Guidelines for the Selection and Use of Various Micro-Irrigation Filters with Regards to Filtering and Backwashing Efficiency

Report to the

Water Research Commission

by

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EXECUTIVE SUMMARY

Introduction

Filtration systems are regarded as the heart of a successful operating micro-irrigation system, because effective filtration will assist to prevent micro-irrigation systems from clogging. When clogging occurs in micro-irrigation systems, it results in ineffective usage of water and the lost of optimum yields. Sufficient maintenance schedules of irrigation systems and the correct choice and management of the filtration system is therefore of utmost importance to ensure optimum performance.

Furthermore, the current design norms are very outdated and not scientifically founded, as only sand filters are for instance prescribed for drip systems. The use of sand filters is, however, unnecessary in some cases, because drip emitters with larger flow-paths (with a lower blockage potential) were manufactured in the last decade. On the other hand, the choice of a disc or screen filter is hampered, because of the various types of discs available that are recommended by manufacturers and each disc has unique backwashing and filtration efficiencies, which are not correctly defined.

Laboratory and field tests, to determine the filtration and backwashing efficiency was therefore required to assist designers and producers in the appropriate selection for a filtration system. With known data, an informed decision can be made regarding the optimum economic choice of a filter, as well as the type of filter that is best suited in areas of stressed water resources with different water qualities.

Through this project, several irrigation filters were evaluated to determine their filtration efficiencies and backwash management efficiencies. The research results were then used to develop guidelines for the choice, management, and maintenance of irrigation filters.

Objectives

The National Water Act of South Africa (Act 36 of 1998) requires effective, economic, and sustainable use of available water by all consumer sectors. To assist the irrigators to utilize their systems effectively, research and testing were carried out on eight different irrigation filters with the following objectives:

- To determine the filtration efficiency and backwashing management of different types of filters under different water quality conditions, as found under different on-farm conditions and irrigation practices as being practised by the producers to operate and maintain their irrigation systems and filter stations.
- To create guidelines for the choice and operation of filters with respect to water quality and maintenance requirements.
- To introduce the results to irrigators by means of field days and circulating articles in this regard.

Methodology

Sand, disc and screen filtration systems that are used in South Africa were identified and their technical data was obtained. Filters from Agriplas, Andrag, Netafim and Terbus were selected as they were the most commonly used filters for micro-irrigation in South Africa. The selection covered about 80% of the filters that are used. Currently, apart from that, an extensive literature study of all the factors that can influence the operation and performance of filters was undertaken. The factors that influenced their operation and performance are water quality, pressure loss, pre-primary filtration, sand selection, irrigation systems, flow-rate, backwashing management, efficiencies and maintenance of filtration systems.

The performance of these filters, eight models in total, was evaluated under controlled conditions in a world class hydraulic laboratory at the ARC-Institute for Agricultural Engineering. The test bench (Illustration 1) is a re-circulating system, consisting mainly of two reservoirs, a pump, pipes, valves, two Dirtiness Index meters, electric pressure and flow sensors and instrumentation that display all the signals and that have two-way communication with the controlling computer.

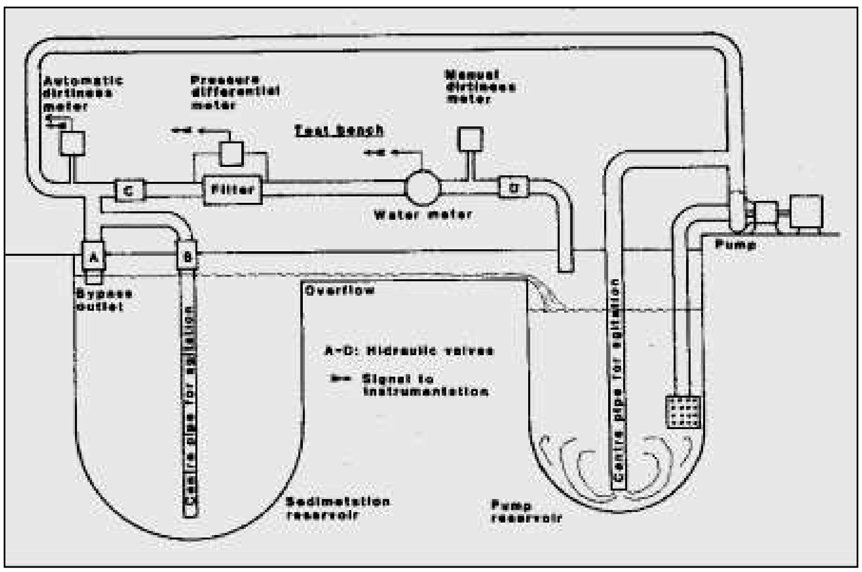

Illustration 1: The irrigation filter test bench

With this test bench, the dirtiness of the water was changed and the following were closely monitored and recorded:

- total volume that was filtered;
- the flow-rate through the filter;
- the pressure differential; and
- the dirtiness index before and after the test.

From these measurements the filtration efficiencies were calculated.

After backwashing the filters, the tests are repeated and the data used to determine the backwash efficiency.

Simultaneously, field evaluations were carried out in five regions around the country where sand, silt, or organic contamination in the water were a problem. The areas were:

- Orange River Valley, Kakamas – sand/silt problems
- Berg River Valley, Paarl – organic problems
- Breede River Valley, Robertson – organic problems
- Sundays River Valley, Kirkwood and Addo – sand/silt problems
- Kouga River Valley, Patensie – organic problems

In each of these areas, three filter stations of the different filter types were selected for testing. At each site, a questionnaire was completed to record the details of the filter station and the filtration management practices. The backwash management test entails the measurement of the different pressures and the flow-rate of backwash water. For the filtration efficiency a unique Dirtiness Index meter was developed by ARC-ILI and used in the test procedure. Water sampling and testing also took place and general observations of the filter station were recorded.

Results

The results of the field evaluations and the laboratory tests gave a new perspective on the performance of filters and required management principles for the different kinds of filters under various water quality situations.

