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Practical experiences at 5 slow sand filtration plants in South Africa

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Slow sand filtration (SSF) is an effective physical and biological technology that employs fine sand beds and low filtration rates to treat polluted and contaminated raw water. Its effectiveness lies in the capabilities of the Schmutzdecke (a thin dirty layer formed at the top of the sand bed) to trap suspended solids as water flows through, and to support organisms that kill pathogens. SSF is simple in design and construction and it usually uses locally available labour and materials. The operation and maintenance are simpler than that for high-rate filtration plants. However, in practice SSF do not benefit for the potential advantages. The aim of this paper is to discuss the practical application of experiences of SSF in South Africa. It is based on findings from visits to some SSF plants. These are compared to the theoretical expectations to draw out some learning points.

Introduction

Slow Sand Filtration (SSF) is known to be the first technology to be used for water treatment. It is an appropriate technology for small and rural communities because of its simplicity in design, operation and maintenance. Although it requires substantial land areas, these are usually readily available in rural communities. The construction is usually simple since it utilises local material and labour. The main drawback of the technology is that it is labour intensive in operation. However, this can be an advantage in the rural communities because labour is readily available but this is not prevalent to urban areas

A good evidence of how effective slow sand filtration is to remove contamination was recorded when it was used to combat the outbreak of cholera pandemic where 7500 people succumbed to death in the small town called Hamburg (Germany) in 1889 (Huisman and Wood 1974). River Elbe, from which the Hamburg residents drew their drinking water had initially been exposed to biological contamination which resulted from sanitation surge on the surrounding camps. When slow sand filtration was applied to reduce the contamination, the death rates were also reduced.

SSF is a physical and biological process that employs fine sand beds and low filtration rates to treat polluted and contaminated raw water for community water supply (Holfkes (1988). Its effectiveness lies in the capabilities of the Schmutzdecke (German word meaning dirty layer) formed within the top sand bed to trap suspended solids as water flows through. Biological life that inhabits this layer is believed to kill or inactivate pathogens. However, the practical application of SSF in many cases does not make use of its advantages.

The aim of this paper is to discuss the practical experiences of SSF in South Africa. It is based on visitations made to 5 small/rural towns which employ SSF to produce potable water and literature review. The field experiences were compared to the theoretical expectations and some learning points are drawn. The plants visited are located in the Eastern Cape (2No.) and Western (3No.) Provinces of South Africa.

Methodology

The information reported on each plant was obtained during site visits to the plants and from literature review. The visitations were limited to one day at each plant , except for the Ashton and Tulbagh plants which were visited several times as they are nearer to the location of the authors.

Plant operators were interviewed to obtain information on the operation and maintenance of the plants. Filter dimensions were measured on site.

The discussions of the information collected were made with reference to what is reported in literature and the local and international experiences of the authors.

General overview:

Small and rural communities water treatment technologies in South Africa

In South Africa, water treatment technologies in small communities are generally conventional rapid gravity and pressure sand filtration preceded by coagulation, flocculation and sedimentation as separate unit processes. (Swartz, 2000). Non-conventional schemes such as direct rapid gravity and pressure filtration are also common where low levels of turbidity, colour and algae are found in the raw water. In such cases, the flocculation and sedimentation unit processes are omitted. Coagulation is applied in pipes and the coagulated water is sent straight to the filters without separate flocculation and sedimentation.

Slow sand filtration is applied sparsely and its application is slowly fading away. It is being replaced with the more robust technologies such as pressure filters. Swartz (2000) evaluated 20 small water treatment plants in South Africa and found that only 5 employed slow sand filtration. Conventional unit processes (coagulation, flocculation and circular or horizontal flow sedimentation and upflow sludge blanket clarifier) preceded all these five (5) slow sand filtration plants.

Summary of problems faced by slow sand filtration plants as reported in literature

The problems faced by SSF are the ineffective and unsustainable operation and maintenance of the conventional pre-treatment processes prior to SSF. As a result flocs overflow onto the SSF and clog the sand rapidly. Table 1 Summarises the findings as reported by Swartz (2000)

Most rural and small town communities in South Africa are well supported by central government. The problems reported in Table 1 can be addressed if responsible local authorities are well informed about how water treatment technologies must be maintained. Training needs are enormous in most towns.

