective of the programme was to evaluate the origin of observed high iron concentrations using the procedure described by Langeneggar (1987 and 1994) and to test the use of a portable iron testing kit manufactured by Palintest.

The pumping test proposed by Langeneggar simply involves flushing out a well that has been left unused for a short period of time and observing the change in iron concentration. The corrosion of pump materials will release soluble iron into the well water at a rate that will generally be greater at low pH. While a well is in use, iron released by the corrosion process will be diluted by groundwater entering the well. However, when a pump is out of use, for example overnight, concentrations will gradually increase and the concentration of iron will be much higher in the morning. The test simply involves pumping a well early in the morning, before it has been used, and measuring iron concentrations at intervals until at least a volume equivalent to the column of water held in the borehole is removed. At this time, the water held in the well is being replaced by fresh groundwater. When corrosion is the main source of iron, concentrations should drop rapidly until they stabilise at the natural background concentration in the aquifer (depending on how long pumping continues). If, on the other hand, iron concentrations remain high throughout continued pumping, it is likely that the iron originates from the aquifer.

Boreholes affected by high iron concentrations often produce very turbid water comprised of corrosion products precipitated in the borehole and sides of the riser pipe, as well as products of bacterial activity. Although this turbidity is generally reported at the start of pumping, increases in turbidity can occur at any time. In order to test samples representative of water quality in the well and in natural groundwater and to prevent unrepresentative 'spikes' in iron concentrations due to turbidity, the samples need to be filtered before testing.

The iron-testing kit selected for the research uses a simple colour comparison technique requiring the addition of a single reagent, in tablet form, to a sample to produce a colour change, the intensity of which is proportional to the concentration of iron. The colour of the test sample is then compared to a standard colour disc (Figure 3). For this study, the High Range (0 to 10 mg/l) test kit was used, the colour disc for which has 9 colour matches at 0.5, 1.0, 1.5, 2.0, 3.0, 4.0, 5.0, 7.5 and >10 mg/l.

Before testing, the boreholes were locked overnight so that test pumping would start after the boreholes had remained unused for a few hours. To enable a suitable period of pumping to be estimated and timing of sampling set, the volume of water held in the riser pipe and in the borehole need to be known. These volumes are significant because the highest iron concentrations would be expected in water held in the riser pipe, while after the removal of at least one well volume the iron concentrations should be close to the natural concentration in the aquifer. For the tests, these volumes were estimated from borehole completion reports, assuming no changes to the borehole had been made and water levels were similar to those at the time of construction. By assuming a pumping rate, the timing of sampling could be predicted. Actual pumping rates were then measured during the test.

Five boreholes with India MkII pumps and GI riser pipes installed were tested at locations indicated on Figure 1. A steady pumping rate was maintained and samples taken at intervals so that the first was representative of water held overnight in the riser pipe, and subsequent samples represented water held in the borehole at various times. Pumping was continued for sufficient time (approximately 2 hours for these boreholes) such that the final samples were taken after at least one well volume had been pumped. In all cases water was pumped using the installed handpump.