- **Field evaluations**

  Field evaluations were carried out in four seasons over two years on 29 farms in the five regions on six filter models. The dirtiness index (DI) of the water sources in the five regions ranges from clean (DI < 1%) to very dirty (DI = 43%) and the filters managed to clean the water to a DI level of between 0,15% and 10,0%. The filtration efficiency of the filters varied between 31,0% to 96,6%. On average, the filtration efficiencies of the different filters were as follows: sand filters 89%, automatic screen filters 20% and disc filters 52%. In the flow-rate evaluation, the measured flow-rates exceeded the recommended flow-rates in only 5% of the cases (102 measurements). It exceeded it from marginally (3%) to excessive (30%). The impact of the latter, combined with a too high pressure resulted in a low 21,5% filtration efficiency for that specific filter. All the measured operating pressures of the filters were within the recommendations of the manufacturers and with the backwash management testing, the sand filters used an average 1,63 m^3, the disc filters 0,37 m^3 and the screen filters 0,15 m^3 of water per backwash. However, the screen and disc filters backwash more regularly than the sand filters (to filter 1 000 m^3 of water with a DI of 10%, both the screen and sand filter used 28 m^3 of backwash water and the disc filters only 4,4 m^3).

- **Laboratory results**

  Three disc filters, two sand filters and three automatic filters were intensively tested in the ILI Hydrolab over a period of one and a half year. Friction loss, filtration capacity and performance (filtration and backwash efficiency, variability efficiency between filters and impact of different cleaning operations efficiencies) were tested.

  The filtration efficiency of the sand filters were 98,5%, the disc filters 50,5% and the automatic screen filters 55,4%.

  With the backwash efficiency, it was confirmed that a flow-rate of at least 60 $(m^3/h)/m^2$ should be used to obtain a 90 to 100% backwash efficiency with sand filters. The backwash efficiency of the disc filters was a low 33,1% and with the automatic screen filters, a backwash water percentage was determined and only 3,5% of the filtered water was used to clean the filters.

Guidelines

The research resulted in guidelines for the selection and use of filters with respect to water quality and maintenance requirements. The guidelines give specific information regarding to:

- Matching the filter type with the water quality and the irrigation system
- Choice of equipment
- Upstream side of the filter station
- Design principles with respect to:
  - Filtration
  - Backwashing
  - Sizing of a filter
- Commissioning of filters
- Operation of filters
- Maintenance of filters

Capacity building

Capacity building took place in several ways (see Annexure E). Through the study, the research team's knowledge was enhanced tremendously. The industry and producers that participated in the research also benefited through the interaction and transfer of technology. Formal capacity building in the person of M.J. Makgae, a postgraduate student of University of Pretoria, Department of Civil and Biosystems Engineering took place where he did a project write-up of the in-field testing of irrigation filters. He is registered for the degree "Baccalaureus Honoures Institutuonis Agraria".

Technology transfer

During the project term, the following technology transfer took place:

- Delivering of a paper: "A test method for filtering and backwashing efficiencies of micro-irrigation filters" by A.S. van Niekerk at an international workshop on "Improved irrigation technologies and methods: Research, development and testing", Montpellier, France, 18 September 2003.
- Training of Swaziland Sugar Association officials on the operation and maintenance of irrigation filters on 12 October 2004.
- Informal presentations on irrigation filter selection and use to students of University of Pretoria (11 May 2004), officials of Gauteng Department of Agriculture (30 June 2004), engineering officials of the Interdepartmental Provincial Engineering Forum (12 May 2005) and extension officials of Pioneer Seed Company (7 June 2005).

An abstract on the Performance of Filters has been submitted to the organizing committee of the 7th International Micro Irrigation Congress, Malaysia to be held from 10-17 September 2006.

Recommendations

A fast amount of information was generated through this project and the following aspects need further attention:

- The compilation of a user-friendly, self-explanatory manual for the choice, installation, operation, management and maintenance of the different irrigation filters.
- Technology exchange on the choice, operation, management and maintenance of the different irrigation filters.
- The compilation of a code of practice for the total irrigation system approach with norms and standards.

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Dr. A. Sanewe	Water Research Commission (Chairman)
Dr. N.L. Lecler	South African Sugarcane Research Institute
Mr. W.A.P. Pretorius	TSB (Pty) Ltd.
Ms. I. van der Stoep	University of Pretoria
Mr A.T. van Coller	Department of Agriculture
Mr. J.F. Taljaard	JTP cc (Secretary)

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- Senior Management of ARC-Institute for Agricultural Engineering who was supportive throughout the project and ensured that the research team had the full backing of the engineering and administrative services of the Institute.
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- The farmers on whose farms the filter stations were evaluated, who gave their fullest co-operation.

Project team:

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1. INTRODUCTION

The National Water Act of South Africa (Act No. 36 of 1998) requires effective, economic and sustainable use of available water by all consumer sectors. Unfortunately, clogging occurs in micro irrigation systems with resulting water wastage and harvest damages for the producer. These can be attributed to insufficient maintenance schedules in drip irrigation systems and the incorrect choice of filtration system for a specific irrigation system, without taking water quality into consideration. The first problem was dealt with in the WRC project K5/1036/01 (Performance of surface drip irrigation systems under field conditions). The results of the project showed the need for further investigation to determine the most suitable filtration method for water that contains organic matter. Pilot studies also showed that filtration efficiency can range from 20% to 91% and it is imperative to determine the efficiencies of the different types of filters to assist in decision-making. The filtration system is considered the heart of the irrigation system and a faulty filtration system could lead to emitter clogging, resulting in water wastage and crop losses for the producer.

1.1 Motivation

Current design norms are very outdated, as only sand filters are prescribed for drip systems. Drip emitters with larger flow-paths (with a lower blockage potential) were manufactured in the last decade, which may make the use of sand filters unnecessary in some cases. The choice of a disc or screen filter in such cases is hampered because of the different types of discs available that are recommended by manufacturers. According to the manufacturers, each disc has unique backwashing and filtration efficiencies.

