Cranfield UNIVERSITY

INTERIM REPORT

THE DEVELOPMENT OF A BIOLOGICALLY-ENHANCED IRON REMOVAL FILTER FOR USE WITH BOREHOLE-HANDPUMP WATER SUPPLIES

Research funded by the Engineering Division of the Overseas Development Administration

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The development of a biologically-enhanced iron removal filter for use with borehole-handpump water supplies - update information

1. Background

Wells and boreholes fitted with handpumps have become one of the most commonly adopted approaches to the provision of affordable, clean water supplies in developing countries. Groundwater is a favoured source of potable water supplies in rural areas in developing countries because it is generally unpolluted and can usually be safely consumed without the need for costly treatment. Unfortunately in many parts of the world, groundwater contains iron. Iron-bearing groundwaters are often a 'rusty' orange colour, causing discoloration of laundry, and have an unpleasant taste which is apparent in drinking and food preparation. The iron is not normally directly hazardous to health but there may be an indirect health impact associated with the unacceptable colour and taste of the water. If people reject the safe water being provided by the handpump they will to resort to traditional, microbiologically-polluted surface water sources and hence a risk of contracting water-borne disease remains. Thus, where groundwater containing an unacceptable level of iron is to be abstracted, a small-scale treatment system is desirable. The Overseas Development Administration (ODA) is currently funding the development of an affordable, handpump-attached, biological iron removal filter at Silsoe College, Cranfield University. The system utilises harmless natural bacteria in the groundwater to remove iron from the drinking water as it passes through a simple sand filter. Experiments are underway with a hand-powered stirring device which will be used to clean the sand when the filter becomes clogged with bacteria and iron. The Researchers aim to develop an affordable prototype system by the end of 1996 which could then be field-tested in developing countries.

2. Project objectives

2.1 The fabrication and testing of pilot-scale experimental filters.

2.2 The development, fabrication and evaluation of a working prototype filter design appropriate for attachment to handpumps.

2.3 The dissemination of the accrued information such that it can reach the widest possible audience.

3. The fabrication and testing of pilot-scale experimental filters

3.1 Experimental summary

The experimental work has been conducted using modified plastic drums filled to varying depth with sand of varying grain size. Summary details are as follows:

Dimensions of experimental filters: Retrospective fitting of a filter to a handpump necessitates a design of < 0.5 m height so that it will fit under the spout. Experimental filters were made by trimming 0.6 m diameter (surface area = $0.283m^2$) plastic drums to the required height of 0.5 m.

Ancillary fittings: Fittings were designed and installed to permit aeration of the influent; drainage from the filter; and water level control.

Filter media: Two different sand sizes were tested - effective size 1.18 mm and 1.30 mm. The smaller sand size required a gravel support layer to ensure that it did not escape through sawcut slots in the filter drainage bar. This was unnecessary for the larger sand size.

Filter bed depth: Sand depths of 0.1 m and 0.15 m have been tested with the 1.18 mm sand and a 0.20 m depth tested with the 1.30 mm sand. A gravel bed depth of 0.05 m supported the 1.18 mm sand.

Flow rates and daily flow duration: Iron-containing groundwater (mean = 7.5 mgl^{-1})was supplied to the filters for 6 hours per day on average. Flow rates were variable, and were governed by the sand size, the level of clogging in the filter, and the height of the outlet which was set at 'bucket height' (0.25 m).

Filter cleaning: A number of filter cleaning methods have been trialed, including backwashing, stirring and bailing of precipitate suspended by cleaning operations.

Monitoring: The total iron concentrations of influent and effluent water samples were determined daily. The discharge from the filter was measured twice daily. Occasional measurements of temperature, pH and DO_2 have also been made.

Experiment duration: The experiments began in January 1996 and were completed in October 1996.

3.2 Results summary

- Both the 0.1 m and the 0.15 m deep filters containing 1.18 mm sand and underlain with 6 mm gravel, consistently produced filtered water which met the WHO recommended levels of 0.3 mgl^{-1} (*i.e.* > 96% reduction).
- The filter containing the larger sand size (1.30 mm) also reduced iron concentrations to below the WHO limit but proved to be less consistent.
- Flow through all filters tested diminished with time due to clogging by trapped gases and iron precipitates:

	Typical flow rate - l/s (m/hr in brackets)	
	Clean	*Clogged*
1.18 mm sand	0.15 (1.91)	0.04 (0.51)
1.30 mm sand	0.25 (3.18)	0.06 (0.76)

- Flow can be re-established using a simple cleaning regime employing backwashing and stirring.
- Care must be taken with cleaning as the bed can be 'over-stirred', leading to disturbance of the biofilm and an increase in effluent iron concentration. A weekly cleaning session lasting about 1 hr during which time the sand bed was completely, but gently, stirred 3 times with a stick provided the right balance between cleaning efficiency and conservation of the iron biofilm.
- Findings indicate that a filter unit with a surface area of 1.42 m^2 will consistently meet WHO standards whilst maintaining a flow rate of 0.2-0.3 l/s.

