WORKING PAPERS ON WATER SUPPLY AND ENVIRONMENTAL SANITATION

VOLUME 1

Iron & Manganese Removal

Simple methods for drinking water

Peter Hartmann

SKAT

Foreword

Iron and manganese are among the most abundant metals in the earth's crust. Groundwater and surface water that contain iron and manganese but little dissolved oxygen are often coloured - reddish-brown with iron or black if manganese is present - and form deposits on laundry and plumbing fixtures. High iron concentrations may cause a bitter taste. Although elevated iron and manganese concentrations in general have no harmful effects on human health, it is recommended that high concentrations of these metals be reduced. Water with high iron or manganese concentrations may be rejected by consumers because of its taste and its effects on laundry. As a result people may drink unsafe, untreated water that has a more acceptable taste, having rejected safe water because it contains iron or manganese.

This bulletin is written for engineers and technicians working in the field. It aims to give an introduction to the subject of iron and manganese in drinking water as well as showing possible methods for their removal. There is a focus on simple methods that can be applied in rural and periurban areas for water supplies that serve up to 25 000 consumers.

As iron and manganese can occur in water in various chemical forms that have different characteristics, it is impossible to offer a universal solution to the problem. Trials and field tests will always be necessary in order to find the most appropriate method of treatment. A lot of research and development has been carried out, but no simple procedure for solving the problem of iron and manganese removal for small supplies has been found. It has been shown that the main problem in community-operated water systems is often not the lack of technical quality in the design, but rather shortcomings in operation and maintenance. Appropriate solutions have, therefore, to be found in a dialogue between the engineer or technician and the community. These solutions should be as simple as possible.

This bulletin is designed for easy copying. Extracts of this publication may be reproduced, provided that the source is acknowledged (SKAT and the authors of the respective case studies). It is also intended that interested persons make direct contact with the organisations related to the case studies if they have specific questions or would like to visit a plant.

Feedback to this first edition is most welcome. Furthermore, SKAT will publish an electronic version of this manual on the Internet at the SKAT website (www.skat.ch) and would like to add further relevant case studies. The intention is to keep the information as updated as possible.

The preparation of this bulletin has been made possible through a backstopping mandate from the Swiss Agency for Development and Co-operation (SDC) to SKAT. SKAT is grateful to all those who have contributed to this bulletin; especially to Prof. Dr. Markus Boller from EAWAG and to Mr. Martin Wegelin from SANDEC, Switzerland, for reviewing the theoretical part. Special thanks are dedicated to all institutions and persons who have contributed their case studies to make this bulletin more field orientated. SKAT also wishes to thank the editorial team of the magazine “Waterlines” for permission to reproduce two articles.

St. Gallen, January 2001

Table of contents

The basics of iron and manganese in water

1

1.1 Iron

About 5% of the rocks in the earth's crust are formed by iron oxides or other iron compounds which can be in either ***ferrous*** (Fe^{2+}) or ***ferric*** (Fe^{3+}) forms. As iron is not a precious metal it does not appear in an uncombined state but in the form of oxides (e.g. ferrous oxide FeO, and ferric oxide Fe_2O_3), hydroxides, carbonates and sulphides. The form and solubility of iron in natural water are strongly dependent upon the pH and the oxidation-reduction potential of the water. Iron may also be present in drinking-water systems as a result of the use of iron coagulants or the corrosion of steel and cast iron pipes during water distribution.

1.2 Manganese

Manganese is found in the ***divalent*** (Mn^{2+}) and the ***quadrivalent*** (Mn^{4+}) forms. Manganese is much less abundant in the earth's crust than iron. Apart from the fact that solutions of manganese compounds are more stable and therefore more difficult to treat than ferrous solutions, the removal procedures are similar for both metals.

1.3 Determination of iron and manganese

Iron and manganese concentrations can be determined by various methods.

For normal water supply purposes the results obtained by colorimetric determination methods are sufficient. The concentration of iron or manganese in the sample is directly related to the colour developed when certain reagents are added to the sample (orthophenanthroline or thiogycollic acid in field methods). The comparison of the colour of the sample with a standard colour chart allows determination of the concentration of the particular metal. Comparison of the sample with standard colours can either be done by eye or using simple instruments (such as the photoelectric colorimeter and the spectrophotometer) which measure the light absorbed by the sample.

Instrumental methods are quite complicated but give precise results. One instrument that is used for this purpose is the flame atomic absorption spectrophotometer, in which samples are aspirated into a flame and atomised. The metal content is detected by measuring the part of a light beam directed through the flame that is absorbed by the atomised element in the flame.

The Hach Company produces test kits and instruments that are recommended by various experts:

Hach Company,
P.O. Box 389,
Loveland, CO 80539-0389, U.S.A.
Phone: ++1 970 669 3050
Fax: ++1 970 669 2932
e-mail: csays@hach.com
URL: http://www.hach.com

A large number of other companies produce test kits. It is advisable to check in advance the availability of products and reagents of any particular supplier.

1.4 Sources of soluble iron and manganese compounds

1.4.1 Groundwater

Groundwater with a low redox potential often contains soluble iron and manganese ions.

As this water does not contain much oxygen[1], some micro-organisms reliant on oxygen for survival can only exist in this environment by reducing ferric compounds into the ferrous form. In the same way manganese is reduced from the quadrivalent to the divalent form.

Iron and manganese can form complexes with organic matter (humic substances). In this case, iron is normally present in its ferric form and bound in the molecular structure of the humic compounds.

---

[1] Natural groundwater originates from seeped rainwater. When starting to percolate, rainwater is saturated with oxygen (from contact with the atmosphere). On the way to the groundwater layer, the dissolved oxygen may be consumed by aerobic bacteria.

1.4.2 Standing surface water (ponds, lakes)

Ponds and lakes retain surface water that contains iron in its ferric form and manganese in its quadrivalent form. In standing surface water these compounds sink to the bottom.

Especially in hot climates, the surface of ponds and lakes is warmed by the sun, resulting in water layers or strata of different temperatures. This arrangement in layers hinders vertical convective movement of water.

In spite of the small extent of water movement, oxygen enters into deeper layers by diffusion. The solubility of gases decreases with the increase of temperature so only small amounts of oxygen reach the bottom layers. Therefore micro-organisms that depend on oxygen for survival may need to get their required energy by reducing iron and manganese compounds into their divalent forms.

1.4.3 Springs and flowing surface water (rivers and streams)

Flowing groundwater has no contact with the air except in caves. In groundwater, iron and manganese are usually present in their divalent forms and as such they are easily soluble and mobile. In springs, groundwater comes into contact with oxygen. Iron or manganese in the spring water are likely to change into their trivalent or quadrivalent forms respectively.

These compounds are no longer soluble. They are transported in the surface water until they settle. This may happen in sedimentation basins of spring catchments, resulting in coatings on the bottom, or in stretches of rivers where the water flows very slowly.

1.5 Effects of high manganese and iron concentrations in drinking water

1.5.1 Effects on health, cloth and plumbing fixtures

Water containing iron and manganese has no harmful effects on humans, whereas high zinc and copper concentrations are toxic[1] . The water quality limits for the concentrations of iron and manganese in drinking water are not based on health considerations but on aesthetic

---

[1] Manganese contents of 0.6 mg/l and more however can have toxic effects especially for babies

aspects. Water containing more than 0.3 mg/l iron can have a reddish-brown colour and generate deposits on plumbing fixtures. High iron concentrations in drinking water may cause a bitter taste. Manganese concentrations over 0.1 mg/l in water are responsible for stained laundry and bathroom fixtures. The presence of manganese often forms a coating in pipes, which may slough off as a black precipitate.

Chapter 2 indicates the recommended WHO guidelines for iron and manganese concentrations in drinking water.

1.5.2 Iron bacteria

Iron also enhances undesirable bacterial growth (iron bacteria) in water distribution systems. Most iron bacteria get their energy from the oxidation of ferrous iron into ferric iron. Iron is obtained either from the pipe itself or from the water inside the pipe. This process is responsible for deposits in pipes and slimy coatings on plumbing fixtures. The deposits cause a reduction in the carrying capacity of water pipes and the slime is especially bothersome in water being used for public water supply and industrial processes (e.g. food processing, cooling, paper and textile manufacture). The presence of these organisms also causes bad odour, taste and colour, and increases the turbidity of the water.

The same process of oxidation is caused by bacteria that utilise manganese.

1.6 Measures to eliminate iron and manganese

1.6.1 General Remarks

The only lasting solution to all problems of high iron and manganese contents in drinking water is to eliminate them by treating the water. Partial solutions (like keeping the iron and manganese ions in solution by adding chemicals) do not really solve the problem because it may appear again sooner or later, for example when the water is boiled. Further, it is very difficult to control chemicals outside the treatment plant but still somewhere within the water supply system.

1.6.2 Conventional removal processes

Introduction

In general one can say that if there is a problem of manganese in drinking water there will also be a problem of iron in the water. Removal of iron is less difficult than removal of manganese. Removal of manganese is almost impossible without either using an oxidising agent (which is usually potassium permanganate $KMn0_4$) or increasing the pH.

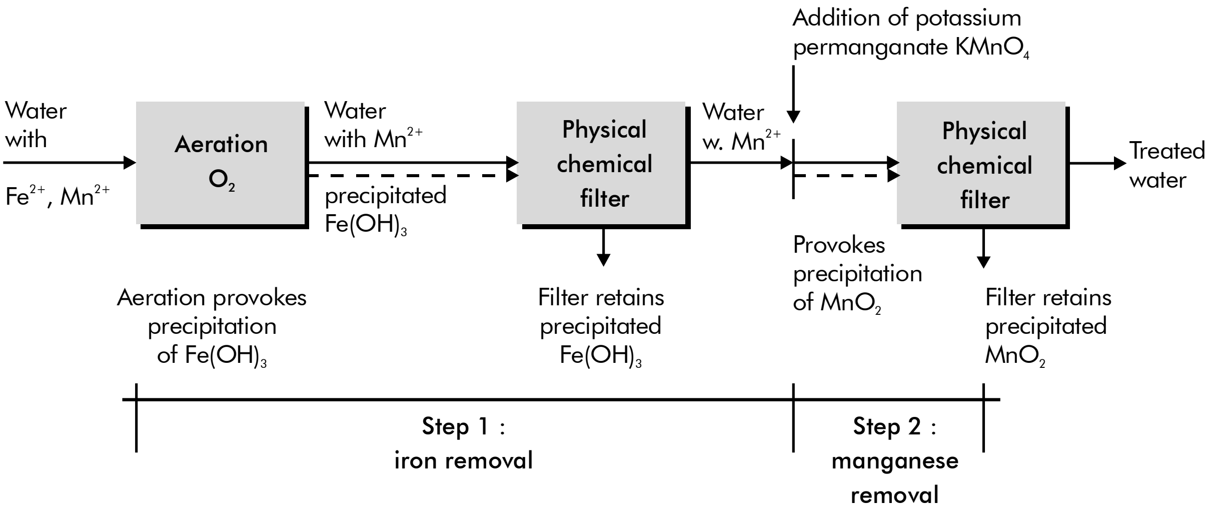
Very often, the removal process is carried out in two major steps: iron is eliminated first either in a physical-chemical or a biological process and then manganese is removed in a physical-chemical process. However, it is clear that application of a two step process is more expensive and it is therefore advisable to carry out tests to determine whether it is possible to remove both iron and manganese together in one step.

