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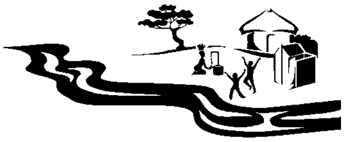
WATER AND SANITATION FOR ALL: PARTNERSHIPS AND INNOVATIONS



Small scale unit for groundwater treatment

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GROUNDWATER PLAYS AN important role in the supply of drinking-water to rural communities. The use of groundwater is usually regarded as being preferable to the use of surface water in that managed groundwater resources are less vulnerable to contamination and usually require a reduced level of treatment. Most of the groundwater of the southern and eastern fringes of South Africa are soft waters, typically with low conductivity (5-50 mS/m), low total alkalinity (0-20 mg/L as $CaCO_3$), low calcium (0-20 mg/L as $CaCO_3$) and low pH (4,0 - 6,0). These characteristics result in the water being **corrosive** (to metals) and *aggressive* (to cement concrete), attacking pipes, conduits and containers. The financial cost of attack can be substantial, comprising both lost water and replacement/repair of pipes, reservoirs, geysers and plumbing. Furthermore, such attack results in a decrease in water quality as a result of raised levels of dissolved metals, often in excess of standard drinking water requirements. In addition, these groundwaters frequently contain problematic levels of naturally occurring *dissolved iron and manganese*, and require removal of these constituents. When present, iron concentrations are typically between 0,5 and 5,0 mg/L, whilst manganese concentrations are typically between 0,1 to 3 mg/L. The presence of even low levels of dissolved iron and manganese causes poor taste, poor appearance and the staining of laundry and walls.

Treatment technologies and know-how to address the above mentioned problems are readily available for both larger water supply systems and areas close to technical support centres. However, effective, low cost, low maintenance, robust systems suitable for small scale rural application of, say, 50 m^3/day are not readily available. To address this need a small scale groundwater treatment system, termed Spraystab, was developed by Environmentek, CSIR.

Stabilisation of soft acidic waters with limestone

General guidelines for the stabilisation of water to prevent aggression and/or corrosion exist (Loewenthal *et al*, 1986). In brief, stabilisation is achieved by adjusting the carbonate chemistry of the water such that the water is slightly supersaturated with respect to calcium carbonate ($CaCO_3$), typically with a Calcium Carbonate Precipitation Potential (CCPP) of, say, 3 mg/L as $CaCO_3$. Conventionally, such stabilisation is achieved via the addition of lime ($Ca(OH)_2$), to increase calcium (Ca^{2+}) and total alkalinity levels, and the addition of carbon dioxide (CO_2), to add carbonate species and adjust pH. However, whilst such stabilisation is well documented and understood, it is entirely impractical and too expensive for small scale rural water treatment systems.

An alternative approach is to use limestone ($CaCO_3$) to effect partial stabilisation which will reduce the aggressive and corrosive characteristics of the water. In this process the natural driving force (calcium carbonate dissolution potential) of the water is used to take up the necessary carbonate and calcium species by exposing the water to solid limestone. Typically a water with a Calcium Carbonate Dissolution Potential (CCDP) of 35 mg/L $CaCO_3$ will take up 35 mg/L $CaCO_3$ if sufficient contact time is allowed to reach chemical stability; in doing so pH, total alkalinity and calcium levels of the water naturally increase to desirable levels. Whilst this will not result in a fully stabilised water, ie with a positive Calcium Carbonate Precipitation Potential (CCPP), as is generally required in large-scale plants, it will produce a water which is essentially non-aggressive to cement concrete, non-corrosive to copper and with a significantly reduced corrosiveness to iron. Stabilisation with limestone has significant advantages over the traditional use of lime and carbon dioxide. These include *inter alia*:

- Limestone is significantly cheaper than lime, approximately SAR180/t vs SAR650/t, 1997 prices (1SAR = 0.22 US$, June 1997).
- pH is controlled naturally at desirable levels as the water approaches chemical equilibrium.
- The process requires little or no operator skill.
- Lime dosing equipment, which is generally impractical on small scale water treatment plants, is not required.