There are no scientifically founded norms for the correct choice of filters. Therefore, designers sometimes choose the incorrect type of filter. Filters that have a good backwashing efficiency should be backwashed over a shorter period of time, which can lead to a decrease in water consumption. Laboratory and field tests, to determine the filtration and backwashing efficiency, are required to assist designers and producers in the appropriate selection for a filtration system. In this way, an informed decision can be made regarding the optimum economic choice of a filter, as well as the type of filter that is best suited in areas of stressed water resources.

1.2 Objectives

The project objectives are:

- To determine the filtration efficiency and backwashing management of different types of filters under different water quality conditions, as found under different on-farm conditions and irrigation practices as being practised by the producers to operate and maintain their irrigation systems and filter stations.

- To create guidelines for the choice and operation of filters with respect to water quality and maintenance requirements.
- To introduce the results to irrigators by means of field days and circulating articles in this regard.

1.3 Description of the Project

An extensive literature study of all the factors that can influence the operation and performance of filters was undertaken. The different filters currently used in South Africa were identified after consultation with manufacturers and suppliers of irrigation filters. The necessary technical information regarding the filters was obtained and extensive laboratory tests were conducted. The filters were evaluated in five catchment areas where sand/silt or organic contamination was a problem (Berg River, Breede River, Orange River, Kouga River and Sundays River). In each of these areas, three filter stations of each of the five different filter types were selected. Seven different filters were intensively tested in the laboratory.

2. LITERATURE REVIEW

2.1 Introduction

Physical water treatment was used to remove suspended matter from the water supply prior to the irrigation system. The physical quality of the water was therefore improved by the removal of harmful materials, such as sand, silt, clay and organic materials, where these occured both in quantity and concentration which could result in immediate or gradual clogging of emitters. The degree and type of filtration determined by the type of irrigation system and emitter involved, as well as the physical quality of the water. The emitters of micro irrigation systems are more susceptible to poor water quality than overhead sprinkler irrigation systems. The types of filtration systems that are available are: sand, disc, and screen filters (sometimes called mesh filters).

2.2 Filter Types

The description and operation of the three main types of filters available are discussed in this section. Filtration systems can consist of one or more primary filters of the same type in parallel, as well as secondary filters in series. For example, a sand filter could be used as primary filtration and a disc or screen filter could be used for secondary filtration. This is to protect the irrigation system against failure of the primary filtration system. In addition to sand, disc and screen filters, where sand is a major contaminant in the water, sand separators (hydrocyclones) are used to filter the water. These filtration systems will be described in the sections that follow.

2.2.1 Sand filters

Sand filters are the most useful method of filtration under a wide range of conditions. A sand filter has the ability to remove sand, silt and organic material such as algae, weed seeds, and bacterial slime formations. Individual bacteria can, however, not be removed by sand filters. Since sand filters are not easily plugged by algae, they can remove relatively large amounts of suspended solids before backwashing is required. They can also, however, provide favourable conditions for increased bacterial growth (Nakayama and Bucks, 1986). Sand filters use a bed of sharp-edged sand or crushed granite as a medium to entrap the contaminants in the water (Rain Bird, 1990). Sand grains of various sizes and shape can be selected for use in sand filters. The filtration fineness is usually in the order of 70 to 80 microns, where the fineness is governed by the size and distribution of the sand particles. When the sharp edges of the sand particles become round due to frictional wear, the effectiveness of the filter becomes reduced.

Water passes through the sand, about 0,36 m deep, with a high velocity and solids become lodged in the sand while the water passes through it (Phillips, 1993). The size and shape of a sand filter plays an important role in the filtration efficiency. The most popular type of sand filter is the cylindrical shape ranging in diameters from 0,6 m to 1,2 m (Rain Bird, 1990). The inside of the cylindrical tank contains sand up to a depth between 0,25 m and 0,5 m which acts as the filtration medium. Sand filters are able to handle more contamination than screen filters as particles are trapped to a depth of several centimetres in the sand.

The source water enters a sand filter at the top and passes through the sand exiting the tank through a drain system in the bottom. The clean water then enters the irrigation system under pressure. Inside, at the inlet of the filter, a diffuser plate is installed to spread the incoming water evenly over the sandbed. The main purpose of the drain system is to prevent the sand from entering the drain. The drain system can consist of rosettes or a manifold (Fig. 2.1).

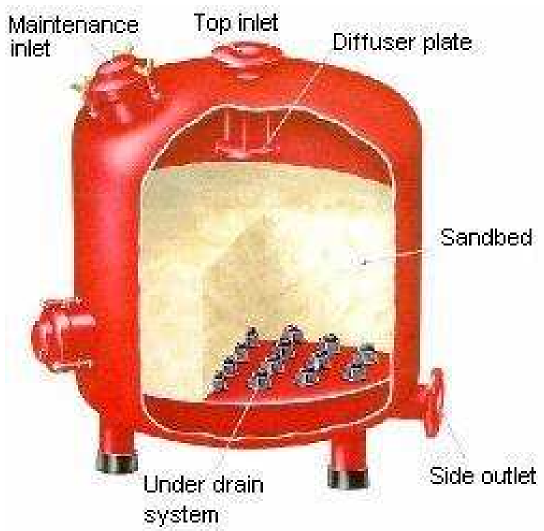


Fig. 2.1: Components of a sand filter (Amiad, 2002)

The range of flow through a sand filter should be from 36 m³ to 72 m³/hour per square metre of sand surface area (Rain Bird, 1990). A general rule for all filters is that the filtration units should be designed/chosen to allow at least a 20% excess capacity when compared to the irrigation system peak demand requirements. This will influence the pump size and will allow sufficient pressure to facilitate backwashing of filters and flushing of lateral lines (Nakayama and Bucks, 1986). Lategan (1999) suggests a flow-rate of 48 m^3/hour per m^2 for sand filters that have 800 μm silica sand as a filtration media. Lategan (1999) states that the filtration efficiency will improve if the flow-rate through the filters is as low as possible. Lowering the filtration flow-rate is acceptable for normal filtration, but it should be remembered that backwashing needs to be performed at the correct flow-rate to ensure that the filter is cleaned sufficiently (Cilliers, 1997).

