Biological removal of iron from well-handpump water supplies

by Sean Tyrrel, Sue Gardner, Peter Howsam and Richard Carter

Groundwater can be easily abstracted and safe to drink — if iron is present, it can also look and taste extremely unpleasant. Filter designs for use with handpumps have been around for a while now — is the latest model more user-friendly?

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Children collect water from a traditional surface-water source in Lyantonde, Uganda: although often heavily polluted, it is preferred to unpleasant-tasting groundwater

GROUNDWATER IS A favoured source of potable water supplies in rural areas in developing countries: it is seen to be unpolluted — and can be consumed safely without treatment. In many areas, simple well-handpump systems are used to abstract and supply the water; in these circumstances, treatment is avoided wherever possible because of the practicalities and costs involved.

But groundwaters may have other properties which can affect, indirectly, health and water use. Iron in rural groundwater supplies is a common problem (levels of 0 to 50 mg/l are found — the maximum WHO (World Health Organization) recommended level is not more than 0.3 mg/l). The iron occurs naturally in the aquifer, but levels in the groundwater can be increased by the dissolution of ferrous borehole and handpump components. Iron-bearing groundwaters are often noticeably orange, discolouring laundry, and have an unpleasant taste which is apparent in drinking and food preparation. Understandably, people are put off these groundwater supplies and resort to the traditional, polluted surface-water sources.

Iron-removal options

Conventionally, one removes iron from groundwater by creating a strongly 'oxidizing' environment. This can be achieved by aeration, by the addition of oxidants such as chlorine — or by raising the pH of the water using alkaline materials such as limestone. Under such conditions, soluble ferrous iron is oxidized to ferric iron which, subsequently, forms a precipitate of insoluble iron hydroxide which may then be removed by filtration. This technology has been used successfully to treat groundwaters around the world for many decades.

Over the last decade, biological iron removal has been promoted as an alternative to the traditional chemical approach. Microbiologists have known for many years now that certain bacteria are capable of oxidizing and immobilizing iron. Some bacteria are able to derive energy from the oxidation of iron, whilst others seem to oxidize and store the iron for no clear purpose. Whatever the reason for this microbiological phenomenon, there has been a growing awareness of the potential for harnessing the bacterial iron-oxidation process, resulting in the establishment of new biological iron-removal filters at borehole sites in the UK and in France.

The bacteria responsible for the process appear to occur naturally in the well environment and, therefore, the micro-organisms necessary to initiate the process are carried with the groundwater onto the filters. The active population of iron-oxidizers, which appears to require aeration in order to stimulate its growth, tends to grow on the surface of the filter-bed in the form of a slimy orange mat. As with all filters, the accumulation of material eventually leads to a reduction in flow-rate through the sand-bed to a point where cleaning is needed. Traditionally, this has been done by backwashing the filter. Proponents of biological iron removal claim that this natural process is more efficient than the chemical process, requires no chemicals, and produces a sludge which settles readily.

Handpump-scale treatment

Wells and boreholes fitted with handpumps have become one of the most commonly adopted approaches to the provision of clean water supplies in developing countries. Where groundwater containing an unacceptable level of iron is to be abstracted, a small-scale treatment system is necessary. A number of criteria should be kept in mind if the transition from a large-scale to a handpump-scale system is to be achieved successfully. Most importantly, the system must conform to the Village Level Operation and Management of Maintenance (VLOM) concept: it must be affordable to build and maintain and the community must be able to operate and maintain the system themselves with locally available materials.

A number of iron-removal filters have been designed for use in association with handpumps in recent years, for example Cecil Chibi's design outlined in *Waterlines* in 1991. These systems have met with mixed success. On the positive side, it has been demonstrated that small-scale systems can remove iron effectively. In addition, it has been shown that small-scale systems may be produced at an affordable cost and implemented at the village level. Between 1984 and 1987, 250 of the design filters developed by Ahmed and Smith were constructed in Bangladesh, using local resources, at a cost of about £50 each.