For two-stage removal of iron and manganese, there are three main conventional removal processes:

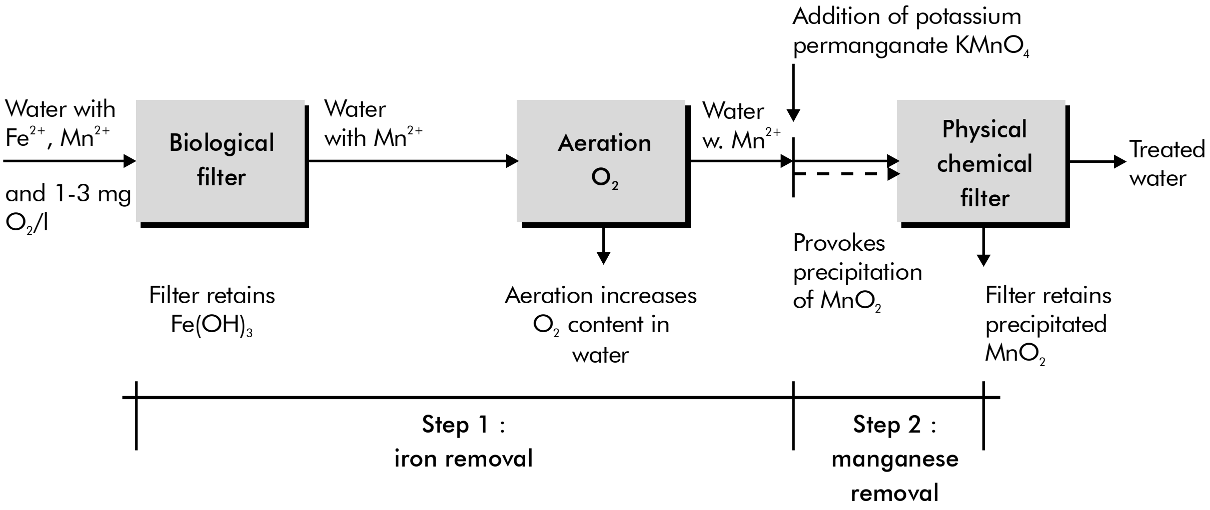
a) the purely physical-chemical process,
b) biological removal of iron and chemical removal of manganese, and
c) the purely biological process.

In the following sections, the three processes are illustrated schematically.

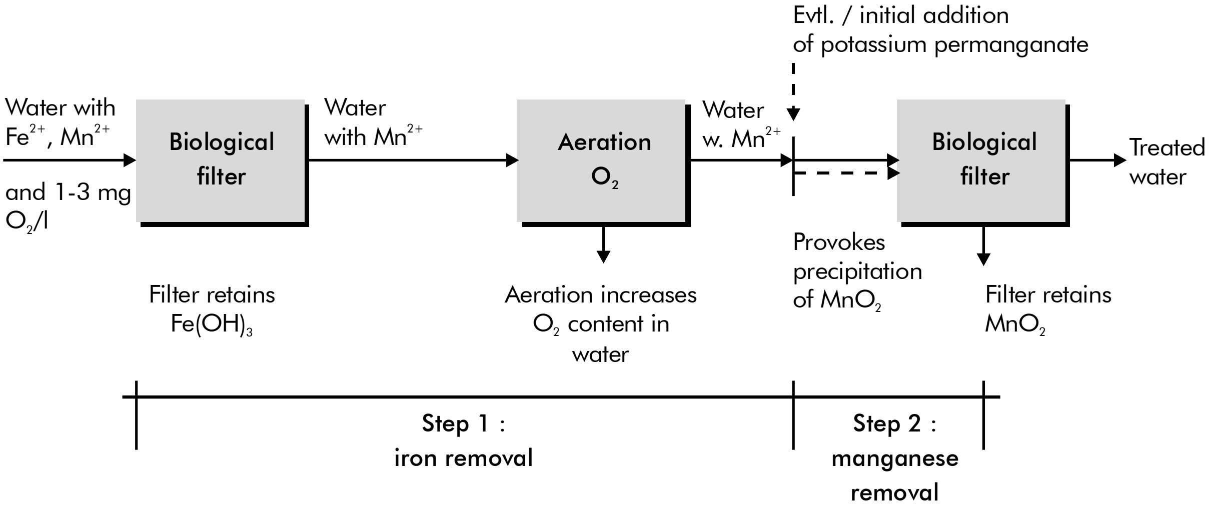
The purely physical-chemical process



Biological removal of iron and chemical removal of manganese



The purely biological process



Possible combined methods

A combined process for simultaneous removal of iron and manganese could be summarised as follows:

1) aeration
2) subsequent addition of an oxidising agent (e.g. potassium permanganate)
3) physical-chemical or biological filtration.

In the case study of Santa Fe, Argentina, three types of combined iron and manganese removal plants are described.

Specific elements or steps used in the processes

Aeration

Aeration provides good contact between the water and the air. This contact has two effects. One is to allow the carbon dioxide to escape from groundwater so that the pH rises, and the other is to increase the concentration of dissolved oxygen in the water to assist the oxidation of iron and manganese.

The diffusion of oxygen into water tends to be rather slow. In order to accelerate this process, water is intensively aerated either by adding compressed air, or by open aeration, in which the area of the surface between the water and the air is made to be very large by spreading the water in thin layers or by forming small droplets.

There are various types of aerators, such as:

- cascades
- inclined aprons
- towers with countercurrent flow of air and water, or stacks of perforated pans
- spray aerators, and
- diffused air aerators

Since manganese cannot be oxidised as easily as iron (pH values over 9 are required), chemical oxidation is most common for manganese removal. The most widely used oxidising agent is potassium permanganate, which will precipitate the manganese when the pH is above 6.5. Chemical oxidation must be followed by effective filtration since suspended particles (flocculated hydrated metal oxides that include a large proportion of water) settle so slowly that it may not be possible to remove them by sedimentation.

The following oxidising agents are used in water treatment:

- Potassium permanganate ($KMnO_4$) is very effective and rapid, and is used at low concentrations.
- Hypochlorite is rapid and effective for some forms of iron, but not for organically bound iron. There is the possibility of the formation of undesirable by-products which may cause tastes and pose health risks. Hypochlorite is often used for disinfecting water.
- Chlorine suffers from the same limitations as hypochlorite.
- Chlorine dioxide is strong oxidising agent, but it is difficult to handle and dose.
- Ozone (O_3) is a gas which is a powerful oxidising agent. It is used for disinfection in some large water treatment plants. It is expensive to produce, needing sophisticated plant.

The oxidation of manganese can be accelerated by raising the pH of the water. This is usually achieved by adding lime or soda (sodium carbonate). This additional intervention may be required in some cases but it adds operational complications. Lime is widely used in water treatment for raising pH; it is relatively safe and cheap, although not always easy to use because of its tendency to form solid lumps.

Oxidising agents can also be useful in iron removal, especially in cases where aeration does not show effective results. However, for rural water supplies oxidising agents are often too expensive and not always available and so, if possible, it is better to use a conventional aeration system to achieve oxidation.

High levels of turbidity in the raw water require sedimentation and filtration to make the water safe and acceptable. In such cases the aeration stage should come before the sedimentation basins. Sedimentation periods should be established for each case but will usually be one to two hours for iron removal.

Filters (both physical-chemical and biological filters)

Physical-chemical filters retain particles containing iron and manganese that are suspended in the water after oxidation. The process is often more effective when the grains of the filter media become coated with iron or manganese oxides, because these deposits have a catalytic effect on the oxidation process. Filters usually consist of a layer of sand (which retains suspended particles) supported by layers of gravel. A variety of designs and filter media can be found in the plants described in chapter 3.

A biological filter uses certain bacteria that are capable of oxidising and immobilising iron (and manganese). Some bacteria are able to derive energy from the oxidation of iron (and manganese) whilst others seem to oxidise and store the iron for no clear purpose. The bacteria responsible for the process appear to occur naturally in and near boreholes and, therefore, the micro-organisms necessary to initiate the process are carried with groundwater into the filters. After a maturation period of several weeks, normally there are enough oxidising bacteria for effective removal of iron and manganese. It may be possible to accelerate this process by using manganese zeolite. Manganese zeolite is a natural greensand, partly coated with manganese oxides, that acts as a catalyst for enhanced manganese oxidation. It can remove manganese if regenerated with potassium permanganate.

The fact that bacteria accumulate naturally in a filter bed suggests that filters designed purely for physical-chemical treatment also act as biological filters.

Deposits that collect in physical-chemical filters must be washed out regularly (usually after one to three days). If this cleaning of the filter media is not done the resistance to flow through the filter may become too high or the quality of the treated water may become unacceptable. It is necessary to clean biological filters when the accumulated deposits clog the uppermost layer (though some biological filters run for months before they need cleaning). It may be possible to clean such filters by scraping off a thin layer from the top of the filter so that bacteria in deeper layers are still available within the filter bed to remove iron and manganese. The washing or cleaning of the filter is a very important part of any water treatment process design. Many plants fail because of poor filter cleaning due to inadequate design or poor operational procedures, so great care is needed to ensure that the filter is cleaned effectively.

1.7 Other iron and manganese removal methods

There are other iron and manganese removal methods such as overland flow, dry filters and the in-situ method. However, they are not described in this bulletin because it is thought they are not appropriate in rural or periurban areas in developing countries.

Recommended WHO guidelines for iron and manganese concentrations in drinking water

2

Source: WHO guidelines for drinking water quality, 1993, Volume 1:

Substances and parameters in drinking water that may give rise to complaints from consumers:

Parameter	Levels likely to give rise to consumer complaints	Reasons for consumer complaints
Iron	0.3 mg/l	staining of sanitary ware and laundry
Manganese	0.1 mg/l	staining of sanitary ware and laundry (health-based provisional guideline value: 0.5 mg/l)

Note: the levels indicated are not precise numbers. Problems may occur at lower or higher values according to local circumstances.