Cleaning a sand filter involves reversing the flow direction of water in the filter by using at least two filters in parallel. One of the filters operates in the filter mode and provides water, which is used to backwash the other filter. The backwash flow-rate can be controlled by placing a restricting valve at the outlet of the backwash manifold of the filters (Rain Bird, 1990). For efficient backwashing and to prevent channelling through the sand the uniformity and density of a filter under drain assembly has to be sufficient to provide an even distribution of flow from below the sand surface (Bruce, 1985). Tests by the ILI-Hydrolabs have shown that the type of under drain has a significant effect on the backwash efficiency (Table 4.21). Several theories therefore exist as to what the backwash flow-rate should be:

- Burt & Styles (1994): the flow-rate must be adjusted to have just a slight trace of sand exit with the backwash water.
- Rainbird (1990): the flow-rate should be adjusted to ensure that the correct sand scrubbing action takes place and that no sand is lost from the filter.
- Cilliers (1997): the minimum backwashing flow-rate is 50% of the specified filtration flow-rate. The threshold (maximum) backwashing flow-rate is 1,25 times the filtration rate, at 1,5 times the filtration flow-rate, backwashing will cause the sand to lift into suspension and be removed from the filter.
- Van Niekerk (1991): the ILI-Hydrolab norms state that the filtration flow-rate can be between 30 and 50 $(m^3/h)/m^2$ of sand surface of which 30 $(m^3/h)/m^2$ is the recommended norm for dirty water. The backwash flow-rate should be 60 $(m^3/h)/m^2$.

A solenoid valve is used to control the backwash water under pressure and it can be activated by:

- An electrical timer
- A pressure differential switch, which monitors the pressure differential over the filters
- Using both. Each time the pressure differential switch is activated, the timer is reset

The last method will ensure that compaction of the sand bed would not develop. Sufficient pressure for backwashing during irrigation can be provided by reducing the flow-rate into the irrigation system with an automatic pressure-sustaining valve at the downstream side of the filter station (Burt & Styles, 1994). Backwashing of sand filters, as a general rule of thumb, is performed once the pressure difference across the filters has increased between 35 kPa and 70 kPa (Rain Bird, 1990). Eurodrip (1999) suggests a value of up to 100 kPa. Table 2.1 shows the allowable pressure differences over filter stations in accordance with the South African Irrigation Institute's (SABI's) design norms.

Table 2.1: Allowable pressure difference over filter stations (SABI Design Norms)

Type	Clean filter station (kPa)	Maximum pressure build-up (kPa)	Pressure difference before backwashing (kPa)
Disc/screen filter	30	40	70
Sand filter	40	20	60

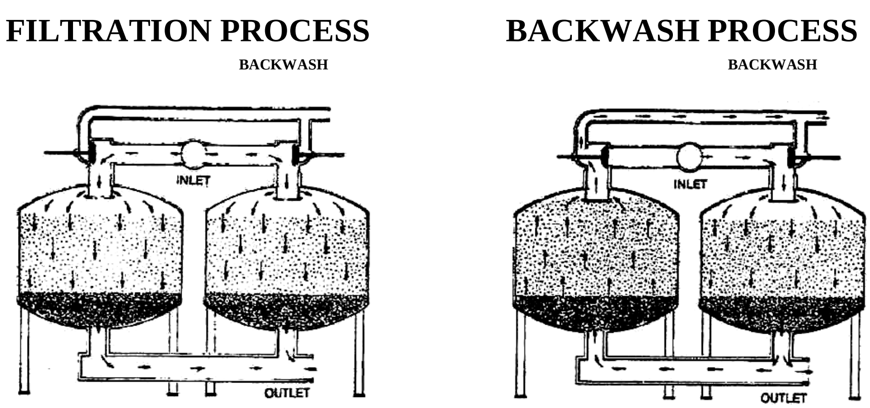
Backwashing duration may vary from less than one minute up to 15 minutes per filter, depending on the quality of the water supply (Rain Bird, 1990). Visual inspection of the backwashing water will show an initial portion of clean water that comes from the volume of water above the sand. The clean water will then be followed by dirty water and the backwashing time will be determined by deciding when the water is sufficiently clean (Cilliers, 1997). Proper backwashing requires a sufficient underdrain design, correct installation and adjustment of the filters, and correct backwashing management frequency, rate and duration (Burt & Styles, 1994).

Cementing together of the sand is as a result of bacteria, water chemistry and certain dissolved gases. The cementing may be caused by all or a combination of these factors. Cemented sand does not get broken up into particles and cleaned during the backwash process. The combination of cemented and free sand in the filter bed results in channels being formed that will allow contaminated water to pass through the filter system into the irrigation system (Rain Bird, 1990). Injecting chlorine before the sand filter will help prevent algae growth and subsequent problems in the sand. A slimy mat may form in the upper layer of sand, which will cause increases of the head loss across the filters and cause a resultant waste of energy (Smith, 1999). Shock treatment of sand filters is done by injecting chlorine to each filter tank, ensuring that the field valve is closed so that no water will leak out. The tanks need to stand for 24 hours and the irrigator needs to beware of breathing in the chlorine fumes. The lids need to then be secured and the field valve opened. A wash cycle needs to be initiated (i.e. system operating as usual), with each filter being backwashed for approximately three minutes. The full sequence (including chlorine application) needs to be repeated several times. One or two shock treatments should be sufficient to unplug an underdrain that is contaminated with organics (Pierce and Mancuso, 1985). Removing the filter sand from the tank and then replacing it, is an alternative to the chlorine shock treatment and is quicker, although the bacteria are not destroyed by using this method.

Sand filters are operated together with secondary disc or screen filters at all times. There are two reasons for this:

- The secondary filter serves as control for the operation of the filter under normal conditions. During incidental tunnelling, the debris will move through the sand bed and will be intercepted by the secondary filter. This condition serves as a warning to the operator that maintenance on the sand filter is inevitable.
- If the sand filter becomes damaged internally, the filtered sand will be intercepted by the secondary filter and will not land in the drippers.

