Research into a Sustainable Iron Removal Plant for Uganda – Summary

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As a drinking water source groundwater is often considered as better than surface water because it does not contain harmful pathogens and generally does not need treatment[1]. However in many locations it contains iron, either from geological formations or from iron pump components. Iron is not harmful to health, but causes people to reject the borehole water, mainly because it tastes bad and stains clothes, containers and skin. When this happens in rural areas in developing countries people return to drinking surface water and this can result in disease and death, especially for young children.

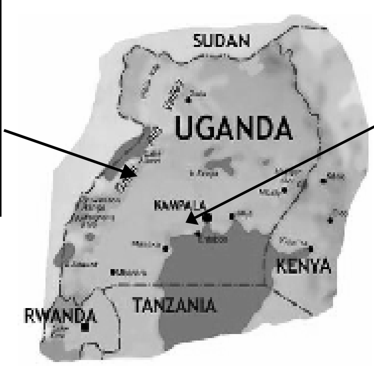
Uganda has areas of very high iron content[2 3] and the Government of Uganda plans to increase the use of groundwater throughout the country[4], therefore it is important to investigate the possibility of a sustainable iron removal plant (IRP).

Hoima District[2]:

Borehole No.	[Fe] mg/l (2000)	[Fe] mg/l (2002)	Uses of water (2002)
1	0.4	2.7	DC, W, L
2	48	44.3	N
3	53	40.5	W*
4	68	14.1	DC, W, L*
5	1.2	1.5	DC, W, L
6	9.3	14.7	W

* These two boreholes had simple iron filters attached to the pump which reduced the iron concentrations from the values quoted here.

Key:
DC Drinking and cooking
W Washing hands, dishes etc.
L Laundry
N Not used



Rakai District[3]

Borehole No.	[Fe] mg/l	Uses of water
1	71	W
2	3.4	DC, W
3	44	W
4	15	DC, W, L
5	6.0	DC, W, L
6	71	N
7	9.5	W
8	3.2	W
9	1.2	DC, W, L

Figure 2 Iron Concentrations in Uganda

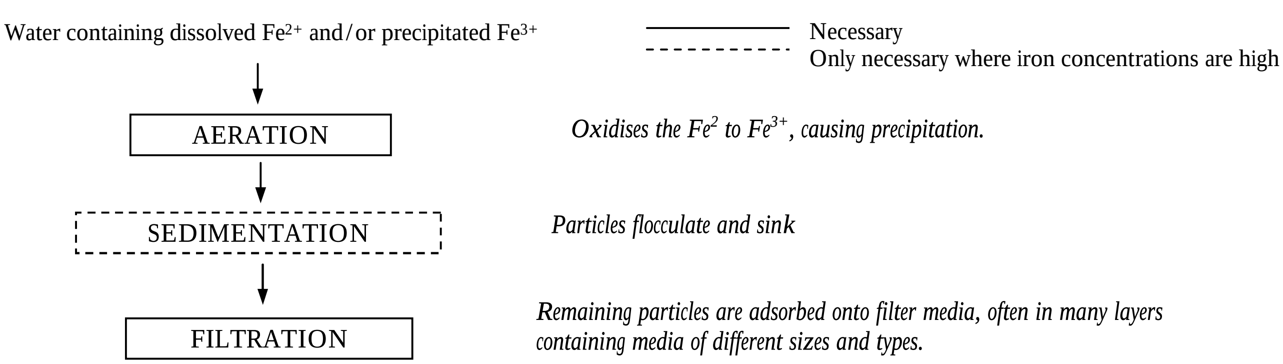


Figure 1 The Iron Removal Process

The Sustainability of IRP Technology for Rural Uganda

Fieldwork was carried out in December 2002 in Uganda and an extensive literature review performed, covering the experiences of engineers in many parts of the world who have developed their own designs of IRP. This included correspondence with engineers from Burkina Faso (8), India (500), Ghana (11), and the Philippines (9) – the figures in brackets show the number of IRPs built – and with researchers from Uganda who had carried out various lab and field trials to develop an IRP. Many of these experiences had direct relevance to the situation in Uganda:

i) The final iron concentration is obviously very important, but the percentage of iron removed tends to increase as the complexity of the IRP increases. Increasing the complexity increases the cost and, more importantly, makes maintenance more difficult. Complexity should be minimised while still producing water with an "acceptable" level of iron. This level varies greatly between communities and depends on factors such as the location of the borehole, who is collecting the water and how aware the people are of the dangers of surface water. At Bugambe (The location of the fieldwork) in a village where the nearest alternative water source was 1km away, borehole water of iron concentration 6mg/l was used for drinking by at least half the village. When this is compared with the WHO guideline of 0.3mg/l and other field work it seems sensible to aim for a final iron concentration of about 3mg/l at the outlet of the IRP.