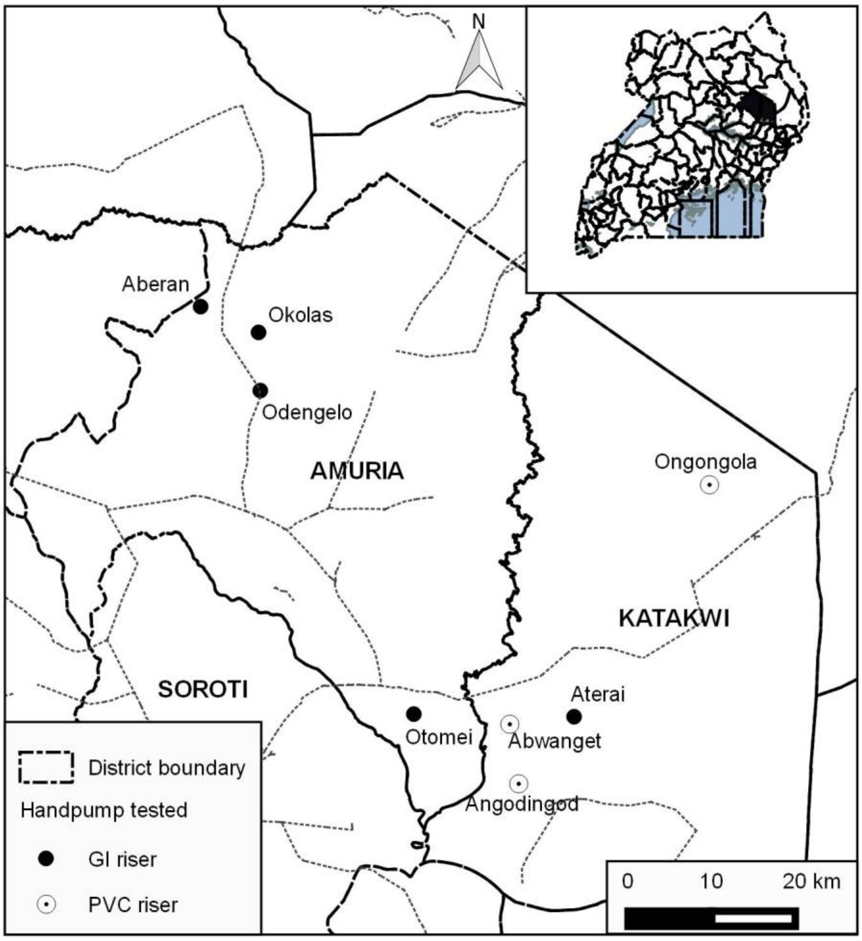

Figure 1. Location of boreholes sampled

In all the boreholes tested, the water discharged was clear and colourless from the start of pumping, although small solid particles, presumed to be corrosion products (rust), were often present. In several boreholes the discharge became turbid for a short period, before clearing again. It was also found that if the boreholes were pumped vigourously, the discharge became brown and turbid. It is supposed that only when this high pumping rate is applied, do biofilm and other corrosion products become detached from the inside of the riser pipe.

Samples were tested on-site for pH and electrical conductivity using calibrated probes. Due to potential interference from particulates originating from pump corrosion, samples tested for iron were filtered at 0.45 μm. If these particles were included the tests results might not be representative of the true groundwater quality. This filtration has the potential to remove any iron that may have been precipitated out of solution in the time between sampling and testing, resulting in lower iron concentrations. However, in all cases filtration was undertaken immediately after sampling and it is considered that this will have minimised the impact of any rapid precipitation. To evaluate this, a number of duplicate unfiltered samples were also analysed on site.

Further duplicate filtered and unfiltered samples were also taken for subsequent analysis at the Ministry of Water and Environment's laboratory in Entebbe. All the samples were kept cool and delivered to the laboratory within 1 week of sampling. Although it was not possible to add any preservative to the samples to ensure iron remained in solution during transport, the samples were subsequently acidified in the laboratory prior to analysis, ensuring that any precipitated iron was re-dissolved.

Following the tests, the riser pipes on some of the handpumps were pulled to allow inspection for signs of corrosion. Evidence of corrosion was seen at all the sites, in particular at Odengelo village where the riser pipe was found to be leaking. The threads on some pipe joints at this handpump were severely damaged (Figure 2) and also indicated the use of sub-standard material. This borehole was only completed in October 2013 and the pump installed in December 2013, indicating how rapidly corrosion can affect a handpump unde certain groundwater conditions.

Figure 2 Threads on riser pipe at Odengelo, 1 year after installation

Main results and lessons learnt

The results from the field analysis using the Palintest kit show a clear colour change from deep red (sampled from riser pipe) to light orange at the end of the test, indicating a decline in iron concentration. An example from the test at the Odengelo borehole is shown on Figure 3 with the iron concentrations interpreted from the comparator disc indicated.

Figure 3. Results of Palintest analysis at Odengelo handpump with GI riser

Table 2 shows a comparison between the field test results from the Palintest kit and analysis at the laboratory for filtered samples. The field results tend to be higher, possibly indicating iron that will have precipitated out during transport was not recovered by acidification at the laboratory. Better results may have been obtained if it had been possible to preserve the samples with nitric acid in the field.