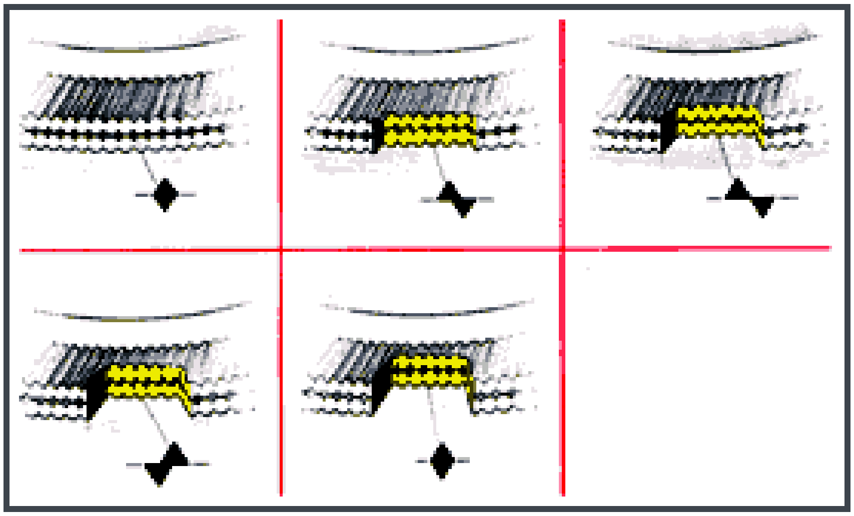
The shape and function of typical sand filters are illustrated in Diag. 2.1.



Diag. 2.1: Filtering and backwashing with sand filters (Burt and Styles, 1994)

2.2.2 Disc filters

Disc filters offer a three-dimensional in-depth filter action and therefore have a much higher filter ability than a screen filter of the same basic dimensions. The filter medium consists of a number of grooved circular plastic discs, which are stacked in a cylindrical form, tightly positioned together. Diag. 2.2 shows the shape of flow-paths between typical discs (Arkal, 2002).



Diag. 2.2: Shape of flow-paths between discs (Arkal, 2002)

The water flows from the outside of the stack of discs and then passes through the flow-paths between the discs. The solids get trapped in these spaces and the cleaner water exits through the middle of the discs. All foreign materials larger than the permeable openings of the relevant grooves, is retained by the discs.

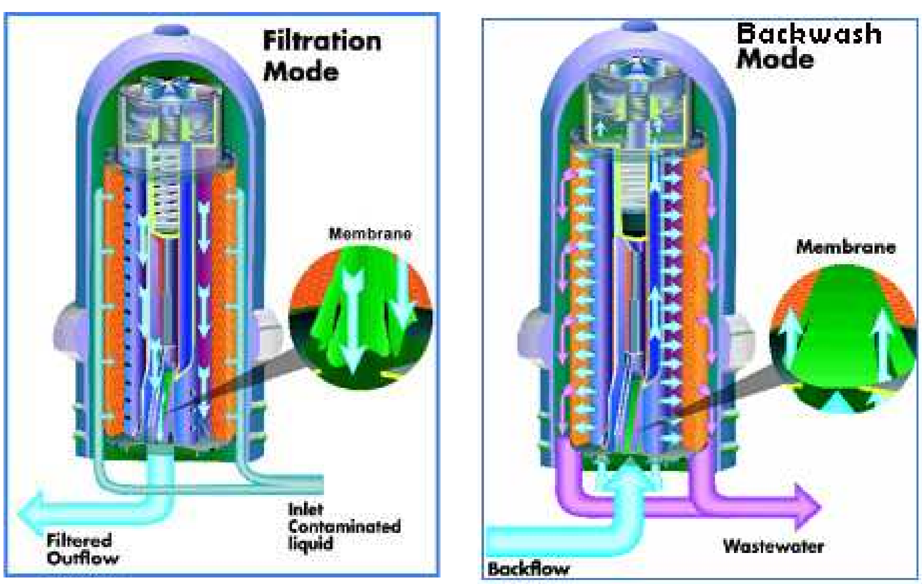


Fig. 2.2: Operating principles of automatic disc filters during the filtration and backwashing mode (Arkal, 2002)

Debris is removed from the discs by backwashing each filter unit with filtered water in an opposite direction through the discs. Automatic filters like the Arkal Spin Klin have the ability to loosen the discs from one another and even to let it rotate during the backwashing action. Activated by a predefined command (differential pressure or time) alternate units of the Spin Klin system go into backwash operation. The inlet valve is shut and the drain is automatically opened. During the backwash process, the compression spring is released. The spine piston rises up, releasing the pressure on the discs. Tangential jets of clean water are pumped at a high pressure direction through nozzles in the centre of the spine. The discs spin free and clear, loosening the trapped solids. Solids are quickly and efficiently flushed out through the drain. Fig. 2.2 illustrates the flow pattern through a typical automatic disc filter.

Any disc/discs that show signs of mechanical damage should be replaced. Discs, of which the channels have become chemically blocked, must be removed and chemically cleaned. If the discs cannot be cleaned effectively, they must be replaced. Always replace discs with the same colour and from the same manufacturer to ensure that the degree of filtering remains the same. It is recommended that the discs are removed from time to time and hand-cleaned.

2.2.3 **Screen filters**

Screen filters have either a nylon or stainless steel screen that provides the filtration surface. The filtering qualities are determined by the size of the screen openings, the total screen area and the ability to clean the screen during regular maintenance operations.

The relationship between mesh and micron sizes can be interpreted with the following equation:

$$M = 10187F^{-0,9327} \tag{2.1}$$

Where: M = mesh size
F = micron size.

Table 2.2: The relationship between micron and mesh sizes (Burt and Styles, 1994)

Micron	300	250	200	130	100	80
mm	0,3	0,25	0,2	0,13	0,1	0,08
Mesh	50	60	75	120	155	200

These filters cannot be backwashed and are more susceptible to damage than sand or disc filters. The filters can clog fairly rapidly and as the pressure drop over the filter increases, solids can be forced through the screen. Screen filters usually have to be cleaned by hand. Some examples of Amiad screen filters are shown in Fig. 2.3. There are screen filters that incorporate a brush that is turned manually to remove solids. An example is the BRUSHAWAY from Amiad filters that is shown in Fig. 2.4. Amiad also have a range of filters called SCANAWAY that clean the screen using suction nozzles that are on the dirty side of the screen. The suction is obtained by opening an exhaust valve that creates low-pressure conditions, sucks in the dirt from the screen and the waste product passes through the exhaust port. The nozzles are moved up and down the screen using either a hand crank or a hydraulic or electric drive mechanism. The cleaning can be carried out during normal operation. These filters can be automated with pressure differential switches.