Examples of operating iron and manganese removal plants in developing countries – Case studies

3

3.1 FINNIDA square type filter unit, iron removal plant

(National Water Supply and Drainage Board (NWSDB), Sri Lanka)

Introduction

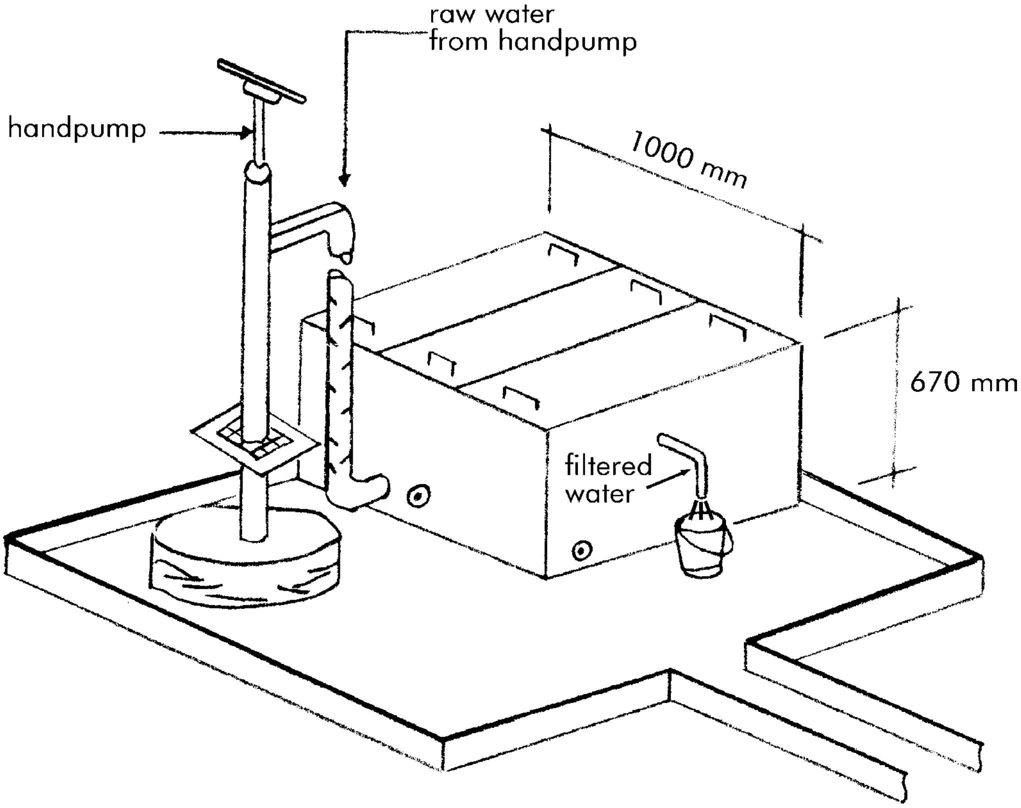
The ***FINNIDA square type filter*** was developed in Sri Lanka in 1989, based on experience with the UNICEF model and the FINNIDA circular type iron and manganese removal plants. The special features of the *FINNIDA square type filter* are simplicity of design and the possibility of in situ construction. Operation and maintenance are easy, so that local caretakers can carry out the work.

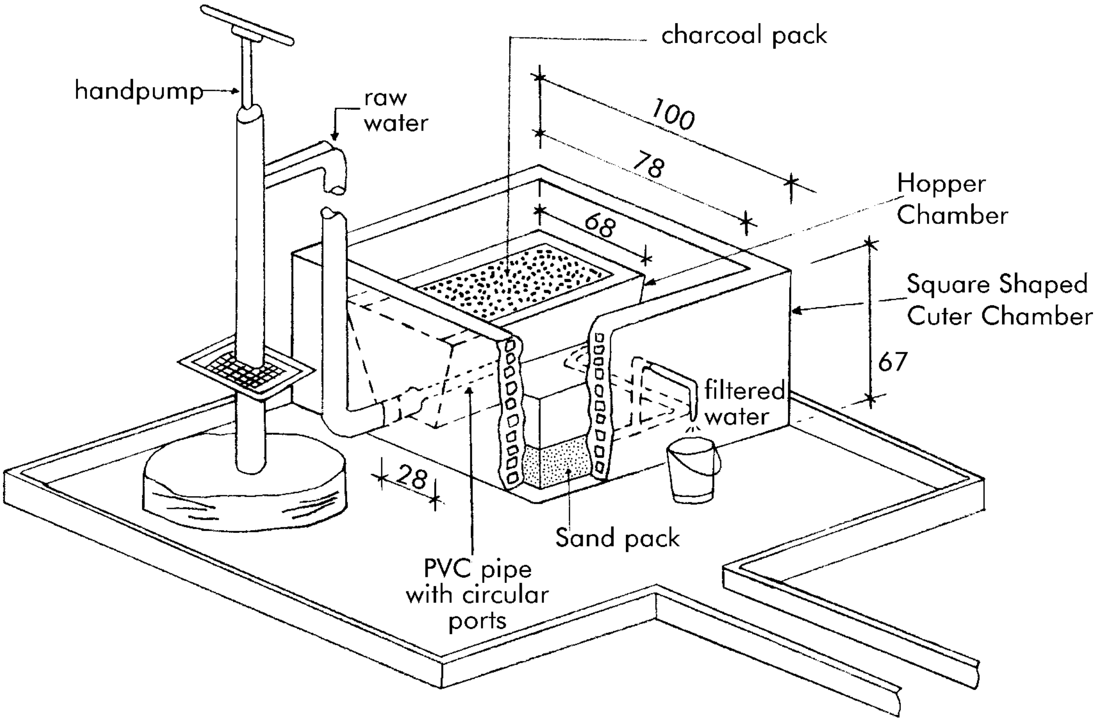
Within the Kandy District Water Supply and Sanitation project, FINNIDA square type filter units were installed at some handpump wells where the groundwater has an excessive iron content.

Plant design

Special emphasis was put on simplicity and economy in construction and maintenance. It can be built mostly of locally available fired bricks (18 cm x 9 cm x 6 cm). The reinforced concrete lid is made in three parts, and each part is fitted with handles, facilitating easy lifting. The square filter unit is subdivided into two chambers. The inner chamber is like a tapered trough formed from concrete slabs, and it is packed with filter media having a grain size range of 1 to 3 cm. Incoming water from the handpump outlet flows through a 7.5 cm diameter inlet pipe and then enters the chamber near the floor through a pipe of 5 cm diameter, which has holes for discharging the inflow along the length of the trough. When this inner chamber is full, water spills out into the outer chamber over sharpened weirs on three sides of the inner chamber. There is a washout port to allow easy draining of the inner chamber for cleaning purposes.

The second chamber contains wood charcoal and sand for filtering this water. There is a horizontal pipe with holes in it near the floor of this outer chamber; this pipe collects the water after it has filtered down through the sand and charcoal. There are also two washout ports which are used for the frequent cleaning of the filter media. The precipitates of iron oxide are filtered out in this chamber, by washed and sieved river sand of size range 1 to 3 mm. In addition a synthetic net is provided to accumulate the precipitated materials.


raw water
from handpump
handpump
1000 mm
670 mm
filtered
water


charcoal pack
handpump
raw
water
100
78
68
Hopper
Chamber
Square Shaped
Cuter Chamber
67
filtered
water
28
Sand pack
PVC pipe
with circular
ports

Filter Media and Maintenance

The wood charcoal pack needs replacement from time to time. This material is available from bakeries, lime kilns, brick kilns and tea factories in the area (in Sri Lanka) and can be bought at a low price. Frequent maintenance of both the charcoal and the sand filter is essential. When the sand layer becomes too thin, fresh washed and sieved sand can be added to the filter unit. The thickness of the sieved sand layer should be 6 cm.

The beneficiaries themselves are able to identify when to clean and maintain the filter unit because a high iron content gives a yellow-brown colour and bad taste to the water. In addition the filtering rate is very slow when the fine iron hydroxide particles have formed a clogging layer on top of the sand bed. Once the filter unit is blocked, water splashes out from the inlet at the handpump.

Experience since start of operation in 1989

Ten years after the construction of the first units and five years after project completion, the majority of the 150 units are still in operation. The only substantial change is the replacement of the filter media: granite chips of 10 to 25 mm size are today utilised instead of wood charcoal in the upflow section (hopper chamber) and granite chips of 1 to 3 mm grain size are used instead of sieved sand in the second chamber. These filter media are readily available in Sri Lanka.

Based on experience in Sri Lanka, iron removal plants of this type have also been constructed in Bhopal, India, by UNICEF.

General Information

Name of treatment plant type:	**FINNIDA square type filter**
Country:	Sri Lanka
Year of first installation:	1989
Number of units constructed:	150

Technical Data

Required space for installation:	1.2 m^2
Effective filter area:	1.2 m^2
Filter media:	Originally wood charcoal and river sand, Today, granite chips, size 10-25 mm and 1-3 mm.
Percentage of iron reduction:	approximately 90 %
Investment cost (1990):	Rs. 1 600.- (US$ 40)
Annual maintenance cost:	Rs. 100.- (US$ 2.50) (excluding labour)
Transportation:	Materials can be transported to site for in situ construction.
Moulds and special facilities for construction:	Only simple shuttering is required for in situ casting.
Maintenance at village level:	very easy

Contact Address

Kandy District Water Supply and Sanitation Project /
National Water Supply and Drainage Board NWSDB
Mr. J.P. Padmasiri / Mr. M.A.S.L. Attanayake
Kandy – Sri Lanka
Phone: ++94 8 388 086
Fax: ++94 8 388 027
e-mail: midwater@slt.lk

3.2 CREPA iron removal plant type AF (aeration-filtration)

(CREPA: Centre Régional pour l’Eau Potable et l’Assainissement à Faible Coût, Ouagadougou, Burkina Faso)