Table 2. Comparison of laboratory and field test results for boreholes with GI risers

Odengelo	volume	(litres)	5	153	459	918	1,224
	Fe Palintest	(mg/l)	>10	2.0-3.0	1.5	0.5-1.0	0.5
	Fe lab	(mg/l)	21	1.6	0.77	0.45	0.5
Aberan	volume	(litres)	6	360	720	1080	1440
	Fe Palintest	(mg/l)	>10	7.5	1.5	0.5-1.0	0.5-1.0
	Fe lab	(mg/l)	26	1.91	1.23	0.74	0.69
Otomei	volume	(litres)	6	360	720	1080	1440
	Fe Palintest	(mg/l)	5	1.5	1.0-1.5	1.0-1.5	0.5-1.0
	Fe lab	(mg/l)	1.17	0.49	0.67	0.63	0.48
Aterai	volume	(litres)	5	324	648	929	1296
	Fe Palintest	(mg/l)	>10	1.0-1.5	0.5-1.0	0.5-1.0	1
	Fe lab	(mg/l)	4.5	0.73	0.71	0.28	0.86
Okolas	volume	(litres)	6	360	720	1080	1440
	Fe Palintest	(mg/l)	>10	4	1	0.5-1.0	-
	Fe lab	(mg/l)	25	3.5	0.36	0.2	0.17

Note: All analysis on filtered samples

pH values in the samples recorded at the end of the test ranged from 6.38 to 6.97, indicating (from Table 1) that GI pipes would not be recommended in four of the boreholes and have limited suitability in the fifth. In three of the boreholes the initial filtered iron concentrations, which varied from 21 to 26 mg/l, had reduced to between 0.5 and 0.17 mg/l by the end of the test. In the remaining two boreholes, the initial iron concentrations were lower at 4.5 and 1.17 mg/l and these had reduced to 0.86 and 0.48 mg/l respectively by the end of the test. The sharp decline in iron concentration in the samples is illustrated graphically on Figure 4.

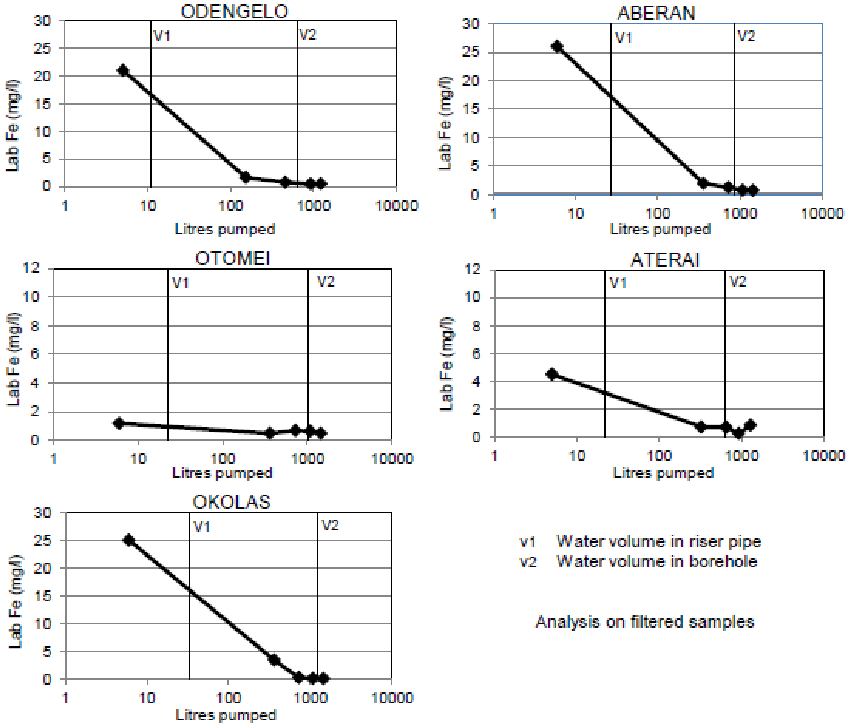

Figure 4. Results of laboratory tests on samples from pumps with GI risers

Iron concentrations recorded from the original water quality testing after construction show that for four of these boreholes the iron concentrations were between 0.08 and 0.68 mg/l. At the fifth borehole, Aterai, a concentration of 13.5 mg/l was measured. This is certainly anomalous when compared to all other samples taken in the district over a 2-year period, but the cause of this is unclear.