Fig. 2.3: Examples of Amiad screen filters (Amiad, 2002)

Fig. 2.4: Amiad BRUSHAWAY screen filter (Amiad, 2002)

2.3 Factors Affecting the Operation and Performance of Filters

There are various factors that affect the performance and operation of a filter for irrigation water. These are the source of the irrigation water, the permitted pressure loss, the pre-primary filtration methods, sand selection, the type of irrigation system and emitter, the filtration flow-rate, the backwashing method used, the backwashing and filtration efficiencies of the filters and the maintenance schedule of filters.

2.3.1 **Source of water**

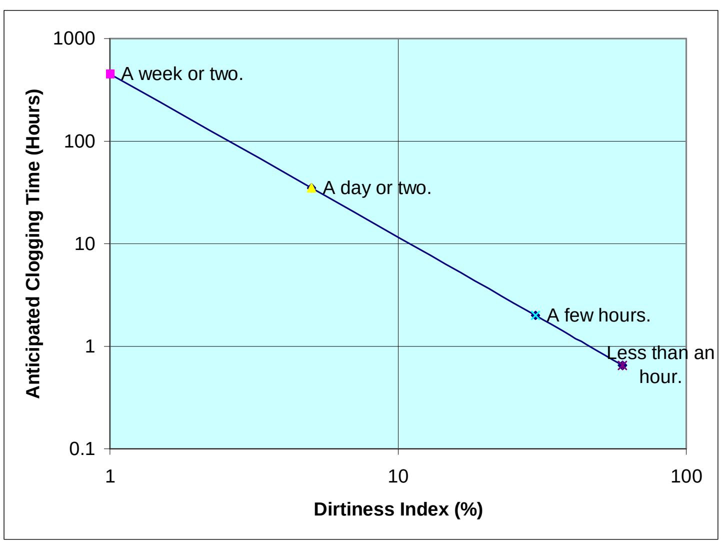
The quality and composition of irrigation water varies both spatially and temporarily. Water that appears to be clean, but contains algae, fish eggs or other microscopic organisms can block a large capacity filter in a short time (Van Niekerk, 1983).

The largest quantity of debris collects on the outside of the element, or on top of the sand bed and very little collects inside the element itself. The thickness of the layer of dirt on the outside of the element, determines the additional pressure difference or what the increase in pressure difference over the filter is. The dirtiness of irrigation water is measured, for filtering purposes, with a special, though simple apparatus, called a Dirtiness Index Meter (Developed by the ARC-Institute for Agricultural Engineering, see: *Measuring the dirtiness of irrigation water for micro irrigation filters* [Van Niekerk, 1995], Appendix D). The Dirtiness Index (DI) is measured and shown as a percentage.

The interpretation of Dirtiness Index is illustrated in Table 2.3:

Table 2.3: Classification of dirtiness index figures for irrigation water (Van Niekerk, 1983)

Dirtiness Index (%)	Classification
< 1	Clean
> 1	Dirty
Approximately 5	Fairly dirty: Clogging of most filters within a day or two.
Approximately 30	Very dirty: Clogging of most filters within a few hours.
Approximately 60	Extremely dirty: Clogging of most filters within less than an hour.



Graphic representation of Table 2.3

2.3.2 **Permitted pressure loss**

During the filtering process, there is an increase in the total pressure drop over the filter as a result of clogging. The allowable increase in pressure loss influences the operation and performance of filters. The pressure loss over a typical filter is illustrated in Fig. 2.5.