Introduction

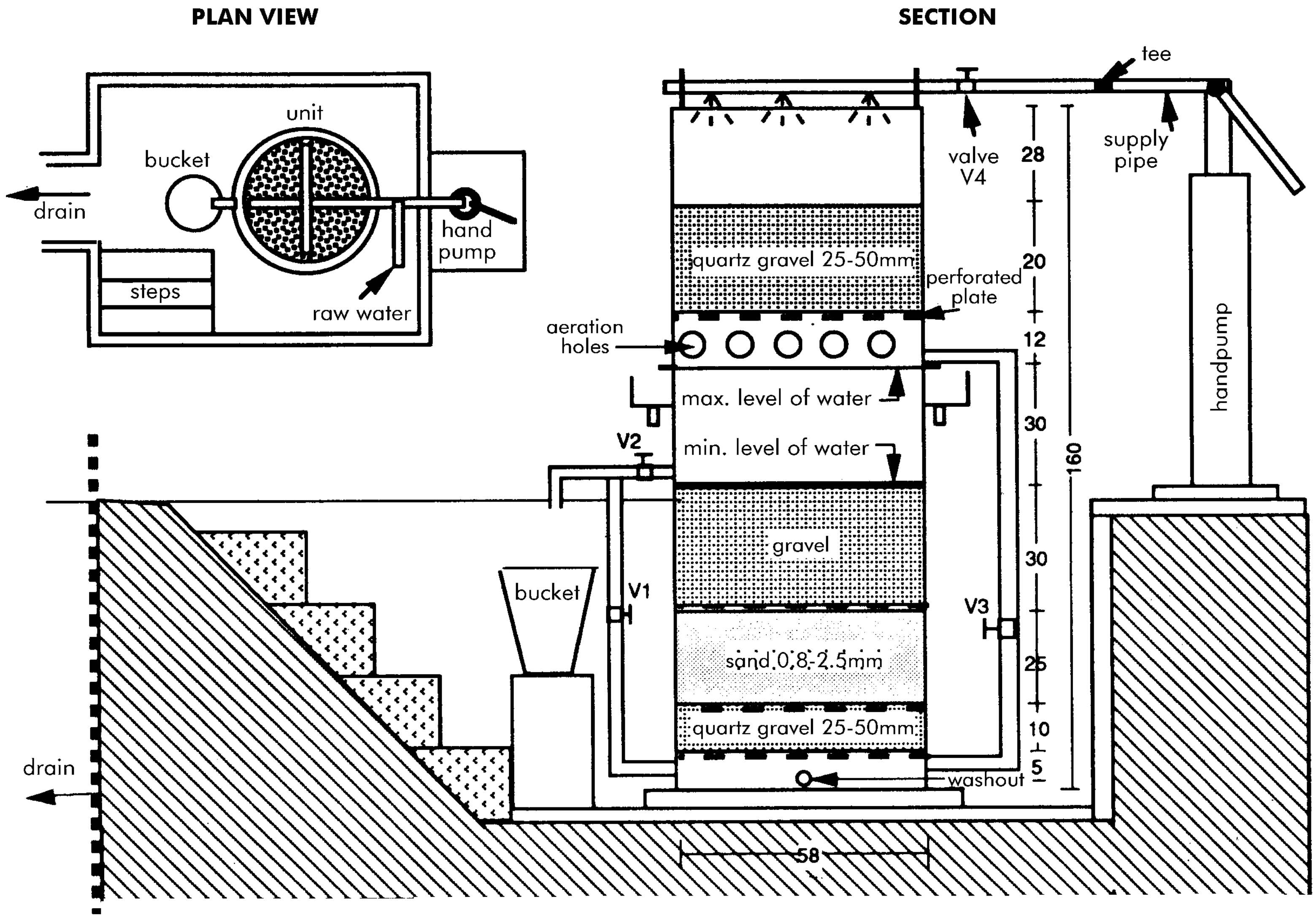
The ***CREPA iron removal plant type AF*** was designed by CREPA engineers in 1990 for handpump sites. Studies were performed at three sites and the results have shown that for iron concentrations lower than 5 mg/l, the AF type unit is recommended (whereas for iron concentrations higher than 10 mg/l CREPA recommends their other design – the iron removal plant type ADAF, also described in this bulletin).

Plant design

The treatment plant consists of two main parts: an aeration zone followed by a filter. The plant can be constructed from steel or reinforced concrete. The advantages of using steel are

- simplicity of construction,
- operation and maintenance is easier because elements can be dismantled,
- the possibility of transporting the plant, and
- lower construction cost.

The outlet of the handpump is joined to the pipe that brings the water to the top of the treatment plant. The end of the pipe is perforated in order to distribute the water over the whole surface of the filter.
The upper chamber is in the form of a 60 cm high barrel containing a 20 cm thick layer of quartz gravel with a grain size of 25 to 50 mm. This rests on a wire mesh and above a zone where there are aeration holes. The bottom of the barrel may be either open or closed, depending on whether the filter in the second chamber is used in the downflow or upflow direction.
The lower, 120 cm high chamber is situated directly under the upper chamber. The lower chamber houses the main filter which consists of three layers: gravel, sand and quartz gravel. Sheets of polyethylene mesh separate the different layers and prevent intermixing. Three outlets for maintenance purposes are placed at the bottom of this chamber.
The installation of pipes and valves can be seen on the right of the diagram.



Section and plan view of iron removal plant type „AF"

Filter Media and Maintenance

The best results have been achieved by selecting the upflow option for the filter, with a filter bed consisting of a bottom layer of quartz gravel, a sand layer and a top layer of lateritic gravel.

One might think that a lateritic layer would increase rather than decrease the iron content of the water. However, results have shown that during aeration in the upper barrel, iron is changed from the ferrous to the ferric form, forming very fine particles that are no longer soluble. The lateritic gravel is able to capture a large amount of these particles and therefore is useful as a filter material.

Cleaning of the filter is necessary at least every 4 weeks, or whenever the flow rate becomes low.

Documentation

In 1996, CREPA published a technical report entitled “La déferrisation des eaux de forage – Synthèse des techniques expérimentées avec succès par le CREPA”. This document describes in detail the layout and functioning of the CREPA iron removal plant types AF and ADAF. The document further contains general information about iron in drinking water and includes the results of the field testing period in the annex.

Documentation

Name of treatment plant type:	**CREPA iron removal plant type AF**
Country:	Burkina Faso
Year of first installation:	1990
Number of units constructed:	3

Technical Data

Effective filter area:	0.25 m^2
Percentage of iron reduction:	approximately 90 % This type is recommended by CREPA when the initial iron content is less than 5 mg/l
Investment cost (1990):	CFA 180 000.- (US$ 360)
Annual maintenance cost: (excluding labour)	CFA 40 000.- (US$ 80)
Transportation:	Transportation of the unit is possible when fabricated of steel impossible when made of reinforced concrete.
Maintenance at village level:	easy, cleaning of the filter at least every 4 weeks

Contact Address

CREPA
Mr. Tounkara
03 BP 7112
Ouagadougou 03
Burkina Faso
Phone: ++226 31 03 59/60
Fax: ++226 31 03 61
e-mail: crepa@fasonet.bf

3.3 CREPA iron removal plant type ADAF (aeration-decantation-adsorption-filtration)

(CREPA: Centre Régional pour l'Eau Potable et l'Assainissement à Faible Coût, Ouagadougou, Burkina Faso)

Introduction

The ***CREPA iron removal plant type ADAF*** was designed by CREPA engineers in 1990 for handpump sites. Studies were performed on three sites and the results have shown that for iron concentrations higher than 10 mg/l, the ADAF type unit is recommended (whereas for iron concentrations lower than 5 mg/l CREPA recommends their iron removal plant type AF, also described in this bulletin).

Plant design

The treatment plant consists of four main parts:
1) Supply channel
2) Sedimentation basin (settlement basin)
3) Adsorption basin
4) Filtering basin

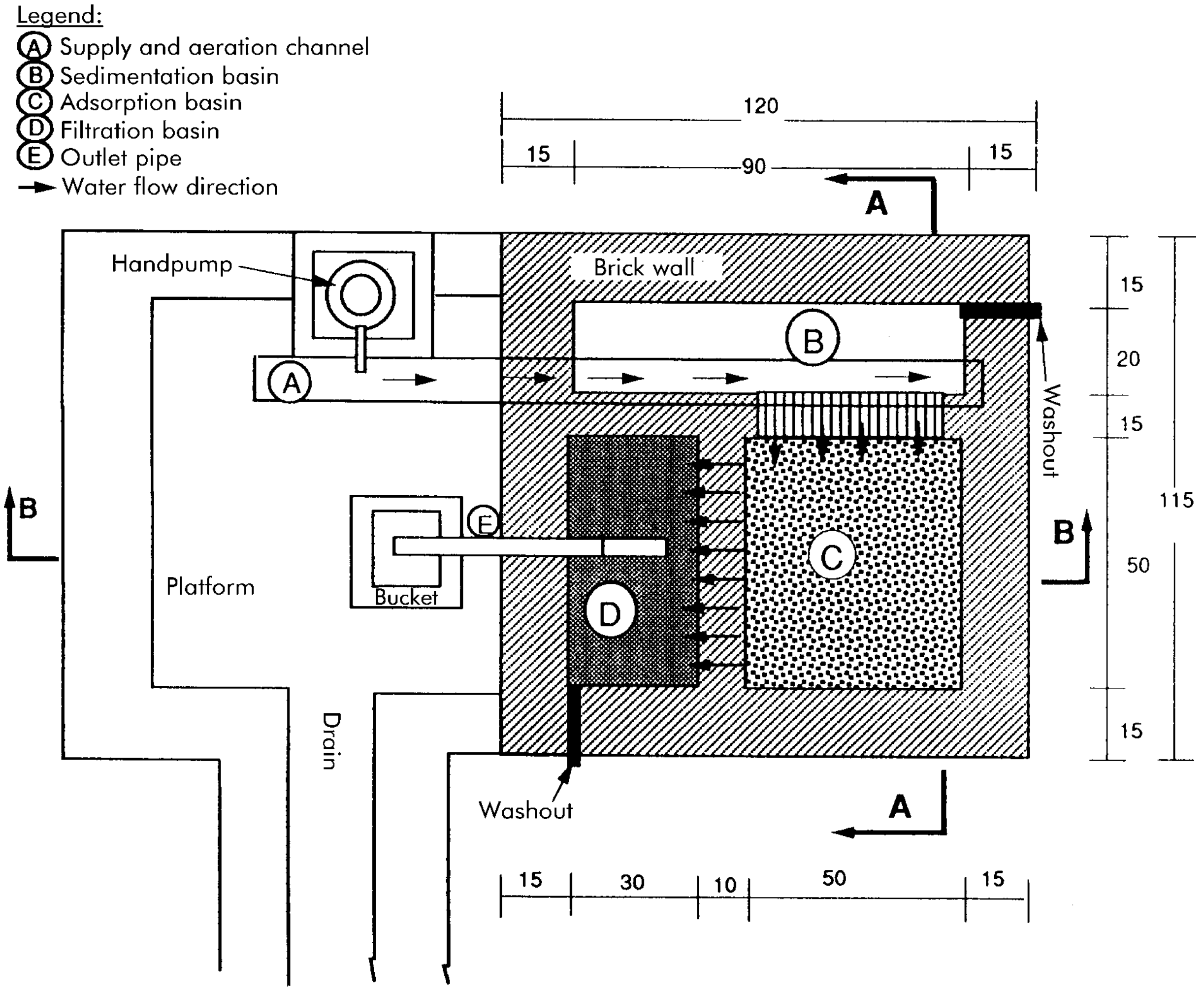
The various sections are integrated into a superstructure made out of brickwork or steel.