Filter cleaning

The principal concerns lie with sustainability and user acceptability of such systems. The need for filter cleaning is the most notable problem. In the case of a full-scale treatment system powered by a diesel or electric pump, the filter would be cleaned by reversing the direction of flow, and backwashing (fluidizing) the sand-bed to dislodge and flush out accumulated deposits. With only limited power available from a handpump and the difficulties of pressurizing current handpump designs, backwashing is not a feasible option. Small-scale filters tend to be cleaned by scraping the uppermost clogged layers of sand. This sand can then be washed and replaced. This is a time-consuming process and may not fully restore the required flow-rate through the bed. In addition, some of the designs tested have been complex involving multiple chambers and several layers of filter material, making cleaning more difficult. Scenarios in which frequent, time-consuming cleaning is required and/or in which the filter remains partially clogged following inefficient cleaning, are of great concern as such circumstances are likely to lead to severe discontent.

A further important constraint on the design of the filter is the need to fit it under the spout of a typical handpump (normally about 0.5m above ground), thus limiting the depth available for filtration.

Developing a prototype

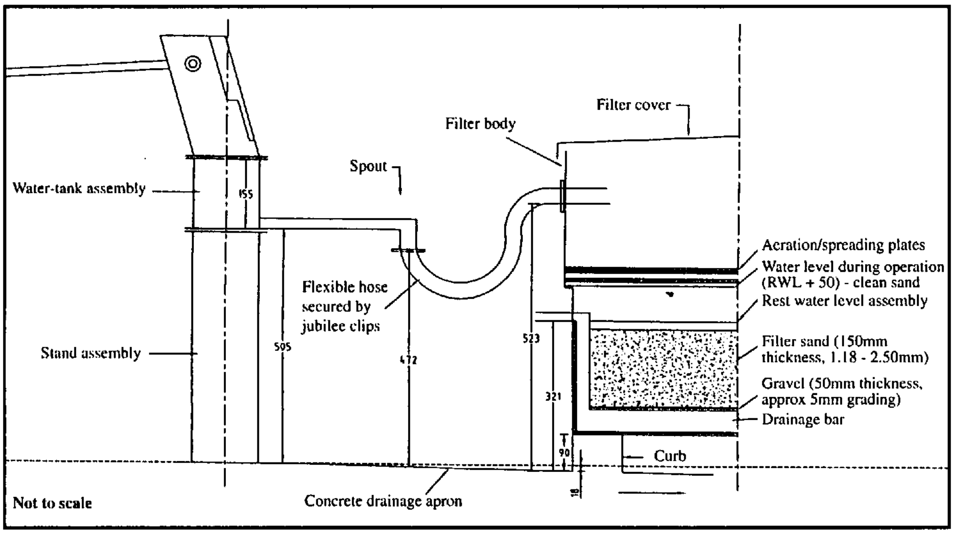
The UK Department for International Development (DFID, formerly ODA) recently funded the development of a small-scale, sustainable biological iron-removal filter at Silsoe College, Cranfield University. Alongside optimizing the iron-removal process within a simple filter design, the studies focused on the development of convenient operation and maintenance methods. Research took place in both the UK and Uganda.

Field trials confirmed that a 15cm layer of uniform medium sand (approximately 1-2mm size range) on top of a 12cm support layer of gravel is capable of reducing groundwater iron concentrations from between 7 and 8mgl-1 to below the WHO limit of 0.3mgl-1. Tests were carried out at handpump discharge rates of approximately 0.15 litres per second. Our own work, and that of other researchers, has demonstrated satisfactorily that biological removal of iron in a simple sand filter is practicable and effective.

User-friendly?

In terms of user acceptability, an ideal system must not only remove iron but must deliver water efficiently and conveniently — as if the filter were not there. Such a design requires careful consideration of the hydraulics of the system. This is not as simple as it might sound. The necessity for a significant head of water above the sand-bed in order to produce an outflow discharge equal to that of the handpump, means that the first user of the day has to pump for several minutes before she sees the results of her efforts. What is more, when she stops pumping, water flows to waste, unless another person is ready to take water straight away. Neither of these situations is acceptable to the user. Our present design avoids these problems, without using valves or other special fittings (which would create their own problems), but by the inclusion of lightweight ballast above the filter bed.

The goal of user acceptability must also apply to the method of cleaning. The filter is likely to be rejected if the frequency of cleaning and effort involved becomes onerous. The flow rate through the filter bed reduces as iron precipitates at the surface, and as gas bubbles build up within the bed. The simplest, effective cleaning action is to displace the gas bubbles from the filter bed, and the iron precipitate from the surface by stirring it every week. Field trials with a simple stirrer demonstrated that weekly stirring for about two minutes is sufficient to restore satisfactory flow through the bed.