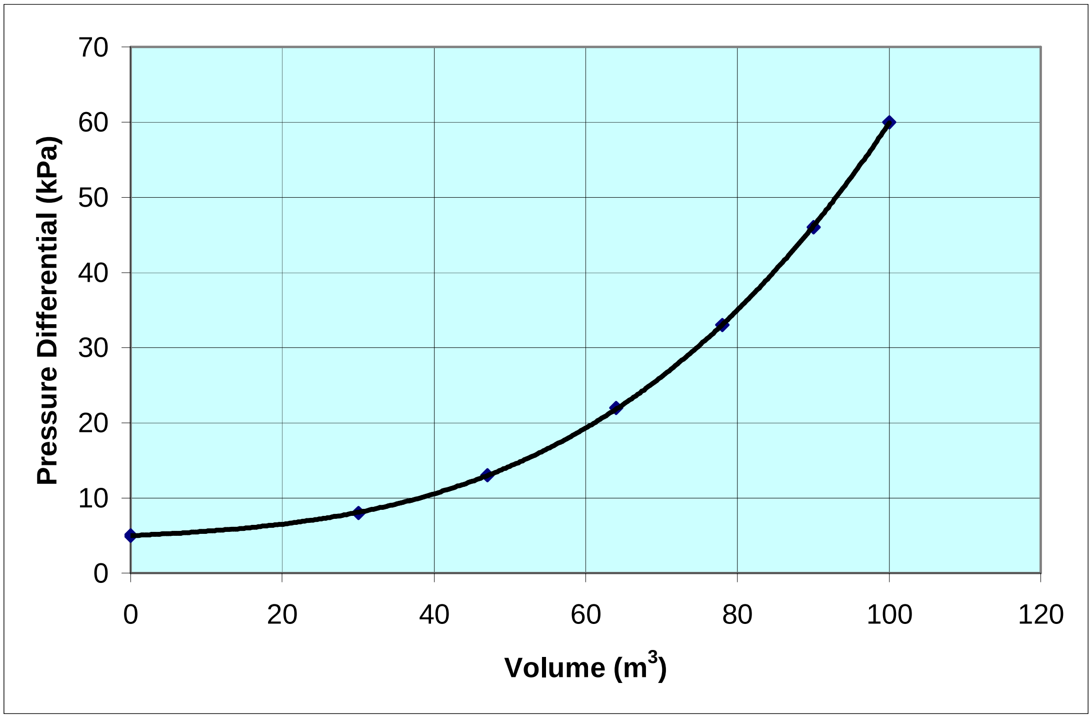


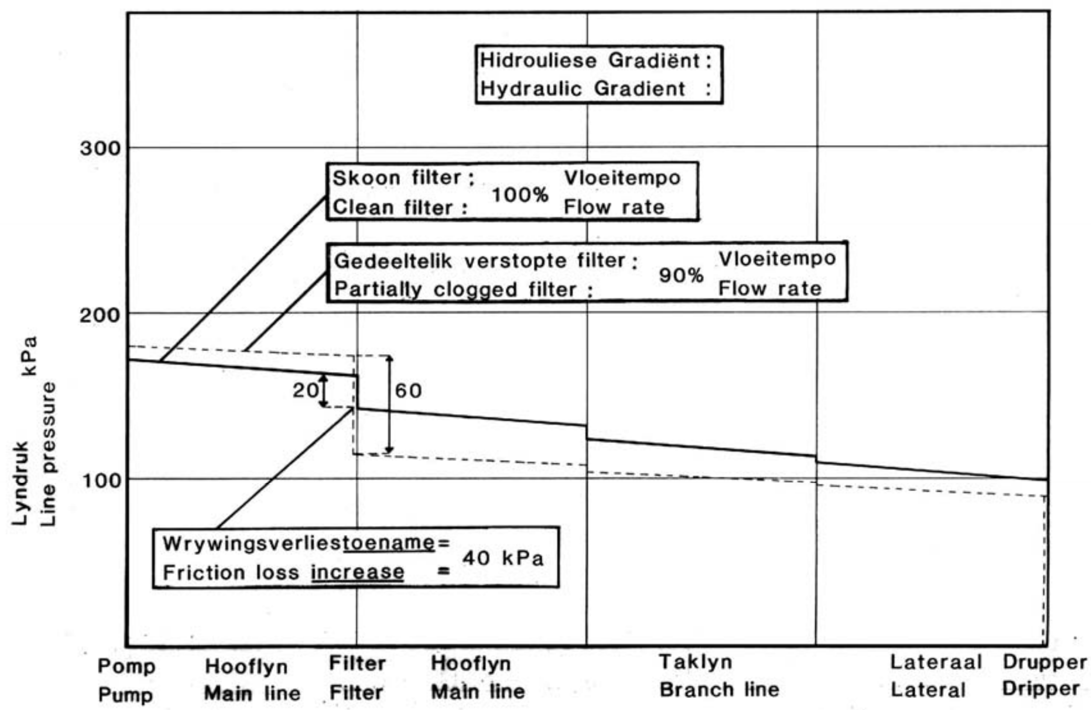
Fig. 2.5: Typical clogging graph of a filter (Van Niekerk, 1983)

According to the results in Fig. 2.5, it is clear that an increase in the permitted pressure differential over a filter results in an increase in capacity (volume of water through the filter) (Van Niekerk, 1983):

- An increase of approximately 15 kPa to 20 kPa can cause tunnelling through sand filters, with resulting dirt penetration into the sand bed.
- With disc and screen filters, excessive pressure drop can cause dirt to be pressed through the medium and can thereby decrease the efficiency.
- In some filters, especially screen filters which filtrate from the outside of the core to the inside, the entire element may collapse if the pressure drop is excessive. In such a case, a large concentration of dirt (that has built up on the element) can be released into the system, resulting in serious clogging of the drippers.
- Elements as well as sand that have lost its function as a result of excessive pressure losses are very difficult to clean and the backwash efficiency decreases drastically.
- The backwash cycle therefore depends entirely on the water quality. Impure water requires shorter backwash cycles, or more and/or larger filters.
- The designs of the under-drains of sand filters will greatly affect the amount of water required for adequate backwashing. In some cases, it can increase the required amount by 300% (Phillips, 1993).

The following guidelines for pressure loss over the filters can be followed (Van Niekerk, 1983):

- For dirty water – a maximum loss of 10 kPa over a clean filter. This loss can be allowed to increase to a maximum of 50 kPa (30 kPa for sand filters) as a result of clogging of the element, but the actual amount that the loss can be allowed to increase with, will be determined by the hydraulics of the irrigation system as illustrated in Diag. 2.3. If the limit of 50 kPa is exceeded, it can lead to the drastic decrease in the efficiency of the filtration.



Diag. 2.3: Permissible friction loss increase over a filter if it is accepted that the discharge of the furthest dripper should not decrease by more than 10% as a result of the clogging of the filter (Van Niekerk, 1989)

- For clean water (borehole water) – a maximum loss of 30 kPa over a clean filter, still with the maximum limit of 50 kPa, as a result of clogging of the element.

2.3.3 Pre-primary filtration methods

The pre-filtration methods of physical water treatment may include all or some of the following (Burt and Styles, 1994):

- **Settling and aeration**

  In cases where irrigation water has more solid matter in suspension than 200 ppm, it is advisable to allow the solid matter to settle in a dam, before it is filtered in the system. If the specific density of this material is very low, it may even be necessary to have it chemically flocculated before settling will be practically possible. Settling can prevent that filters are overloaded and excessively backwashed.

A settling basin provides an area for the mixing action and motion of the incoming water to be slowed down, thereby causing the coarse particles, such as sand and larger sizes of silt, to be removed from suspension (Rain Bird, 1990). Table 2.4 shows the sedimentation speed of different soil particle sizes.

Table 2.4: Settling velocity of soil particles of different sizes (Burt and Styles, 1994)

Soil texture	**Granule size (mm)**	**Settling velocity (m/min)**
Coarse sand	>0,500	38
Medium sand	0,250 – 0,500	22
Fine sand	0,100 – 0,250	5
Very fine sand	0,050 – 0,100	0,9
Silt	0,002 – 0,050	0,015
Clay	<0,002	0,0008

Special treatments can also be used to induce the settling out of some types of clays, chemical components and organic matter. Some of the organic matter may form large accumulations, such as algae and leaves, and will float around on the surface of the basin. These impurities will have to be removed from the surface by using a skimming device. Algae can be effectively controlled by adding copper sulphate in bags equipped with floats, or by broadcasting it over the water surface. Some applications of the design of basins include: the screening of intakes to prevent large debris from entering the two separate basins, to allow the cleaning of one whilst the other basin is used for irrigation; and some basins may even have shaded covers to reduce the growth of algae and prevent any windblown debris from falling into the basin.