The outlet of the handpump feeds into the *supply channel* that brings the water to the top of the sedimentation basin. The channel consists of a folded metal sheet that is perforated along the side walls in order to increase the aeration of the raw water coming from the pump outlet. Through a tube at the end of the channel, the water enters into the

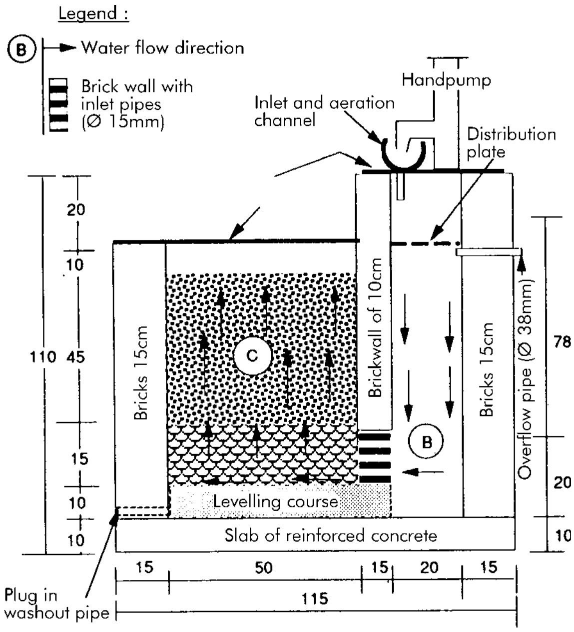
Sedimentation basin. This basin has a size of 90 x 20 cm and is 100 cm deep. It is equipped with a distribution plate on top and a drainage outlet for maintenance work at the bottom.

The *adsorption basin* is square in plan, 50 x 50 cm, and is 70 cm deep. The floor of this basin is 10 cm above the floor of the sedimentation basin. The two basins are linked through plastic tubes 20 mm in diameter. The adsorption basin is filled with layers of graded gravel to which the finest particles attach by adsorption. The different layers of this upflow filter are separated by sheets of polyethylene mesh.

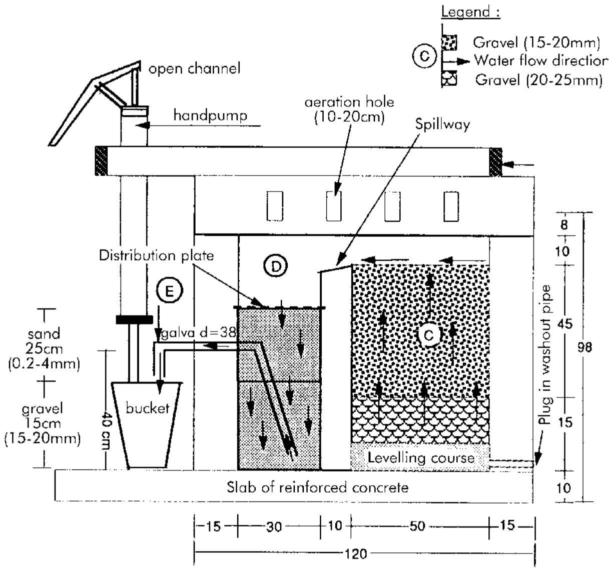
The *filtration basin* has plan dimensions of 50 x 30 cm and is 80 cm deep. The upper level of the separating wall between the adsorption and the filtration basin is in the form of a spillway. The downflow filter consists of a layer of quartz gravel having a grain size of 2.5 to 5 cm at the bottom, and a layer of 0.8 to 2 mm sand on top. The basin



Plan view of iron removal plant type „ADAF“



Section A-A



Section B-B

is further equipped with a treated water outlet, an overflow outlet (10 cm above the top of the filter bed) and a drainage outlet (at the bottom) for maintenance purposes.

The arrangement of the basins and the installation of pipes and valves can be seen to the right of the diagram.

Filter Media and Maintenance

CREPA has tested various filter media such as quartz gravel, granite gravel, laterite gravel and sand for both the adsorption and the filter basins.

Good results for the adsorption basin have been achieved by using two layers of different filter media. The best result for the filter basin has been achieved by using a 20 cm layer of 0.8 – 2 mm sand and a 15 cm deep quartz gravel layer. Cleaning of the filters is necessary at least every 10 weeks, or whenever the flowrate becomes too low.

Documentation

In 1996, CREPA published a technical report entitled "La déferrisation des eaux de forage – Synthèse des techniques expérimentées avec succès par le CREPA". This document describes in detail the layout and functioning of the CREPA iron removal plant types ADAF and AF. The document further contains general information about iron in drinking water and includes the results of the field testing period (obtained using different filter media) in the annex.

General Information

Name of treatment plant type:	**CREPA iron removal plant type ADAF**
Country:	Burkina Faso
Year of first installation:	1990
Number of units constructed:	Five, of which 4 are made of brickwork and 1 of steel.

Technical Data

Effective filter area:	0.25 m^2, 0.15 m^2
Percentage of iron reduction:	approximately 90 % This type is recommended by CREPA when the initial iron content is above 10 mg/l
Investment cost (1990):	CFA 200 000.- (US$ 400)
Annual maintenance cost: (excluding labour)	CFA 30 000.- (US$ 60)
Maintenance at village level:	Easy, filters need cleaning at least every 10 weeks

Contact Address

CREPA
Mr. Tounkara
03 BP 7112
Ouagadougou 03
Burkina Faso
Phone: ++226 31 03 59/60
Fax: ++226 31 03 61
e-mail: crepa@fasonet.bf

3.4 Seven villages water supply near Cape Coast, Ghana

(Community Water Supply Division (CWSD) Cape Coast, in collaboration with BURGEAP Consulting Engineers)

Introduction

The ***Seven villages water supply*** is designed for a total population of 11 000 (the estimated population in 2009), living in seven communities west of Cape Coast. Aboransa is the biggest of these communities. Water is pumped from a borehole which is 180 m deep to the main storage tank that is combined with the iron removal plant. From there the water flows by gravity to six community storage tanks to be distributed afterwards to 19 standpipes.

Plant design

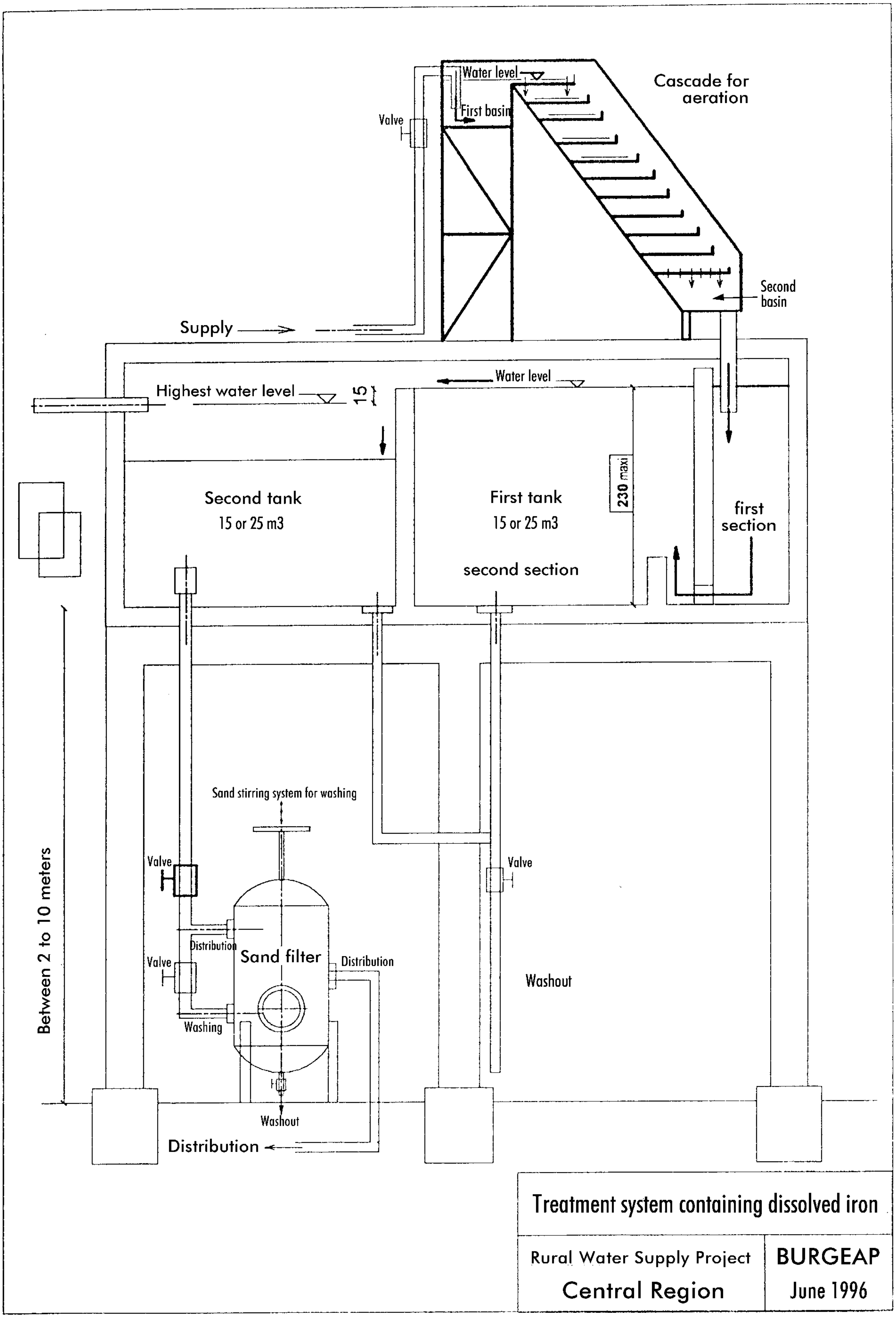
Water flows from the main storage tank into the first small basin and then over a cascade aerator into a second basin. From there the aerated water flows into the first tank which is divided into two sections. In this tank the water flows downwards in the first section and upwards in the second so that sedimentation of suspended particles can take place. Water from the second section of this tank overflows into the second tank, which feeds the filtration stage.

The filters consist of two downflow pressure filters in parallel. The filter beds consist of an upper layer of fine sand from the seashore, resting on a lower layer of coarse sand. Backwashing (upflow) of the filters is done twice each day, each time for 30 to 40 minutes (15 to 20 minutes for each compartment).

Experience so far (January to September 1998)

The iron content in the borehole is in the range 5 to 6 mg/l. After filtration, the iron content was being reduced to 0.5 to 0.6 mg/l, which is still above the WHO recommended level but seemed to be acceptable to the population.

If the backwash flowrate is too high, there is a risk that the finest particles of the filter sand will be washed out. Because of concern about some of the sand being washed out the backwash rate was decreased and the duration of each backwashing operation was increased. However, it is possible that the loss of the finest particles can be the result of inadequate sieving of the sand when it is being prepared for the filters, or of some other fault in the installation of the filters. The finest particles were not being washed out of the filters in the Mampong water supply (described below) which are of the same type.