4. The development, fabrication and evaluation of a working prototype filter design appropriate for attachment to handpumps

4.1 Filter constructed at Silsoe College field site

A prototype filter, designed on the basis of the preliminary findings from the experimental filters, was fitted to a handpump at the Silsoe College experimental site (Figure 1). The filter unit comprises a box constructed from 3 mm sheet steel, measuring 1.40 m x 1.40 m x 0.48 m (width x length x height)(surface area = 1.96 m^2) with a removable sheet steel lid. Water exiting the handpump spout is directed onto two aeration trays made from perforated 2 mm metal sheet separated by 20 mm aluminium spacers. Aerated water is then filtered through a 0.15 m thick sand bed (1.18 mm effective grain size) overlaying a 0.05 m thick support layer of 6 mm gravel. The filtered water drains via a slotted 40 mm (i.d) durable plastic pipe placed diagonally across the base of the unit and exits through an outlet pipe at a height of 0.25 m. The filter can be backwashed by directing water from the handpump spout into a downpipe connected to the drainage pipe. Overflow pipework is included for water level control and to aid the removal of the effluent resulting from the cleaning process. The filter lid was designed to accept multiple, rotary stirring devices. This design will undergo a structured evaluation procedure forthwith.

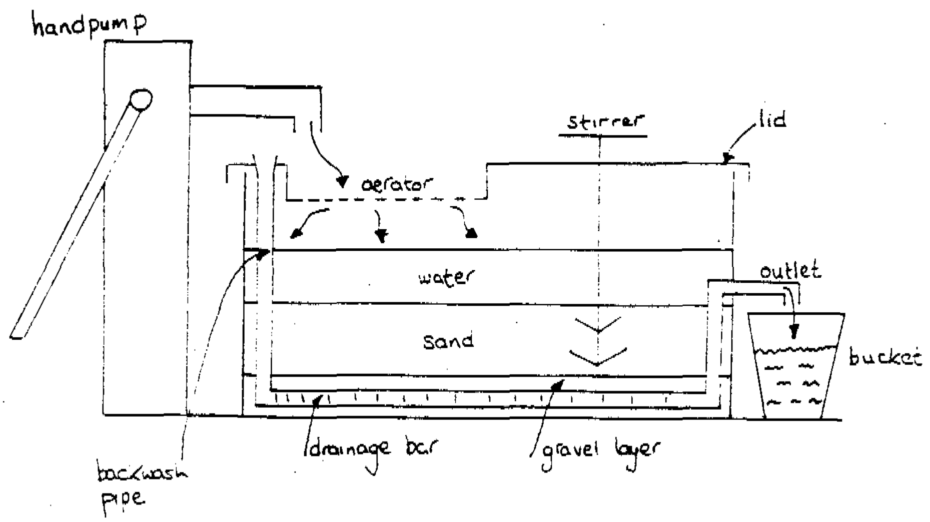

Figure 1 Sketch diagram of the prototype handpump-attached iron biofilter

4.2 Field testing of a prototype filter design in Uganda

A prototype filter was constructed and installed in Uganda during a two week visit by the project research officer, Sue Gardner, in early October 1996. This work was conducted in conjunction with Mott MacDonald, Cambridge and the Directorate of Water Development (DWD), Uganda, with financial support from DWD and ODA. The Ugandan prototype design is similar to the UK design but was modified in accordance with the availability of local materials. The filter was installed at a handpump site close to a school in Lyantonde, approximately 230 km South West of Kampala. Initial observations indicated the filter to be highly successful in removing iron from groundwater as inlet water had a characteristic orange brown colour whilst outlet water was clear. Tests undertaken at a University laboratory in Kampala, found the total iron concentration of inlet water to be 16.5 mgl^{-1} and the outlet water 0.15 mg l^{-1}. Further evaluation of this system will occur in the coming weeks.