When the results from filtered and unfiltered samples were compared it was apparent that filtered samples generally had a lower iron concentration, for example at the Okolas borehole (Figure 5). This may be due to solid corrosion products being removed by filtration, but also to removal of any iron that had precipitated in the short period between sampling and filtering. Nevertheless, the filtered samples clearly show the rapid fall in iron concentration attributable to the removal of iron present due to corrosion of the handpump.

The unfiltered samples from Okolas also show a sudden increase in iron concentration after about 1,000 litres had been pumped, corresponding with an increase in turbidity during pumping. This illustrates how concentrations can be anomalously large if solid corrosion products are present in an unfiltered sample.

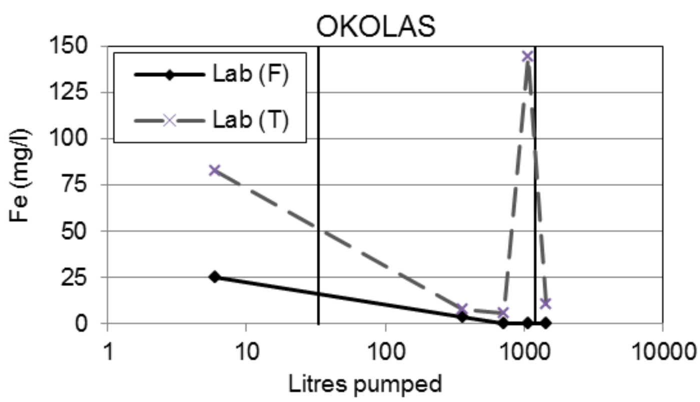

Figure 5. Comparison of laboratory analysis on filtered and unfiltered samples

Three boreholes fitted with PVC riser pipes were also visited (locations shown on Figure 1). These were not tested after being locked overnight so the results cannot be directly compared with those from the India Mk II (U2) installations. Nevertheless, inspection of the pumps and the water quality results are revealing. Two boreholes fitted with U3M pumps (PVC riser and stainless steel pump rods) recorded exceptionally low pH values, between 6.00 and 5.68. The borehole at Amaratoit recorded iron concentrations (filtered) of between 1.0 and 1.5 mg/l from the Palintest kit and 1.56 and 2.22 mg/l from laboratory analysis. The second borehole at Abwanget recorded concentrations (filtered) of 0.5 mg/l from the Palintest kit and 0.06 mg/l from laboratory analysis.

The third borehole at Angodingod (Figure 6) was a U2 fitted with 1¼″ PVC riser pipe (supplied by Davies and Shirtliff, Kampala) and GI pump rods. The Palintest results from two samples indicated iron concentrations less than 0.5 mg/l, confirmed by laboratory results of 0.06 mg/l. A pH of 6.2 was measured in the sample. Overall experience of this installation has been positive to date, and the community has reported an acceptable yield and an absence of coloured water in the early morning, as was the case with pumps with galvanised steel riser pipes.

Figure 6. 1¼″PVC riser pipe fitted to an India MkII pump at Angodingod

The high iron concentrations recorded in the Amaratoit borehole (noted above) appear to be natural given that the pump components are corrosion-resistant. This well had a severe turbidity problem, possibly as a result of a completion which included an inappropriate screened section in weathered deposits. Although the turbidity was not related to corrosion, unfiltered samples tested at the laboratory had iron concentrations of between 3.85 and 4.6 mg/l and one sample a concentration of 45 mg/l.

The following observations can be made from the field testing:

- The Palintest comparator kit performed well at identifying the decline in iron concentration as the well was pumped,
- Iron concentrations from the comparator were slightly higher than those measured at the laboratory, possibly a consequence of the lack of on-site preservation,
- All the samples from boreholes with GI components showed a sharp decline in iron concentration when pumped continuously for two hours. In the final samples, iron concentrations in filtered samples were between 0.17 and 0.86 mg/l.
- The unfiltered samples often showed very high iron concentrations, 144 mg/l in one case, indicating that solid corrosion particles are likely to be present.
- The filters used (syringe filter with 1µm prefilter 25mm, 0.45 µm) were highly effective and did not block. Only in one of the U3M installations (Amaratoit) did turbidity (non-iron related) cause the filters to rapidly clog up. However, the use of on-site filtration does need to be treated with some caution. Filtering may distort the results if there is a rapid alteration of Fe^{+2} to Fe^{+3} in the time between taking the sample and filtration. In this case the measured iron concentration may be lower than is actually the case. Selecting a larger filter size may compensate for this.
- PVC riser pipes appear to be working effectively at one U2 installation where the pH of the groundwater suggests that corrosion and poor water quality would be a problem if GI pipes were fitted.
- Naturally high iron concentrations were recorded in one of the boreholes fitted with a U3M pump.