Iron and manganese removal

Treatment requirements for the removal of dissolved iron and manganese from water are well understood and documented. In brief, groundwater contains iron and manganese in the divalent state, Fe(II) and Mn(II) respectively, and these elements must be oxidised to the trivalent state, Fe (III) and a Mn(III) respectively, before proceeding with flocculation and filtration. Fe(II) requires a pH > 6,5 in order to be oxidised at a reasonably rapid rate, whilst Mn(II) requires a pH > 8,5, above which the reaction will become autocatalytic. If oxidation by aeration is used, stripping of carbon dioxide will also occur, thereby raising the pH. However, soft acidic waters with low pH and low total alkalinity will require dosing with an alkali to assist adjustment of pH and alkalinity to desirable levels to achieve a significant removal of these ions by oxidation. The oxygenation of Fe (II) is catalysed by the reaction product Fe(III) (Sarikaya, 1990). The associated significantly improved efficiency of oxygenation can be capitalised on by contacting the aerated water with Fe(III) in, for example, filter media.

Conventionally, oxidation of iron and manganese in soft waters is achieved by the dosing of lime (pH and alkalinity adjustment) and chlorine (chemical oxidant). However, this is both impractical and too costly for small rural water treatment systems. An alternative approach is the combination of contact with limestone (Smith *et al*, 1993) with effective aeration. Combination of these simple treatment processes potentially has significant advantages including:

- Low maintenance and low operator skill requirements.
- No risk of oxidant and/or alkali overdosing.
- Significant chemical cost savings.
- pH is controlled naturally at desirable levels.

System requirements

The following treatment objectives were set for the prototype small scale groundwater treatment units:

- Achieve an appreciable level of pH adjustment and stabilisation.
- Remove iron such that the treated water has an iron level of at most 1 mg/L and preferably less than the iron taste threshold of 0,3 mg/L .
- Remove manganese such that the treated water has a manganese level of at most 1 mg/L and preferably less than 0,1 mg/L .
- Filter the water.
- Treat between 25 m^3/day and 50 m^3/day.

In order to fulfill the demand criteria for an effective, low cost, low maintenance, robust system for rural application, the following requirements had to be satisfied:

- All make-up components of the unit easily handleable by two people and transportable on an ordinary pick-up vehicle.
- Materials and equipment to allow for low cost and easy construction and repair.
- The unit to be simple to operate and maintain, requiring a minimum of operator attention and skill.
- The unit to utilise a minimum of chemical dosing, and where required this should be self regulating.
- No dosing pumps.
- No water pumps other than the borehole pump.
- Robust and reliable.
- Non reliant on electrical control or operating systems.

The Spraystab system

Following laboratory and pilot scaled development, the *Spraystab* system was developed. The system is shown in Figures 1 and 2. The system consists of three main components with the following specific functions:

- *Aeration unit*, to strip excess carbon dioxide from the water and dissolve some oxygen into the water to assist in the oxidation of iron and manganese. The aeration system is housed in the lid of the unit and comprises spray nozzles, aeration ducts and ventilation holes.
- *Stabilisation unit*, to increase calcium, total alkalinity and pH of the water such that the CCDP is significantly reduced. Partial stabilisation is achieved via providing sufficient contact time with a suitable limestone aggregate. The limestone bed is supported on a support screen, the aerated water from the spray nozzles cascading over the limestone bed. The associated increase in pH and total alkalinity promotes the oxidation of iron and manganese to their trivalent state, which is insoluble and precipitates to form floc.
- *Filtration unit*, to remove limestone fines and other insoluble matter such as iron and manganese floc. The filter is a dual media filter comprising both hydro-anthracite and filter sand. The filter bed is divided into two by a splitter to allow backwashing of half the filter area at a time, using the available low volume supply to the aeration unit.

Spraystab design

The configuration of the unit is shown in Figure 1, while Figure 2 provides more detailed sketches of the main components. The aeration unit comprises two air ducts affixed through the removable lid, each with a 60° full-cone spray nozzle located centrally in the duct. The height of the nozzle above the bottom of the duct is chosen such that maximum air suction into the duct is obtained, provid-