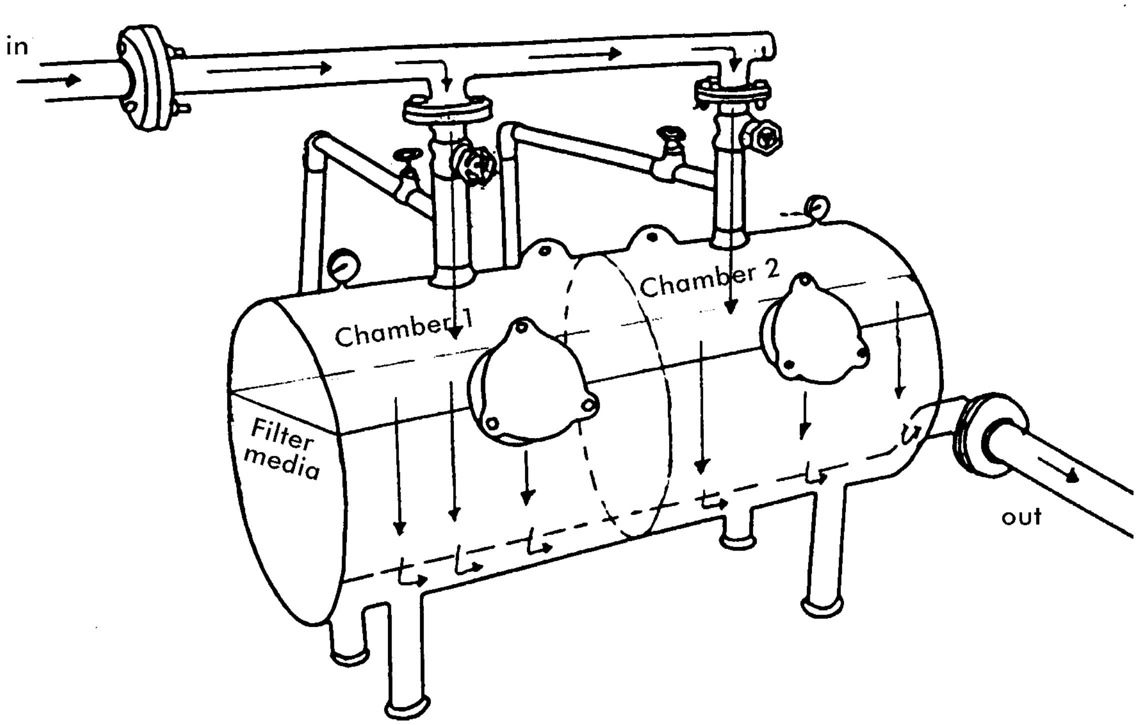


Treatment system containing dissolved iron

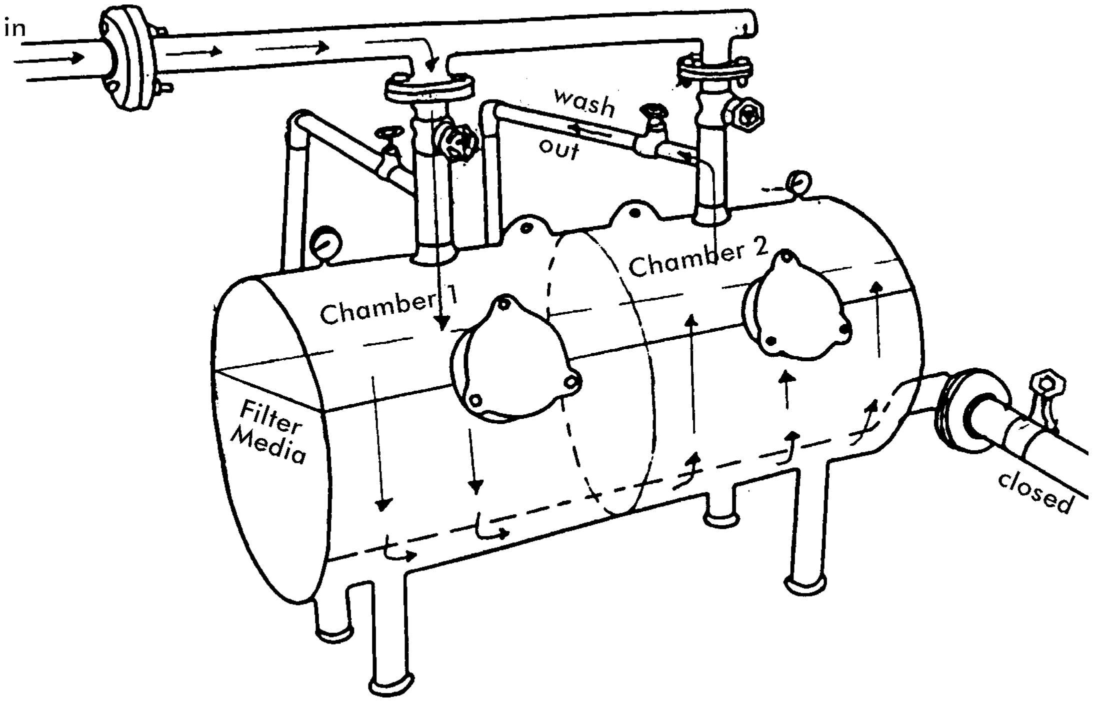
Rural Water Supply Project
Central Region

BURGEAP
June 1996

Layout of sand filter



Normal function of filter



Wash out of chamber 2

The same system has been applied to the Mampong water supply in the same region. Whilst the system was working well in the Seven Villages water supply, the iron removal process was much less effective in Mampong. It is assumed that the different colour of the raw water in Mampong (whitish instead of reddish in the seven villages) is due to the fact that the iron has adopted a complex form with another mineral – in other words that the chemical form of the iron is different in the two places. The addition of potassium permanganate into the basin after the aerator has produced good results. Recent experiments with chlorine have also shown encouraging results, but chlorine would be much more expensive to use than potassium permanganate.

General Information

Name of project:	**Rural water supply project in the Central Region**
Country:	Ghana
Year of installation:	1998
Number of units constructed:	One in the Seven Villages Water Supply One in Mampong (mentioned in the section above on experiences)

Technical Data

Filter capacity:	7 – 7.5 m^3 per hour
Volume of water treated per day:	60 m^3 – 160 m^3 (designed daily production)
Effective filter area:	Approximately 1 m^2
Iron content in borehole water:	5 – 6 mg/l
Iron content after treatment:	0.5 – 0.6 mg/l
Investment cost (1998):	Aerator: approximately US$ 4 000 Filter chambers: approximately US$ 10 000 (Both the aerator and the filter chambers were imported from France.)
Operation and maintenance:	Washing of the filters twice a day, each time for 30 to 40 minutes. One caretaker is fully in charge of the whole water supply system, another person is able to deputise for the caretaker.

Annual operation cost (excluding labour), evaluated after one year:	Pumping system:	US$ 1300
	Pipe network:	US$ 1700
	Fuel cost for pump:	US$ 3000
	Potassium permanganate for the Mampong water supply:	US$ 100
	Filter media: no costs for Seven villages water supply because taken from seashore.	

Contact Addresses

Community Water Supply Division (CWSD)
Mr Ahmed Ewura
P.O. Box 1315
Cape Coast / Ghana
Phone: ++233 42 322 31
Fax: ++233 42 326 37

BURGEAP
Mr Christophe Kasprzyk
P.O. Box 1315
Cape Coast / Ghana
Phone: ++233 42 322 31
Fax: ++233 42 326 37
e-mail: burgeap@ghana.com

3.5 Iron and Manganese removal in the province of Santa Fe, Argentina

(Centro de Ingeniería Sanitaria, Facultad de Ciencias Exactas Ingeniería y Agrimensura, Universidad Nacional de Rosario)

Introduction

This case study from Santa Fe province, Argentina, gives an overview of the situation in this region. Two operating iron and manganese removal plants and one preliminary project are briefly presented. The case study concludes with some general recommendations from the Centro de Ingeniería Sanitaria and a description of other R&D activities of the centre. All the information presented here has been drawn from the article: "Experiencias de Eliminación de Hierro y Manganeso desarrolladas en la provincia de Santa Fe", by A. M. Ingallinella, G. Sanguinetti, V.A. Pacini of the Centro de Ingeniería Sanitaria, 1997.

The situation in the province of Santa Fe

Within the province of Santa Fe, about 25 communities face problems with groundwater containing high iron and manganese concentrations (1 to 3 mg/l for iron and 0.5 mg/l for manganese). Of these 25 communities, only two have operating treatment plants for removing iron and manganese that are based on the processes of oxidation and physical-chemical treatment.

The following limits for iron and manganese in drinking water were defined by the province of Santa Fe in 1996:

Parameter	*Compulsory limit*	*Recommended limit*
Iron	0.2 mg/l	0.1 mg/l
Manganese	0.1 mg/l	0.05 mg/l

The treatment plant of the community of Avellaneda (population in 1991: 21 000)

The treatment plant of Avellaneda has a capacity of 300 m^3/h and is operated in two lines, each treating 150 m^3/h. The raw water is pumped out of 15 boreholes in sequence in order not to overexploit the aquifer.

The raw water is first piped into a basin with a capacity of 500 m^3 in order to mix the water from the different boreholes to achieve a uniform water quality at the beginning of the treatment process. The treatment process starts in the oxidation tower that is in the form of an aerator with perforated steps so that the water falls down in droplets. Subsequently, dosed quantities of chemicals are added. The chemicals that are used are soda (sodium carbonate) for raising the pH (to over 8 or 9) and sodium hypochlorite as a strong oxidising agent for the dissolved iron and manganese. Subsequently, the water flows through the sedimentation basins where flocs can settle. The sedimentation basins are equipped with inclined plates to enhance the effectiveness of the settling process. Filtration follows sedimentation. The filter consists of a double layer – anthracite over sand. After the filters, the water flows to the treated water tank (which has a capacity of 500 m^3) and is pumped from there to an elevated reservoir. Operational data of this removal plant can be seen in the table below.

Location	*Iron [Fe] in mg/l*	*Manganese [Mn] in mg/l*
Entrance of treatment plant	0.2 – 1.2	0.1 – 0.7
Exit of treatment plant	0.14	0.02

Treatment plant in the community of Villa Ocampo (population in 1991: 11 800)

The water supply of Villa Ocampo supplies 2 850 connections that cover the entire urbanised area of the community. The iron and manganese removal plant was inaugurated in 1984. The production of drinking water is in the range of 70 – 100 m^3/h during winter season and twice this in the summer season.

Groundwater is pumped out of eight boreholes directly to the aerator. It is of cylindrical shape with a height of 3.5 m and a diameter of 1.2 m and contains a bed of PVC rings. Air is injected in the counter-current direction. At the outlet of the aerator, hypochlorite and soda are added. The water then flows through the sedimentation basins and conventional rapid filters. After filtration, the treated water is collected in a basin of 500 m^3 before being pumped to the elevated storage tank for distribution.