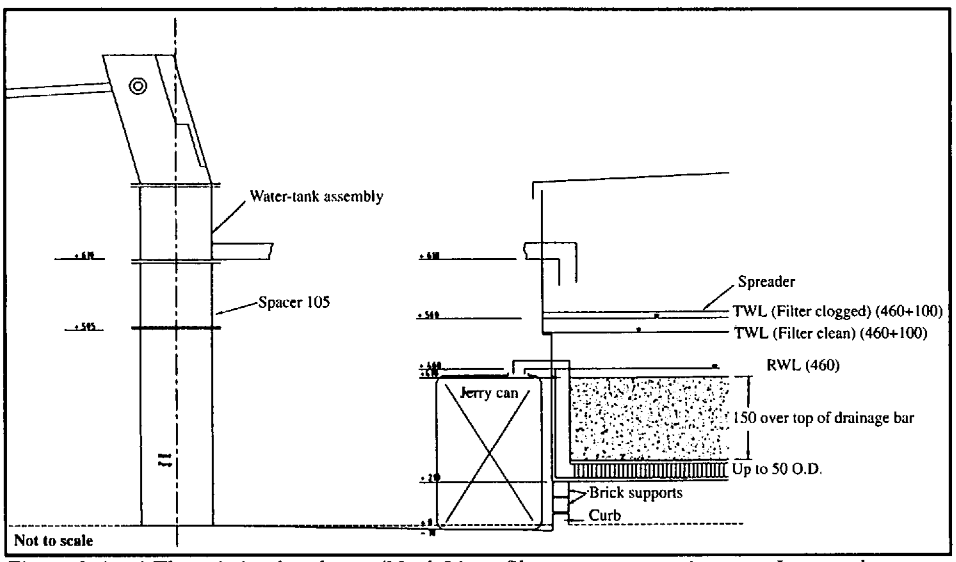


Figure 1. (top) The existing handpump/Mark I iron-filter arrangement in use at Lyantonde.
Figure 2. (below) The research team's proposed handpump-filter arrangement.

Future work

Now that the iron-removal process and practical operation and maintenance procedures are well understood, construction and wide-scale field-testing are essential. Construction could take place through the publication of a complete design into the public domain, but we believe that commercial manufacture would be a better option. Commercial manufacture would mean that (a) the iron-removal filter would be available 'off-the-shelf', just like the handpump to which it would be fitted; (b) user communities, governments and NGOs would not have to go through the lengthy process of adapting designs to the widely varying materials, skills, and operating conditions which exist at community level; and (c) iron-removal filters could come into widespread use much more rapidly than otherwise. Commercial manufacture would ideally be carried out in-country, or partially within country, as is increasingly the case with handpumps. The iron-removal filter would become simply an optional add-on to the handpump itself.

We are continuing work on certain aspects of the filter design detail, and intend to bring the iron filter to production and dissemination as soon as possible.

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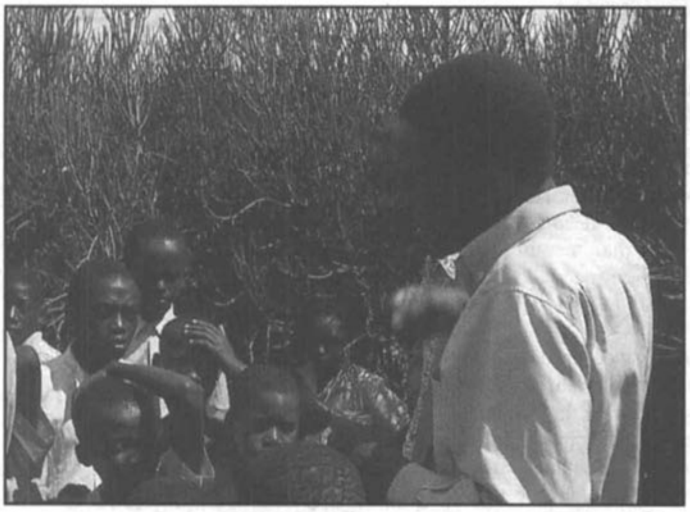

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Installing the iron-removal filter in Lyontonde (above). Teaching local children about health and hygiene (left).

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