ii) It is unlikely that a generic iron removal plant can be designed for all areas of Uganda because the iron concentrations take any value up to about 50mg/l and the oxidation reaction is affected by the pH, temperature and organic content of the water[5]. This suggests that it will be difficult to manufacture large quantities of IRPs commercially and this is also indicated by the scattered nature of high iron groundwater within Uganda[6]. This suggests that a locally built design (probably using stones or bricks) is likely to be the most suitable, therefore the design itself has to be robust so that deviations from the initial specifications do not result in a poorly performing IRP.

iii) Some of the designs studied used chemical additives (e.g. limestone) or activated carbon[7], but these need to be replaced on a regular basis and the costs and procurement difficulties make these designs impractical for rural Ugandan communities.

iv) Slow flow-rate through the IRP can be a problem[1], especially when the number of users is high. Another problem is that a certain head must be built up across the filter by each new user before the flow rate increases to a satisfactory level and when the user leaves this head runs to waste. This only becomes a major consideration when the pump is not working well[2], but many hand pumps were found to be operating poorly in a recent survey in Uganda[8]. The flow-rate can be increased by building a filter with a large surface area, but this increases the time needed to create adequate head for satisfactory flow, therefore the surface area of the filter should be between 1-1.5m^2 and the depth of any fine filter media used (<2mm diameter) should not be greater than about 150mm.

v) The height of a jerry can (the standard collection vessel in Uganda) is only 50mm below the pump outlet, and no IRP has been designed with a head loss equal to or less than this value. This problem has been solved by raising the pump, but an easier solution where the borehole is on a slope, which is often the case, is to recess the collection area underground, while also ensuring adequate drainage.

vi) Poor maintenance has been a major cause of IRP failure. Often designs are complicated, with many chambers, or many layers of different sizes of media in each chamber and institutional or community structures for maintenance have not been adequately arranged. From studies of the maintenance structures for handpumps in Uganda[8] it seems likely that villages will have to provide their own system of maintenance and that salary structures will be hard to implement leaving voluntary organisation as the only alternative. This is hard to sustain over a long period, but if a community chooses an IRP from a variety of water supply options and is aware of the maintenance requirements and of their own responsibilities it could be possible.

vii) Hygiene is an important consideration and cleaning implements must be kept clean. Any openings into the IRP must be screened to prevent people throwing things in and insects entering to breed and good drainage must be provided around the IRP.

viii) Many boreholes in Uganda have GI pump components and experience from hundreds of IRPs in India show that this causes bacterial oxidation and reduction cycles to take place which result in increased iron concentrations in the outlet water[9]. This problem can be eliminated by replacing the GI parts with PVC and stainless steel:

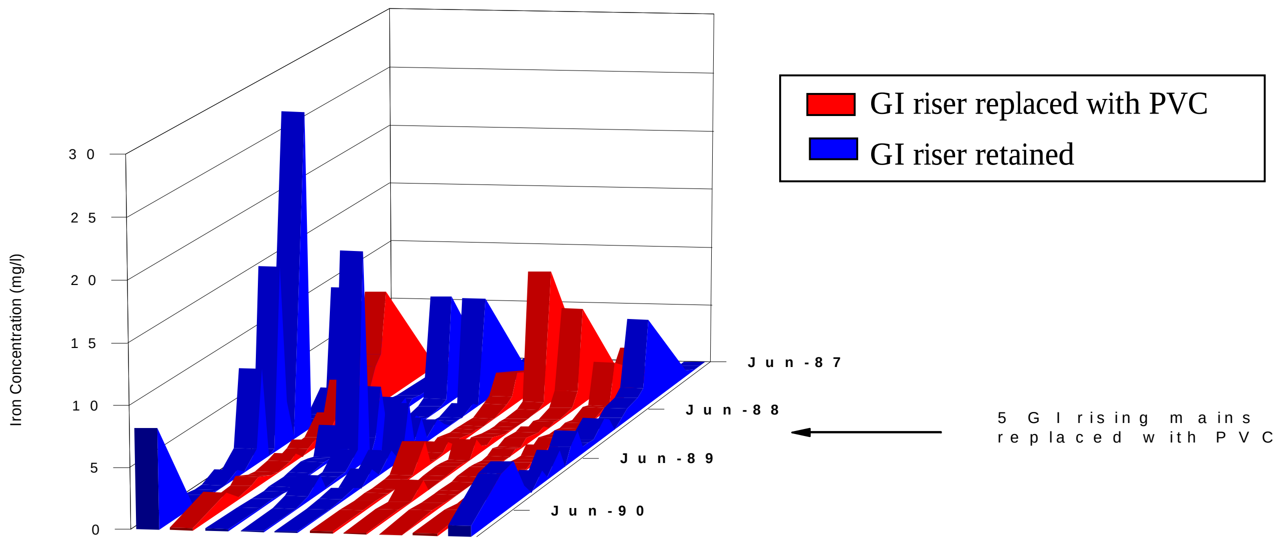


Figure 3 **Total Iron content from India Mark II pumps – GI and PVC pipes**

Evaluation of the Silsoe Filter in the Field.

A simple IRP that focussed on the action of bacteria in a filter to remove iron, had been developed at Silsoe (Cranfield University – UK), but not tested extensively in the field[1]. This design aimed to maximise the bacterial action, thus could be simple with one chamber and one size of filter media and it was hoped that maintenance requirements would thus be reduced.

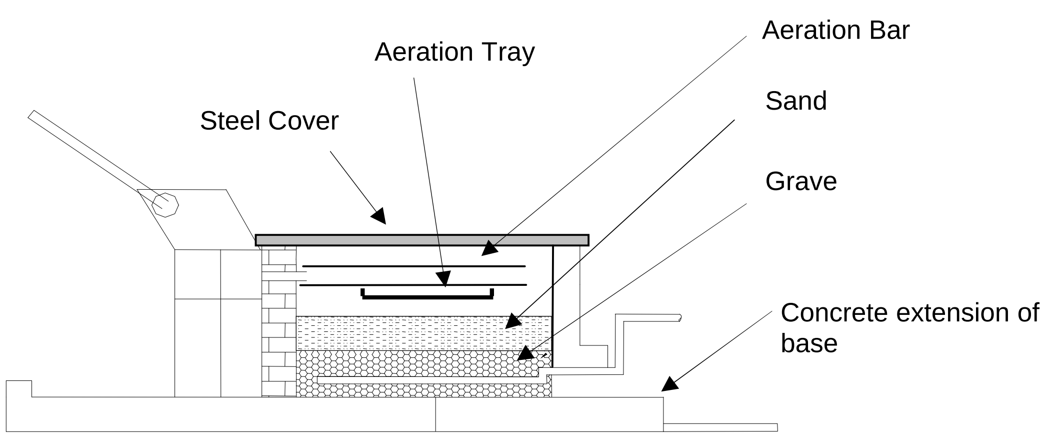


Figure 4 **Elevation of the Silsoe Filter as at Bugambe**

In 2000 three filters of this type were constructed in Western Uganda and monitored for a few months[2], but had not been visited since. The author travelled to Uganda to evaluate the performance of these filters, to uncover any problems that had arisen during the two years of operation and to investigate ways to improve their performance. The tests showed that the filters were not performing as well as previous research had indicated. Iron concentrations of 40.5mg/l were reduced to 15.5mg/l which was not acceptable for drinking, but water from one of the other boreholes of 14.1mg/l iron, reduced to 6.0mg/l by the filter, was drunk by villagers despite slow flow-rate through the filter. The filters were maintained by paid staff, who found cleaning them hard work and only cleaned the filters when the water quality was bad enough to cause complaints from the villagers. Tests were done to investigate the cause of the poor performance of the filters and to find out how to improve it. Four areas were studied and conclusions arrived at:

- The media size is not critical, but if the grains are too fine (less than about 1mm diameter) the filter clogs very quickly. This is hard to specify for a rural community as sieved sand can only be purchased at Entebbe and if sand is sieved on site it is very difficult to guarantee the media size.
- The position of the Rest Water Level, either above or below the sand level, does not seem to make a big difference to the performance.
- Aeration is very important, especially with high iron concentrations.
- Installing an up-flow roughing filter before the sand filter increases iron removal to an acceptable level (5.1mg/l), even with high initial concentrations of 42mg/l. However after a few months of field trials this filter had been rejected by the community because of poor iron removal.