Table 1. Status of conventional pre-treatment prior to slow sand filtration at 5 Plants (Swartz (2000))

Plant Name; Location; scheme	Status of Chemical Dosing facilities	Status of Sand filtration Process
Moganya; Northern Province; Hydraulic Coagulation/Flocculation; Up-flow sedimentation ; Slow Sand Filtration; Gas Chlorination	Electrical disruptions; Lime feeder not working ; lack of spare parts for dosing equipment; Lack of chemicals	High filtration rates; Turbidity break-through rapid clogging, hence frequent cleaning; Process by-passed
Boschkloof ; Northern Province; Hydraulic Coagulation/ flocculation; horizontal flow sedimentation; Slow sand filtration; Liquid chlorination	Mixing not effective; Dosing methods not reported	Filtration by-passed due to operational problems
Mosvold hospital Kwa Zulu Natal ; Hydraulic (pipe) Coagulation/flocculation; up-flow sedimentation; Slow sand filtration; Liquid chlorination	Both coagulant and chlorine added by drip method but there is no control over rates	Low sand-bed depth (6cm!) High filtration rate
Frischgewaagd Kwa Zulu Natal Hydraulic Coagulation /flocculation; up-flow sedimentation; Slow sand filtration; Liquid chlorination	No control over dosage (HTH used); Lime dosing out of order; Inadequate coagulation resulting in poor coagulation / flocculation	Low sand-bed depth (1/2 of design value); Poor operation
Caitzdorp Western Cape; Coagulation/ flocculation; circular sedimentation; Slow sand filtration; gas chlorination; lime stabilisation	No control over dosing rate hence inaccurate- under or over dosing common; Gas chlorinators used	Rapid clogging (2 weeks filter run) as poor chemical dosing and floc carry over

Collected information during visitation to the 5 slow sand filtration plants (Dec 2002)

The plants visited were evaluated by inspection of water treatment works and interviewing of plant operators. The main interest was to check whether the filters were designed according to standard practice and that they were running according to standard operation and maintenance requirements. Brief information on each plant is presented in the following sections.

Eastern Cape Province SSF Plants

Seymour SSF

- Treats raw water from dam medium to high turbidity
- Preceded by coagulation/flocculation & sedimentation
- Has sand washing bay, which is not well designed
- When cleaning the filter, Sand is utterly dried before scraping off the dirty layer
- Sand was last replaced in 1996
- No overflow for filter
- Clogging is frequently experienced
- Filtration rates are not known.

Lady Frere SSF

- Treats inland raw water with high turbidity
- Preceded by upflow sludge blanket clarifier
- Filter sand has visibly high clay content and reported to be clogging more frequently (2 weeks)
- As result, SSF are removed and replaced by high rate filters
- Effluent turbidity is < 0.5 NTU respectively
- No provision for overflow system on filters
- Filtration rates are not known
- Being replaced by pressure filters at time of visit

Western Cape Province SSF

Ashton SSF (See Photograph 1)

- Treat surface water (of low to medium turbidity) from river
- Preceded by coagulation/flocculation and sedimentation
- When cleaning the filter, sand is dried before scraping

Figure 1. Slow sand filter in Ashton

Figure 2. Slow sand filter in Tulbagh

the dirty layer and this all takes 2 – 3 weeks

- When commissioning the filter it is not filled by introducing water from below. This is recommended to drive out air between grain particles that otherwise might impair production
- No water quality analysis

Tulgbagh SSF (see Photograph 2)

- Treats mountain water – this is usually of low turbidity but occasionally is high due veldt fires
- No pre-treatment
- The sand is drained a day before scrapping and cleaning process takes 5 days
- Filter run is 3 weeks
- Sand protected by fabric material (woven polypropylene) (see Photograph 3)
- Clogging is more frequently (see Photograph 4)
- There are no guidelines to guide on cleaning procedure because no studies prior to installation.
- No water quality analysis

Figure 3. Negative pressures lifting SSF fabric material in Tulbagh

Swellendum SSF

- Treats coloured (Apparent Colour) mountain water (>300 mg/l - Pt) and low turbidity (<5 NTU)
- Preceded by coagulation/flocculation and sedimentation
- Water quality analysis done on site
- Effluent quality between 1 and 2 NTU
- Cleaned by scraping after complete drying
- Chemical dosing working well
- Has sand washing bay.