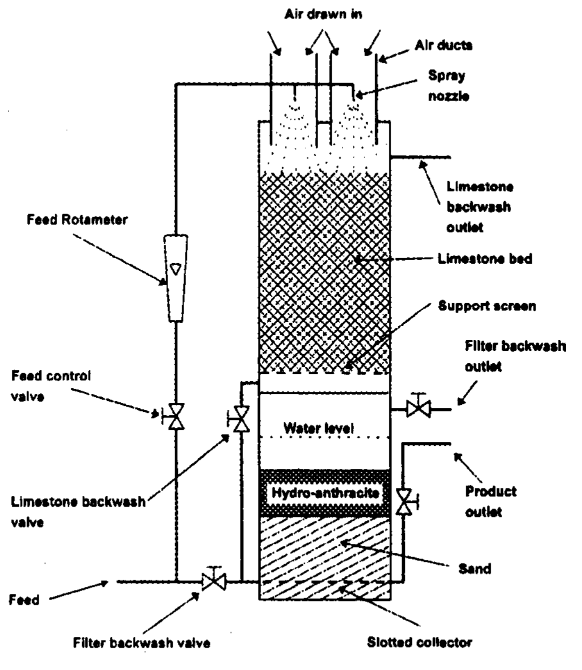

Figure 1: Configuration of Spraystab Unit

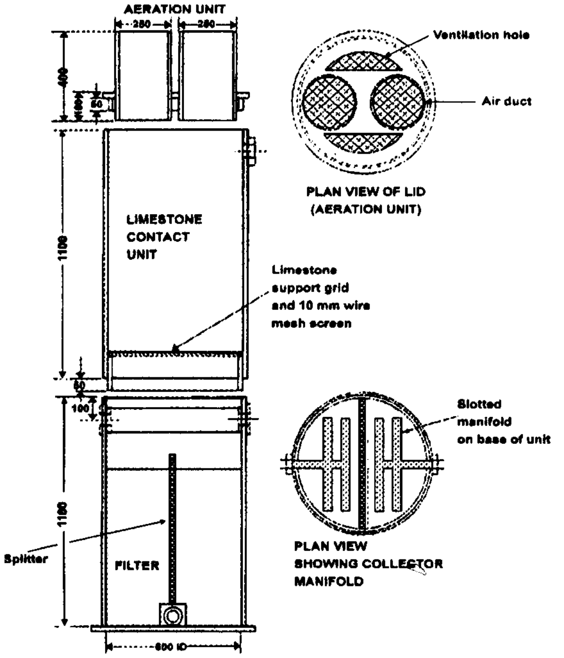

Figure 2. Main component dimensions of Spraystab Unit Field testing and results

ing maximum aeration. The vents in the lid allow the air which is drawn in to the system to escape. Coarse stainless wire mesh screens cover both the ducts and the vents to prevent ingress of leaves, etc. The spray nozzles are fed directly from the borehole pump, the nozzles being sized such that they provide sufficient spray action with the pressure and flow rate available. A feed control valve and a rotameter (flow rate meter) may be fitted in the feed line if required for additional control, but are not essential.

Table 1. Raw feed water quality at sites A and B

Determinant	Unit	Site A	Site B
pH		6.0	4.7
Calcium as $CaCO_3$	mg/ℓ	6.5	0.5
Alkalinity as $CaCO_3$	mg/ℓ	19	6
Conductivity	mS/m	22.5	18
CCDP as $CaCO_3$	mg/ℓ	87.1	207
Iron as Fe	mg/ℓ	0	1.55
Manganese as Mn	mg/ℓ	0	0

The limestone contact unit comprises a simple cylindrical section, with a 10 mm wire mesh screen on a support grid near its lower end. A bed of suitable granular porous grade limestone, approximately 800 mm deep, rests on this support. The limestone used has a grading of -15 mm +12 mm, and the support screen allows limestone fines, iron and manganese floc and insoluble silica to drop through to the filter section, where this material can be removed during backwashing.

The filter unit is divided into two compartments. Each compartment has a slotted pipe under-drain, as shown in Figure 2, feeding into a common manifold fitted with a raised outlet which controls the water level in the filter. The compartments may be backwashed individually, using the untreated water from the borehole pump. This allows a higher backwash rate to be obtained from the supply pump, which normally will have insufficient capacity to backwash the entire filter in one operation. The filter media comprises a lower layer of 0.3 to 0.5 mm graded filter sand, to a depth 300 mm above the under-drain, and an upper layer of 1.0 to 1.5 mm graded hydro-anthracite.

Field testing and results

Spraystab units have been installed at two separate sites, both treating soft, acidic groundwater. The water at site A contains no iron or manganese, whilst the water at Site B contains 1.55 mg/L dissolved iron. A typical analysis of the raw feed waters is shown in Table 1. Each unit has been operating for approximately two years.