The sand of the filters is replaced every 1.5 years. The filters are backwashed three times a week with water from the storage tank. On each occasion, 150 – 200 m^3 of treated water is required. The operational data for the Villa Ocampo plant are:

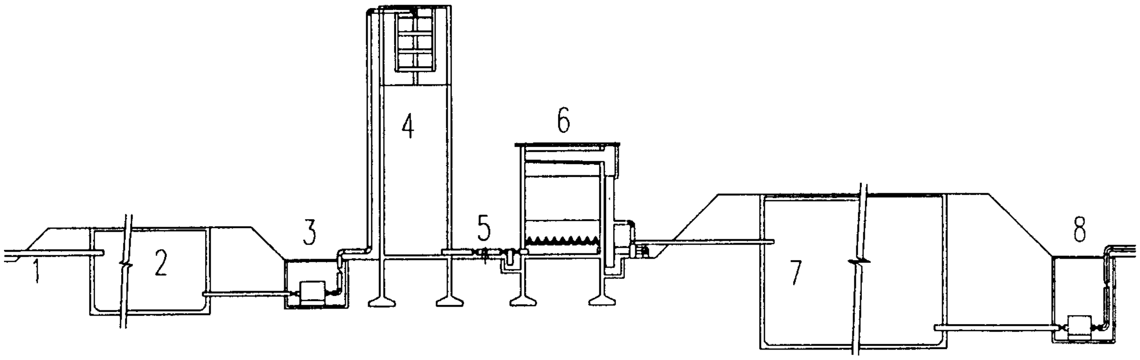
Location	*Iron [Fe] in mg/l*	*Manganese [Mn] in mg/l*
Entrance of treatment plant	0.16 – 1.48	0.04 – 0.54
Exit of treatment plant	0.14	0.13

Note: the content of manganese in the treated water is very high. It is assumed that the reason is that no adjustment of the pH (to 9 or 10) is made.

Preliminary project for an iron and manganese removal plant in Las Toscas (population in 1991: 9 300)

The Centro de Ingeniería Sanitaria has designed a preliminary project for an iron and manganese removal plant in Las Toscas. This community is facing problems because of a high iron content in groundwater. It is planned to include the following components in the treatment plant:

1) Water extraction from various boreholes
2) Raw water basin
3) Low-lift pumps to
4) Elevated aerator
5) Injection of chemicals
6) Upflow filters (filtros directos ascendentes)
7) Treated water basin
8) High –lift pumps to storage tank



Design parameters:

Design period:	20 years	Treatment capacity:	167 m^3/h
Demand 1997:	180 l/cap·d	Daily operation time:	16 hours in 2017
Demand 2017:	202 l/cap·d	Population in 2017:	10200 inhabitants

The use of upflow filters in an iron and manganese removal plant is new for Argentina. Their main advantages are lower construction costs, less clogging and better utilisation of the area of the filter compared to a horizontal filter.

Importance of a pilot plant construction

Before constructing an iron and manganese removal plant, the Centro de Ingeniería Sanitaria strongly recommends that tests and trials in an on-site pilot plant should be carried out. In such a pilot plant, the treatment processes are operated according to the same parameters as those foreseen for the full-scale plant. Laboratory tests can be carried out as a backup, but they should be regarded as only an approximation to the field reality. (For example, water extracted from a borehole can quickly change its characteristics. Chemical analyses for water straight from the borehole might not be the same as the results obtained when it is later tested in the laboratory.) The investment for a pilot plant in terms of money and time is worthwhile and enables the optimisation of the full-scale project resulting in a much more economical solution of the problem.

Other research and development activities undertaken by the Centro de Ingeniería Sanitaria

A major disadvantage of the conventional iron and manganese removal plants is seen to be the use of chemicals, especially in the difficulty of determining optimal dosage rates. The Centro de Ingeniería Sanitaria therefore is assessing the potential of biological processes (biological oxidation) for removing iron and manganese. They plan to establish new research pilot plants for investigating these processes.

The Centro de Ingeniería Sanitaria has designed an iron removal plant for the wastewater treatment of a sheet steel factory (industría de laminación de aceros). Sodium hydroxide will be added to the wastewater and the iron precipitate removed in a gravel up-flow filter. This plant is situated near the town of Rosario.

Contact Address

Facultad de Ciencias Exactas, Ingeniería y Agrimensura,
Centro de Ingeniería Sanitaria,
Mrs. Ana Maria Ingallinella (Director)
Riobamba 245 bis
2000 Rosario - Argentina
Phone: ++54 341 480 8546
Fax: ++54 41 480 8546
e-mail: cis@fceia.unr.edu.ar

3.6 Community-level iron removal plant, South Africa

Design and performance of a community-level iron removal plant

by Cecil Chibi

A simple iron removal plant can make water taste, smell and look better. This system will satisfy local desires for clean and safe water.

IRON IS FOUND in groundwater throughout the Lowveld region and in the semi-arid areas of the northern Transvaal. Many of the rural areas are served by handpumps which yield water with iron concentrations well in excess of the World Health Organisation (WHO) upper limit of 1.0mg/*l*. Concentrations exceeding 20mg/*l* are noted frequently, and result in taste, odour, and colour problems. Upon contact with oxygen in the air, soluble iron compounds in the ferrous form are oxidized into insoluble ferric compounds, which are responsible for the colour problem. Unpleasant taste and odours arise from the decay of some organisms (iron bacteria) present in iron-rich water. Because of these aesthetic considerations, rural people generally refuse to use tube-well water in iron problem-areas, and they are more inclined to use unprotected surface water sources.

In an informal survey around the Majaneng area near Hammanskraal it was found that people would be willing to pay a reasonable amount of money if a low-cost iron removal unit were to be developed. Thus a primary consideration in the design and development of the plant was to ensure the use of readily obtainable materials so that with a little technical guidance any household would be able to construct their own treatment unit.

Plant design

The first system tested comprised four different chambers. The first was an aeration stage in which water was sprayed over charcoal, and the second was when the precipitated iron was allowed to settle. Stages three and four were merely where two different-sized media were used to strain the unsettled iron precipitates. Although the water quality from the system was very good (<1mg/*l*), the system was considered too bulky and therefore unsatisfactory. After further investigations, the compact system shown in Figure 1 was designed and constructed, featuring a 200-litre drum and pieces of guttering as the main components.

The aeration channel is made of a 100cm-long, 10cm-diameter polyvinyl chloride (PVC) pipe, which is capped at the two ends but has an inlet opening near the right end and an outlet opening near the left end of the pipe. About half the depth of the pipe is filled with 2 to 3cm charcoal chips. The inlet of the pipe is made to take water coming from the spout of a tube well. Water entering the PVC pipe flows horizontally over the charcoal chips till it drips through the perforated bottom end of the pipe into another channel, which is half-filled with granite chips. The water is suffi-

A completed iron removal unit in a homestead yard.

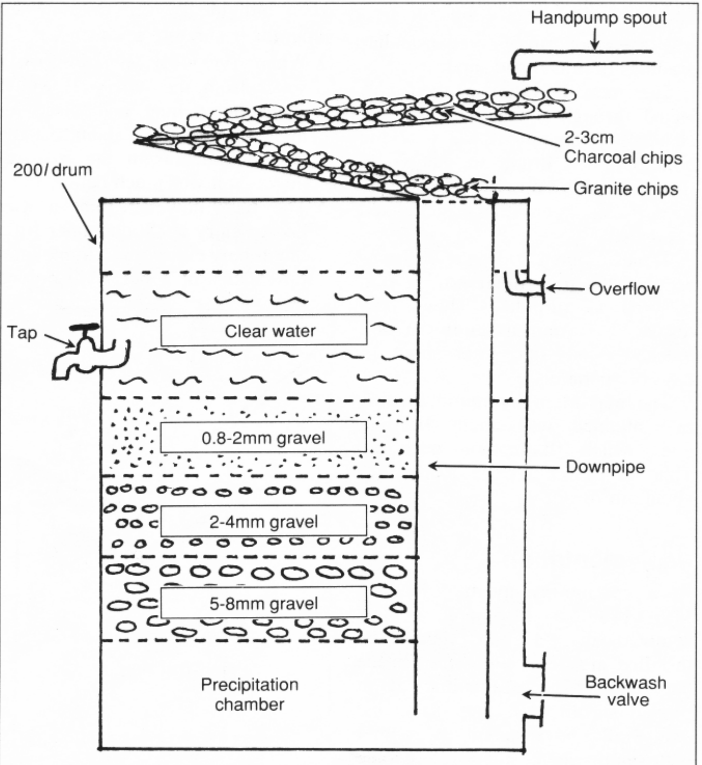
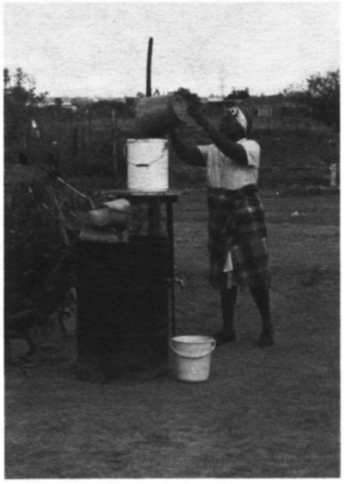


Figure 1. Section through the iron removal plant.

Cecil Chibi is an Environmental Engineer and a Project Leader for the Division of Water Technology, CSIR, PO Box 395, Pretoria 0001, South Africa.

ciently aerated because of the increased contact with air.

The aerated water then drips through the downpipe into the sedimentation chamber, which has a minimum retention time of five minutes. At this stage a portion of the precipitated iron particles settle at the bottom of the chamber. Because of pressure differences within the downpipe, the water then flows upwards through three different layers of successively smaller gradings of gravel and sand.



Using the iron removal plant: note tubewell behind to the right.

The treated water is then collected through a tap. The filter is cleaned by opening a valve at the bottom of the drum, so that water flows quickly down through the sand, flushing out the accumulated deposits.

Tables 1 and 2 show the performance of the plant in removing iron as well as turbidity. They show results from start-up until the unit reached steady-state after about 13 days of operation.

The maximum hydraulic loading rate attained was about 10*l*/min, after which fluidization occurred. This implies a surface loading of about $3m^3/m^2/hr$.

Implementation

At a community meeting held in May 1989 at Majeneng it was resolved that a unit should be installed in one of the homes in the community for evaluation. If it proved satisfactory, then a second one would be installed at another well-stand where interested people from the neighbourhood could help build it and would thus learn enough to go on to build more for themselves.

Table 1: Iron content of raw and treated water

Day	Raw (mg/*l*)	Treated (mg/*l*)
1	9.50	2.25
2	10.30	2.50
3	10.50	2.25
4	10.00	5.25
5	11.50	2.30
6	0.46	0.12
7	14.25	0.76
8	8.75	0.41
9	10.25	0.40
10	13.00	0.18
11	36.25	0.39
12	14.75	0.20
13	19.75	0.24

Table 2: Turbidity of raw and treated water

Day	Raw (mg/*l*)	Treated (mg/*l*)
1	95	38
2	63	30
3	73	70
4	64	47
5	105	24
6	65	23
7	84	14
8	56	7
9	73	7
10	79	5
11	117	9
12	78	8
13	87	7

The unit was set up next to a community handpump. As a precaution against vandalism, the community proposed that the unit be installed in the yard of a householder next to the tube-well.