5. Interim conclusions

5.1 Studies with experimental filters indicate that effective and sustainable iron removal is achievable.

5.2 A novel, mechanical stirring device has proved to be capable of restoring flow through clogged filter sand. With further improvements to the device, it is anticipated that a sustainable, village-level maintenance protocol can be developed.

5.3 Feedback from collaborators in many countries confirms that there is a demand for a hand-pump attached filter. Collaborators have emphasised the importance of placing the development of a new technology within the context of 'the community'. Small-scale water treatment technologies have a history of failure at village-level due to a lack of consideration of issues such as user acceptance and sustainability. This must remain the focus of further development of this system.

6. Dissemination activities

We intend to follow up this interim summary with the following dissemination activities:

- Production of a Manual of best practice for the design, operation and maintenance of a handpump-attached iron biofilter.
- Produce scientific papers and articles.
- Develop a web page promoting the technology

All those on our mailing list will receive copies of the Manual and future papers/articles. Information will also be forwarded to the GARNET centre for Iron and Manganese removal at CREPA in Burkina Faso.

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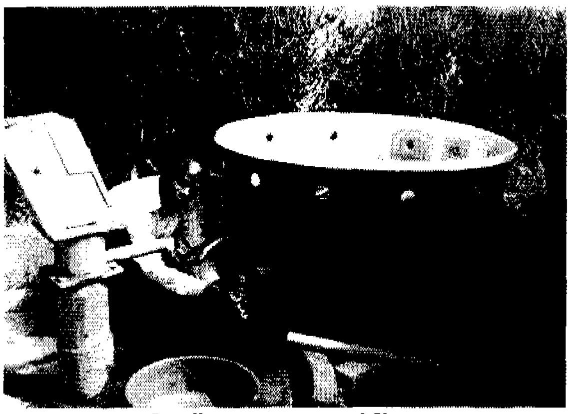
Biological removal of iron from handpump water supplies

The iron problem



Installing an iron removal filter in Lyantonde, Uganda.

Groundwater is a favoured water supplies in rural area countries, because it is gen as unpolluted and can be s without the need for treatm conditions simple well-hand are used to abstract and su such circumstances treatm wherever possible because practicalities and costs invo groundwaters may have ot which can indirectly affect h use.

Iron in rural groundwater supplies is a common problem (level 0 to 5 recommended <0.3 mg/l). The iron occurs naturally in the aquifer bu groundwater can be increased by dissolution of ferrous borehole an components. Iron-bearing groundwaters are often noticeably orange causing discoloration of laundry, and have an unpleasant taste whic drinking and food preparation. People are put off such groundwater resort to the traditional, polluted surface water sources.

Biological iron removal

In the past ten years, biological iron removal has been promote removing iron from groundwater within water filters. Microbiologist many years that certain bacteria are capable of oxidising and imm bacteria responsible for the process appear to be natural inhab environment and therefore, the microorganisms necessary to initiat carried with the groundwater on to the filters. The active populatior which appears to require aeration in order to stimulate its growth, the surface of the filter bed in the form of a slimy orange mat.

Developing a prototype filter

The UK Government Department for International Development rec development of a small-scale, sustainable, handpump-attached biol removal filter at Silsoe College, Cranfield University. Alongside optir removal process within a simple filter design, the studies focused or

development of convenient operation and maintenance methods. R
development work took place in UK and Uganda.

Field trials confirmed that a 15 cm layer of uniform medium sand on
support layer of gravel is capable of reducing groundwater iron conc
7-8 mgl^{-1} to below the WHO limit of 0.3 mgl^{-1}.

In terms of user acceptability, an ideal system must not only remove
deliver water efficiently and conveniently ie. as if the filter were not t
as simple as it might sound. There are many problems associated w
producing an outlet discharge equal to that of the handpump. Resea
continuing into the optimisation of the filter to ensure that it is both c
obtain water from and easy to maintain. Once these operation and r
issues are resolved the prototype filter needs to be constructed and
widely. We believe that there would be many advantages in comme
village level manufacture and we are keen to hear from commercial
filters and/or handpumps who might be interested in the further dev
technology.

Dissemination

We are continuing work on certain aspects of the filter design detail,
bring the iron filter to production and dissemination as soon as poss
guidelines for the design, construction and operation of the filter are
and will eventually be disseminated on the worldwide web.

Main contact pe

Updated 10/07/98
by Tim Hess

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