Figure 4. Mud trapped by SSF fabric in Tulbagh

The following are the concluding comments on the critical aspects of SSF taking into what was observed.

Filtration rates (vf)

It is depended on the incoming raw water flow therefore the quantity has to be known and controlled by inlet or outlet system to get recommended filtration rates (0.1- 0. 3 m/h).

In all the plants visited, except Swellendum, the quantity of raw water supplied to each SSF is not known because there are no flow measurement devices supplied in the outlet or inlet structure. However the effluent quality (turbidity) is acceptable, less than 1 NTU, which complies with local drinking water guidelines (Swartz, 2000)

Flow control

It can be done either at the inlet or outlet system. In the inlet control system, headloss increase in the sand bed is compensated for by an increase in the depth of water above the sand. In the outlet control system, an outlet valve is gradually opened to compensate for headloss increase. In Ashton, the flow is not controlled because there is no weir to measure quantity of influent.

Overflow

None of the plants evaluated are provided with overflows. When maximum headloss is reached, supernatant water will flow over the filter box. Scum and floating objects are removed by operator using a sieve or they remain on the surface until the filter box is full to overflow or due to be drained for cleaning.

Backfilling System

SSF design has to be provided with clean water system to fill the water from the bottom at the low rate whenever restarting after a cleaning a cycle, to prevent airlock in the filter medium. In all plants visited, none had a backfilling provision.

Maintenance (cleaning of sand/filter, sand washing/ days)

It was found that more of the SSF plants were properly maintained. When scraping off the dirty layer (schumutzdecke), supernatant layer is drained and the sand is often allowed to dry completely. This process in Ashton SSF lasts for 3-4 weeks. Standard practice recommends that cleaning have to be done within 24 hrs to preserve biological life just below the dirty layer and hence ensure speedy maturation of SSF when the plant is restarted. Most of the plants visited removed the dirty layer together with (2-3cm) of sand is simply set aside. It is not washed and stored for re-use. Washing bays are not provided except in Swellendam and Seymour plants.

The Swellendam plant is operated and looked after better than the other plants. It was found the person in charge was qualified.

Water quality monitoring, which is most important, is not done in 4 of the plants visited.

Conclusions

The design, operation and maintenance of SSF in South Africa compared to literature are different. The overflow and backfilling system are omitted. The most important parameter (filtration rate) that maintains efficiency removal is not monitored. Filter cleaning that has to be done within 24 hours is done in several days. All of these factors have an influence in the production rate, water quality and operation and maintenance costs.

It is globally and locally known that SSF is an effective physical and biological treatment technology when operated and maintained properly compared to any other water treatment technology.

In developing countries, it is common to have such kind of problems in rural and small water system. Water treatment plants are poorly managed and not given adequate attention by local authorities. Ignorance and lack of concern for quality and costs many local authorities is the source of such problems. The transfer of knowledge, research and development of skill is scanty. Water quality is not monitored and design issue are poorly addressed. In some cases, operators know what to do but are less conscious and supported. However, central government usually gives overall support but local authorities fail when it comes to implementation.

Recommendations

Usually, many education institutions are well equipped with relevant research and development resources. The degree of innovation and initiation in research is very high. Therefore, it is proposed to local authorities responsible to collaborate with education institutions to address research and development issues in order to promote sustainability. The following measures are recommended:

- Providing operators with adequate training on how to operate and maintain SSF.
- Developing and providing operation and maintain manuals for reference.
- Supporting plants with in-house basic water quality analysis facilities to check filtration performances.
- Providing maintenance infrastructure such as sand washing bays to wash and reuse sand.

References

Huisman L., Wood W.E. (1974) *Slow Sand Filtration*. WHO, Geneva

Holfkes E.H. (1988) *Small Community Water Supplies: Technology of Small Water Supply in Developing Countries*, IRC, The Hague, The Netherlands

Swartz CD. (2000). *Guidelines for the upgrading of small water treatment plants*, Water Research Commission Report No 738/1/00, South Africa

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