Turbidity and total iron content was monitored fortnightly for about two months, and thereafter monthly. Over the six months the plant was monitored, and the iron and turbidity removal efficiencies were in excess of 90 per cent.

The following views emerged when individuals were interviewed about the iron removal unit:

- Where previously the raw, rusty water from the tube-well would stain their china and discolour their porridge and laundry, the treated water from the iron removal unit was much better.
- The fact, however, that a user had to carry a 25*l* container from the tube-well to the drum filter (a distance of about 10m) proved somewhat unpopular. It was strongly suggested that a unit which would treat the water direct from the spout would be even more welcome. The community would be keen to contribute towards such a system should the need arise.

Taking into account user's views, a new prototype has been developed. It works on the principles of aeration and uses South African tubewells, which usually have a spout height of only about half a metre, and therefore could not be connected to the initial iron-removal unit. In the new unit the air is introduced into the water though the sucking action of a venturi valve, which eliminated much of the loss in head experienced initially. The water then goes through a sedimentation chamber, overflows into the filtration chambers, and finally goes out through another spout and into a receiving container. The unit has not yet been fieldtested.

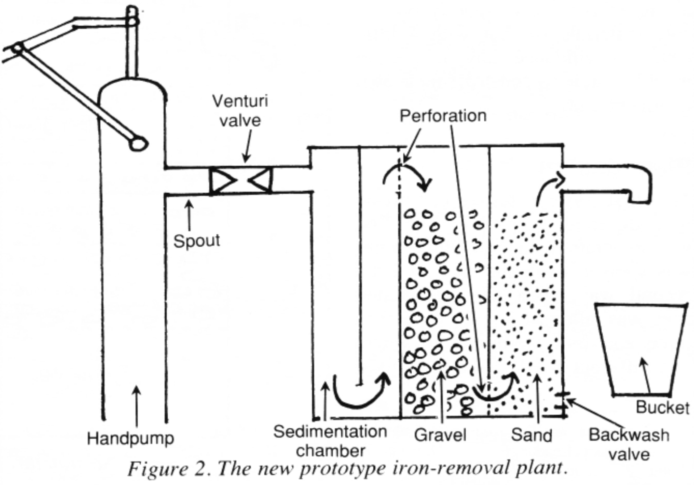


Figure 2. The new prototype iron-removal plant.

3.7 Biological removal of iron from handpump supplies, Uganda/UK

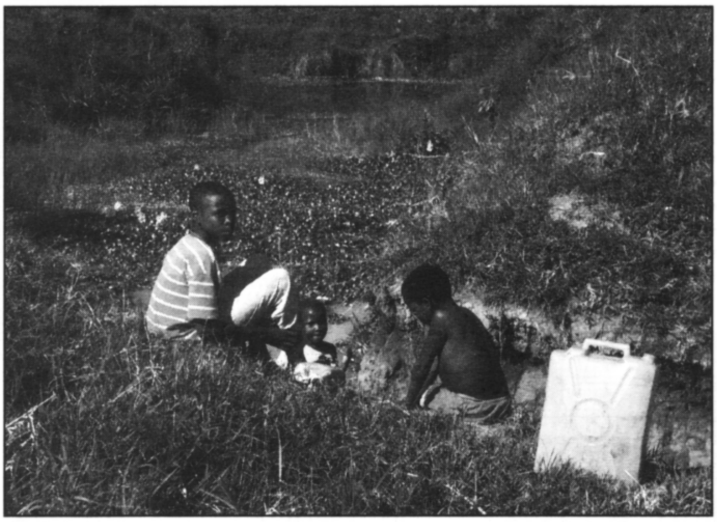
Biological removal of iron from well-handpump water supplies

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?

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.



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

Sean Tyrrel

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

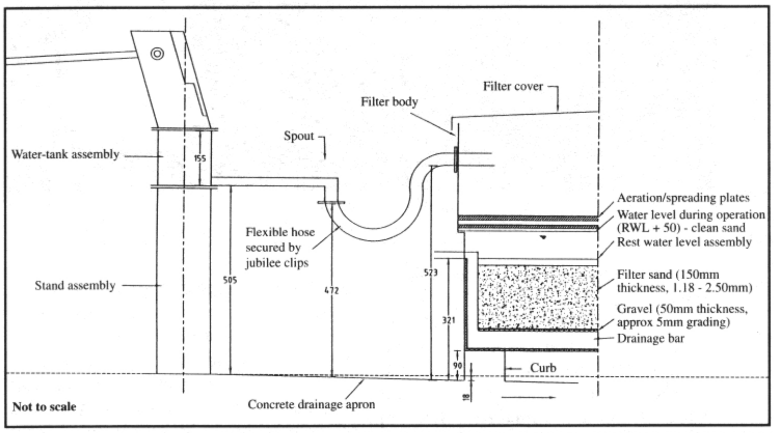
The UK Department for International Development (DFID, formerly ODA) recently funded the development of a small-scale, sustainable biological iron-removal filter at Silsoe College, Cranfield University. Alongside optimizing the iron-removal process within a simple filter design, the studies focused on 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.



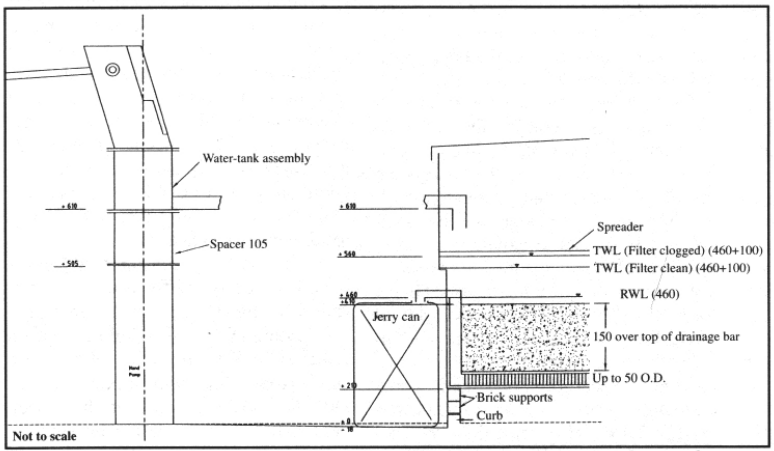


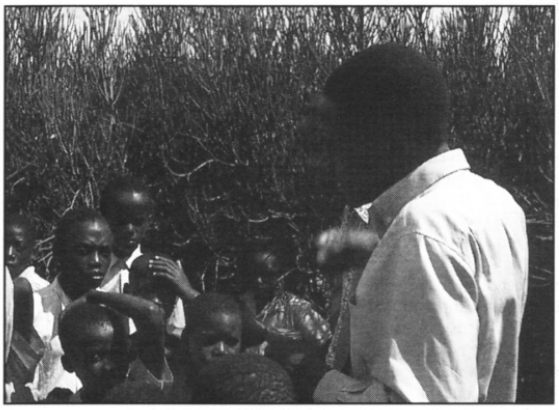
Figure 1. (top) The existing handpump/Mark I iron-filter arrangement in use at Lyantonde.
Figure 2. (below) The research team's proposed handpump-filter arrangement.

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.

Sean Tyrrel



Sean Tyrrel

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

References

1. Bourgin, F.P., Gennery, M., Chapman, J.I., Keral, H., Green, J.G., Rap, R.J., Ellis, S., and Gaumard, C. (1994). 'Biological processes at Saints Hill Water-Treatment Plant, Kent,' *Journal of the Institution of Water and Environmental Management*. Vol. 8, No. 4, pp.370-393.

2. Mouchet, P. (1992). 'From conventional to biological removal of iron and manganese in France,' *Journal of the American Water Works Association*. Vol. 84, No., 4, pp.158-67.

3. Chibi, C. (1991). 'Design and performance of a community-level iron-removal plant,' *Waterlines*. Vol. 10, No. 2, pp.9-11.

4. Ahmed, F. and Smith, P.G. (1987). 'Design and performance of a community type iron removal plant for handpump tubewells,' *Journal of the Institution of Water Engineers and Scientists*. Vol. 41, pp.167-72.

The authors are members of a research team working on a DFID-funded project in the Water Management Department at Silsoe College, Cranfield University, Bedford, UK. MK45 4DT. We would like to encourage interest in the new iron-removal filter. If you would like to receive more detailed information please contact us at the above address or e-mail us on S.Gardner@silsoe.cranfield.ac.uk

A selection of existing literature 4

Operation and control of water treatment processes, *Charles R. Cox, published by WHO, third edition, 1973*
This book subdivides iron and manganese appearance into five major types and describes ten different removal processes. Aeration is treated in a separate chapter. It is an excellent reference for treatment processes.

Basic water treatment*, George Smethurst, second edition published by Thomas Telford Ltd., 1988, ISBN 0 7277 1331 0*
The book describes the type of operating conditions (including iron and manganese problems) that water treatment works may have to cope with. It will help those who are designing plants for unfamiliar countries.

Water quality monitoring*, Bartram/Balance, published on behalf of UNEP/ WHO by E&FN Spon, 1996, ISBN 0 419 22320 7 (Hardback)*
This book provides a sound basis for designing and implementing water quality monitoring programmes and studies of the impacts of human activities on water bodies. It is the outcome of a collaborative programme of UNEP and WHO, with inputs from WMO and UNESCO. It describes also how to analyse iron and manganese in drinking water.

Guidelines for drinking water quality*, 3 Volumes, WHO, 1993/ 1996/1997*
Volume 1: "Recommendations", includes a chapter each for iron and manganese and WHO guideline values for drinking water.
Volume 2: "Health criteria and other supporting information" contains detailed descriptions and conclusions regarding iron and manganese, but does not discuss removal processes.
Volume 3: "Surveillance and control of community water supplies", describes a design for aerators.

La déferrisation des eaux de forage – Synthèse des techniques expérimentées avec succès par le CREPA*, Centre Régional pour l'Eau Potable et l'Assainissement à Faible Coût, Ouagadougou/ Burkina Faso, 1996*
This publication (in French) describes the research and development leading to two different types ("AF" and "ADAF") of iron removal plants. The test results are discussed and conclusions are made. Both the "AF" and the "ADAF" removal plant type are represented as case studies later in this bulletin.

Waterlines
Waterlines is a magazine devoted to low-cost water and sanitation. It is written for administrators, engineers, project managers, policy makers, trainers and field workers. It does not only focus on technical matters but includes also institutional, economic and social issues. Waterlines can be ordered from ***Intermediate Technology (IT) Publications***,
103-105 Southampton Row, London WC1B 4HH, UK,
Tel: +44 171 436 976, Fax: +44 171 436 2013,
e-mail: journals.edit@itpubs.org.uk