Following the installation and commissioning of the Spraystab units, the units were left to run at retention times of 10 minutes for two weeks; thereafter they were sampled, inspected and backwashed. Flow rate measurements, pH, total alkalinity and calcium determinations were done on site, with further checks on pH, calcium, alkalinity, conductivity and tests for iron and manganese being performed at the laboratory. A number of two day tests were then initiated for a range of retention times.

Typical results obtained during these tests are shown in Figures 3 and 4. The results obtained showed that:

- Where stabilisation only is required (Site A), the Spraystab unit proved to be effective. A limestone “contact time” of 3 minutes (or 2 m^3/h flow rate) was found to be sufficient to reduce the CCDP from about 100 mg/L as $CaCO_3$ to about 5 mg/L as $CaCO_3$, with a concomitant increase in pH from 6.0 to 8.2. Longer retention times gave improved results.
- Where iron removal and stabilisation is required present (Site B), the Spraystab unit gave good iron removal and stabilisation results. At a limestone “contact time” of 5 minutes (1.1 m^3/h flow rate) the CCDP was reduced from about 207 to about 2 mg/L as $CaCO_3$, the pH increasing from 4.7 to 8.2. Dissolved iron content was significantly lowered from 1.55 mg/L to 0.05 mg/L. Longer retention times gave improved results.

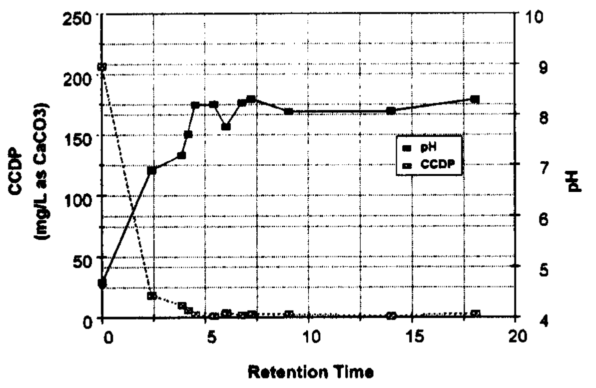

Figure 3. Typical changes in CCDP and pH for Spraystab Unit (Site B)

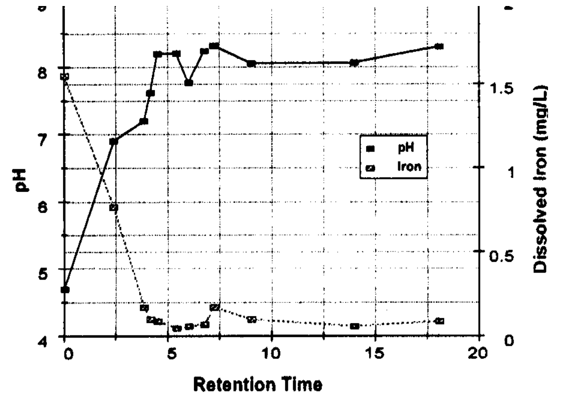

Figure 4. Typical changes in dissolved iron and pH for Spraystab Unit (Site B)

Practical observations

The two prototype units have been in continuous operation for approximately two years. Operator attention and maintenance requirements have remained consistently low. The unit operating on the water containing no iron is serviced once a fortnight. Service requirements are:

- Remove aeration lid, thoroughly spray down limestone bed with flushing hose to dislodge any deposits and fines.
- Backwash the limestone bed for 15 minutes.
- Backwash the filter.
- Top up the limestone bed, and clean flow meter and spray nozzles once a month.

The unit operating on the water containing dissolved iron is serviced once a week. Service requirements are as above.

Conclusions

The following conclusions can be made:

- The Spraystab unit has been shown to be effective at treating soft acidic groundwater, being able to stabilise the water to an acceptable degree with a limestone "contact time" of 3 minutes.
- The Spraystab unit has shown to be effective at treating soft acidic groundwater with dissolved iron levels of about 2 mg/L , requiring a limestone "contact time" of 5 minutes to effect stabilisation and iron removal.
- The Spraystab unit was shown to be inexpensive to build and operate, compact and robust, requiring minimal operator attention and/or maintenance.
- The Bredasdorp limestone (SW-Cape) of particle size -15 mm +12 mm was found to be both practically suitable and effective as a stabilisation media.

Acknowledgement

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