It seems unlikely that pH and Eh values are adequately controlled to ensure that only biological filtration occurs[10] therefore this filter probably performs in a similar way to other IRPs developed with physical, electro-chemical and biological filtration occurring.

An IRP design for Uganda

An IRP should never be installed where GI pump components are still being used and replacing these with PVC and stainless steel should be the first improvement made. It is also possible that another borehole with acceptable iron levels could be drilled near to the one that has been rejected (as at Bugambe) or that other water sources could be used, such as springs or rain water, in a more sustainable way than that provided by an IRP. However where the source of iron is geological it is clear that a technical solution does exist which might be sustainable in the right community environment. From the field work and literature review the author has developed a new design which is shown below. It is more complex that the Silsoe design to improve the efficiency and incorporates three chambers, which should also reduce the frequency of cleaning. While the first chamber is a sedimentation chamber and the third a slow sand filter, the middle chamber can either be a second sedimentation chamber (for lower iron concentrations) or an up-flow roughing filter. This design seeks to minimise maintenance requirements, but also takes into account the fact that different water conditions and user preferences mean that a generic solution to the iron removal problem is not possible. The design is simple enough for villagers to construct under the guidance of one literate artisan, and does not present itself as a "magic solution" from the West which might discourage villagers from taking an active role in maintenance. The design has been chosen to be as robust as possible to allow deviations from the drawing below with regard to dimensions and media size, while construction materials can be chosen at the discretion of the artisan:

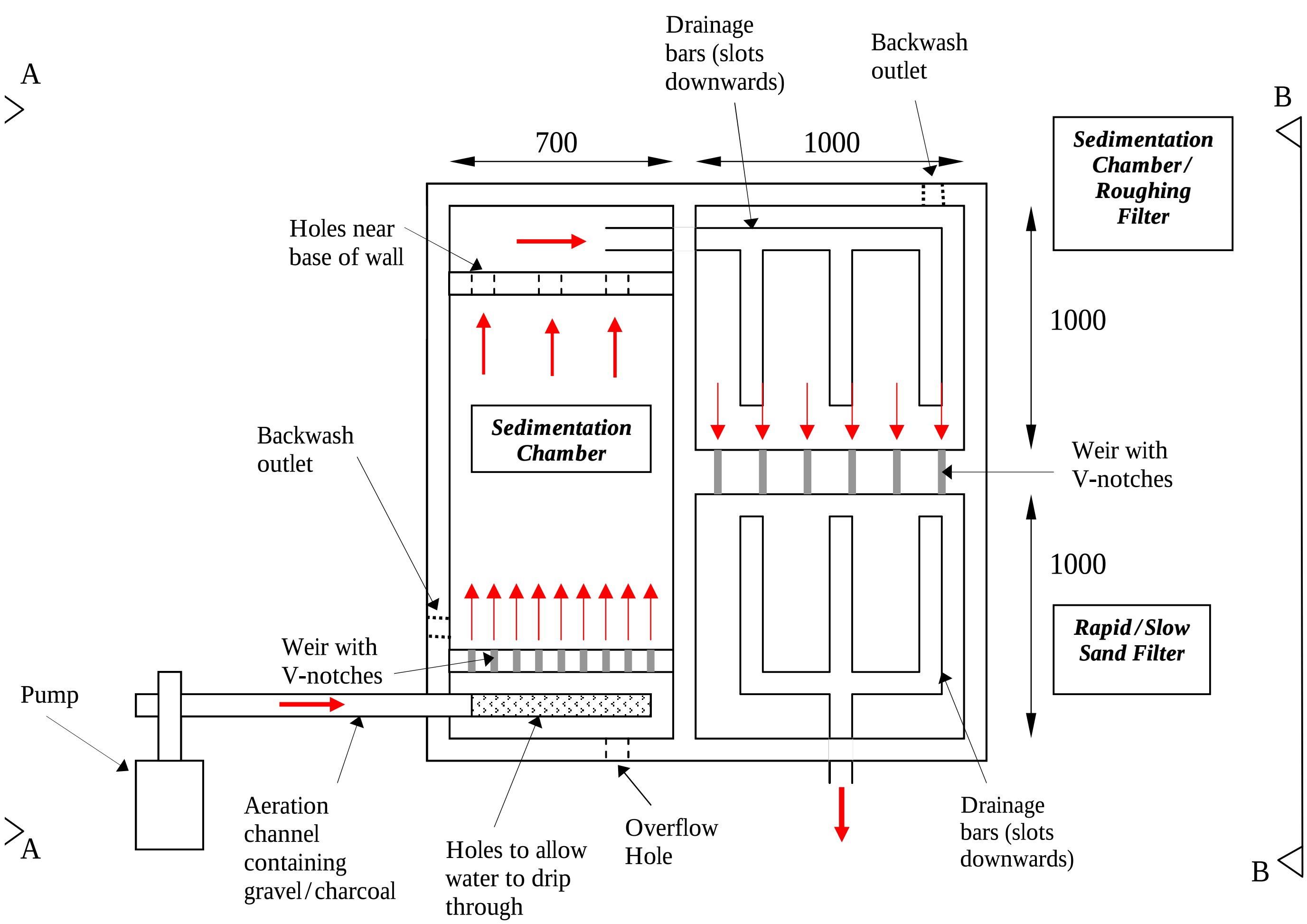


Figure 5 **Plan View of Proposed Filter Design**

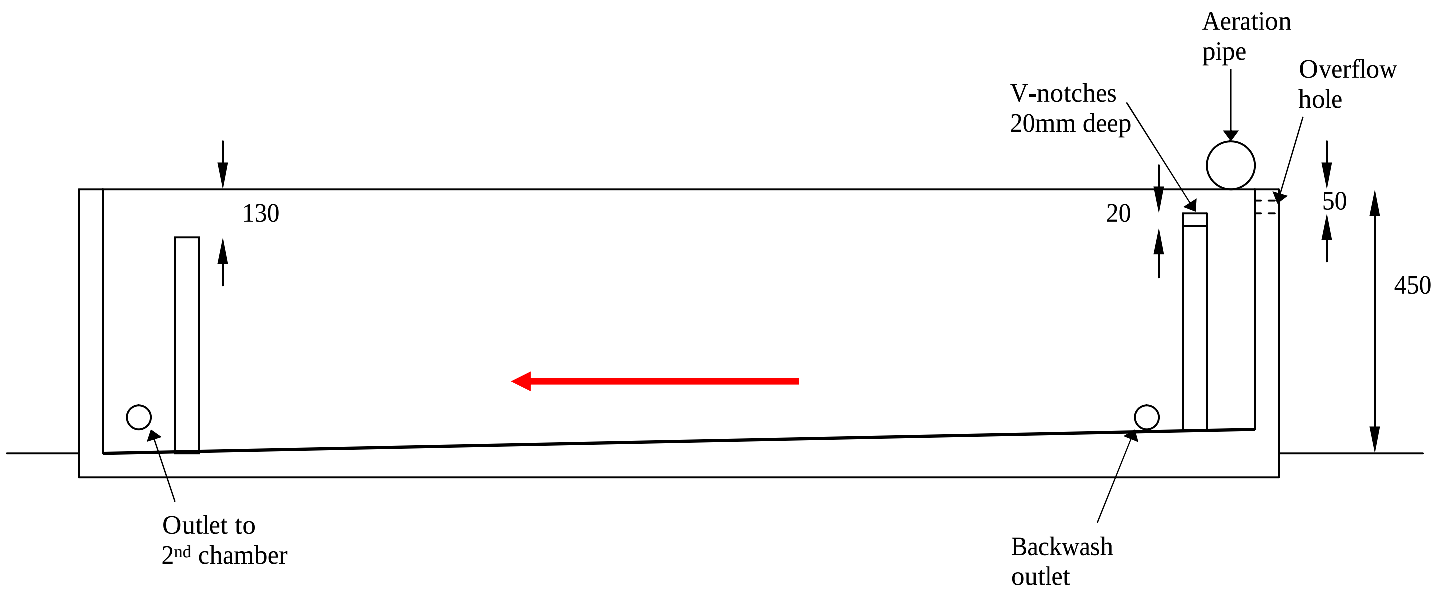


Figure 6 Elevation View of Sedimentation Chamber

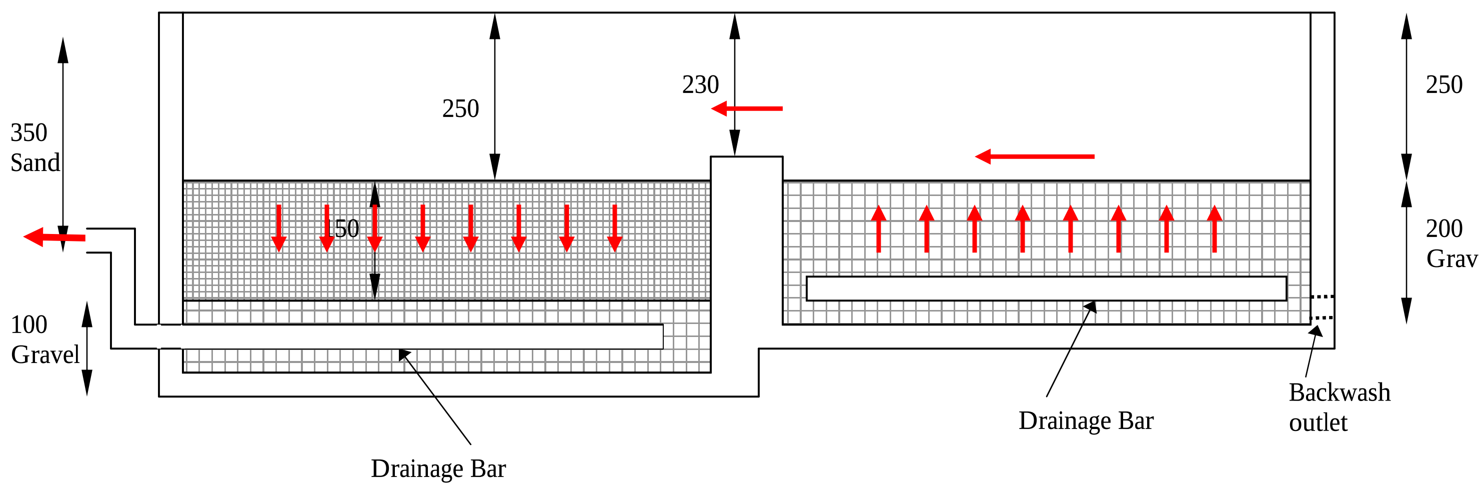


Figure 7 Elevation View of Filter Chambers

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[1] Tyrrel, S. (1997) *Interim Design, Construction and Operation Guidelines for a Biologically –Enhanced Iron Removal Filter for Attachment to Handpumps*
[2] Evans, R. (2000) B*iologically Enhanced Removal of Iron from Groundwater* Unpublished Msc Thesis WEDC Loughborough
[3] Johansson, J., Andersson, H (2002) *Iron Removal from Groundwater in Rakai District Uganda* Unpublished thesis Karlstads University, Sweden (http://epubl.luth.se/1402-1617/2002/292/LTU-EX-02292-SE.pdf)
[4] Okuni, P.A. (2000) *Developments in Addressing the Corrosion Problem in Uganda* HTN 2000 Workshop – India http://www.skat.ch/htn/Publications/download/p_okuni.pdf
[5] Sommerfeld, E.O. (1999) *Iron and Manganese Removal Handbook*
[6] Kasingye Directorate for Water Development – Uganda kasingye@dwd.co.ug *Personal communication*
[7] Siabi, W. Engineer for TREND, Ghana wksiabi@hotmail.com *Personal communication*
[8] Harvey, P.A. et al (2003) *Sustainable Hand Pump Projects in Africa – Report on Fieldwork in Uganda* (http://www.lboro.ac.uk/wedc/projects/shp/00513%20-%20Uganda%20report%20insides.pdf)
[9] Daw, R.K. (2002-3) – UNICEF Engineer, India rdaw@unicef.org *Personal communication*
[10] Mouchet, P. (1992) *From Conventional to Biological Removal or Iron and Manganese in France* AWWA April 1992 Vol. 8