During the fieldwork it also became apparent that there was a lack of knowledge regading the installation and maintenance of the corrosion-resistent U3M pump. Consequently certain instalations were not performing optimally.

<u>Outcomes</u>

Since the research was completed, WaterAid has undertaken a number of actions to address the issues identified:

- The results of the research were presented to a meeting of District Water Officers in 2015 triggering use of stainless steel riser pipes in Amuria District.
- WaterAid Uganda has been advocating the abandonment of the use of GI by partner organisations, particularly where the groundwater is known to be aggressive. Subsequently, all boreholes drilled by partner organisations during 2015 in Amuria District were fitted with U3M pumps (where installation depth was up to 30m) and twenty-six boreholes drilled in the first quarter of 2016 in Amuria, Napak and Kotido Districts were installed with stainless steel components.
- Training courses on the maintenance and installation of U3M pumps has been undertaken in Katakwi and Amuria Districts.
- A number of boreholes in Masindi and Katakwi Districts are being retrofitted with stainless steel components following discussions wth the fundng organisation (EU).

Conclusions and Recommendations

At existing handpumps where iron-related water quality problems have been identified, boreholes should be tested to establish whether it has been caused by corrosion of susceptible pump components, or due to naturally high concentrations present in the aquifer. The choice of rehabilitation methods can then be determined.

The influence of bacteria in accelerating pump corrosion was not specifically addressed in the research and this is a potential avenue for further work. An important aspect of this is that bacterially-enhanced corrosion can occur in situations where the pH of the groundwater is >7. Possible options for avoiding or reducing problems incude:

- Use of PVC riser pipes where shallow installation depths are possible
- Use of stainless steel riser pipes and rods at deeper installation depths
- Use of corrosion resistant pumps
- Trialing of the Poldaw PVC/steel coupling riser main configuration
- Ensuring wells are sterilised following completion and following maintenance where the rising main and pump components have been removed, and
- Ensuring good sanitary seals are placed to prevent iron bacteria entering the well after completion.

The main recommendation for preventing the corrosion-induced water quality problems is considered to be improvement to the planning stage of water supply projects:

- Pre-implementation planning for projects must include serious consideration of pH levels using on-site tests. Reference should also be made to government databases and water quality mapping, if available, and treated with the appropriate caution. Communication and coordination with local government and other NGOs working in the area can also reveal concerns about aggressive groundwater. A full assessment should be undertaken to identify problems that may be already known within the project area such as water quality and handpump sustainability, which can have major implications for new boreholes.
- Based on appropriate planning, properly formulated contracts and BoQs are required with sufficient flexibility to allow changes as necessary. Budgets should include sufficient contingency to allow alternative materials to be installed if proven necessary by on-site experience.
- Consideration should be given to separation of the various tasks involved with drilling and pump instalation so that the drilling contractor is not responsible for handpump installation or water quality testing. For example, it is not unreasonable to suppose that water quality sampling could come under the responsibility of the project supervisor.

Improvements to the implementation stage include:

- the provision of competent supervision so that specifications are followed
- ensuring water quality testing is undertaken correctly and critical parameters are measured on-site if possible.

Where aggressive groundwaters are known to be present, there should be a focus on communication, data sharing, collaboration, and advocacy among government, private sector, NGOs and communities on the issue of corrosion-resistant handpump options. Sector coordination bodies, such as UWASNET (Uganda water and sanitation network) and NETWAS (Network for Water and Sanitation) in Uganda, could be an appropriate focus for such discussions.

Finally, where the selection of approved corrosion-resistant pumps is limited, stakeholders should advocate for revision of the relevant government standards.

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Contact Details
Name of Lead Author: Jacinta Nekesa
Email: jacintanekesa@wateraid.org

Name of Second Author: Vincent Casey
Email: VincentCasey@wateraid.org