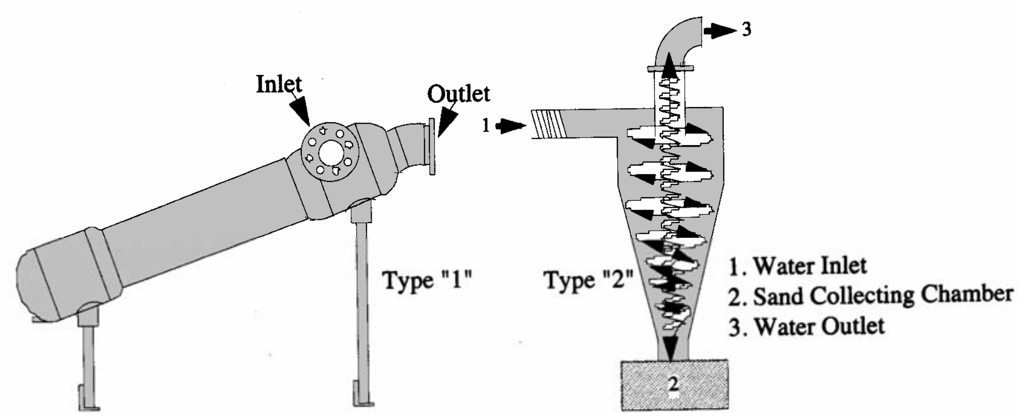
Cleaning of sedimentation basins is achieved by draining the water out and removing the debris from the floor. The frequency of cleaning is determined by the level of sediment in the basin. If the incoming flow is not disturbed by the depth of the basin due to sediment accumulation, then no sedimentation will occur and the basin needs to be cleaned. Further signs that point to a fully loaded basin are outflow water from the basin is noticeably dirty when viewed in a clear container; and the filter station becomes over-loaded and needs backwashing too often and may become clogged.

The suction point depth for the water supply from the basin is another factor that influences the quality of the irrigation water. Generally, water from the basin floor will have a higher level of suspended sediment than water from levels closer to the surface. This depends greatly on the basin shape and inlet point relative to the outlet point. The best shape of the basin is a long and narrow structure with the inlet and outlet points on opposite ends. The length of the basin will affect the settling of suspended solids and the dam should be of a sufficiently length to ensure that solids near the outlet has settled.

❖ **Sand separators**

A sand separator is used to remove sand particles from water. It is usually used to pre-filter irrigation water before primary filtration. Water enters a sand separator tangentially and this causes the water in the body of the separator to rotate. As the water rotates, the solid particles are flung to the outside of the separator by centrifugal forces. Clean water is removed from the centre of the rotational flow using an outlet pipe. The sand particles sink to the bottom of the sand separator where they can be flushed. Sand separators come in different shapes and designs. The operating principles of the sand separator are also shown in Diag. 2.4. Removal efficiencies of at least 95% should be possible with sand separators (Norum, 1999). Although there are advantages associated to installing the sand separator to the suction end of the pump, some features of such an installation must be carefully noted:

- The sand separator can protect the pump by removing sand, which can cause abrasion, from the water.
- Any equipment installed on the suction side of the pump increases the possibility of air intake and the resulting cavitations can eventually cause more damage to the pump than the sand would.
- To be truly effective, most sand separators absorb up to as much as 12 m pressure. If there is not sufficient water pressure on the suction side of the pump for this purpose, cavitations can occur.
- For effective performance of the sand separator, the flow-rate through the system must be kept relatively constant, which is seldom the case.



Diag. 2.4: Two types of sand separators (Burt and Styles, 1994)

In some instances, foot valve screens, screen filters or settling basins are all used in combination to remove some of the load.

2.3.4 **Sand selection**

Modifying the sand used, changing the depth of the filter bed, and altering the flow-rate of the filter can influence the performance of a sand filter. The fineness of the sand as well as the uniformity of the distribution will influence the performance. A filter with fine grade sand with high uniformity will perform better than coarse grade sand with lower uniformity. The mesh equivalent of graded sand is shown in Table 2.5. The factors in selecting the proper sand include (Burt & Styles, 1994):

- The degree of filtration needed, which is determined by the emitter design and anticipated micro-irrigation system maintenance programme.
- How sand type, sand size and the flow-rates per tank combine to provide the necessary degree of filtration.

The depth of the filter bed has an influence on the performance. A bed depth of 360 mm has been found to be the optimum depth. Filters with a depth greater than 360 mm will have a greater filtering ability, but will not be as cost effective as the 360 mm bed. Increasing the velocity of the flow through the bed reduces the filtration quality as more suspended solids pass through the bed because of the shorter contact time (Phillips, 1993).

Table 2.5: Sand grades (Haman, et al. 1994)

Sand designation number	Mean effective sand size (mm)	Filtration quality (mesh)	Filtration quality (microns)
8 – Crushed granite	1,50	100 – 140	150 – 130
11 – Crushed granite	0,78	140 – 200	130 – 80
16 – Crushed silica	0,66	140 – 200	130 – 80
20 – Crushed silica	0,46	200 – 230	80 – 50
30 – Crushed silica	0,34	230 – 400	50 – 40

2.3.5 **Type of irrigation system**

The system type and the degree of dirt in the water to be handled, influence the operation and performance of the filters. As dripper clogging is difficult to perceive and drippers can only be repaired by means of replacement, a higher degree of filtration is required for drip irrigation in general. For drip irrigation with normal stored water or running water, it is normally recommended that sand filters, equipped with secondary filters, are used. Because screen filters can basically not be backwashed, discs filters are usually recommended as secondary filters. In cases where irrigation is done with clean water, such as water from most boreholes, discs filters are usually sufficient. The filtration level will be sufficient enough and the only limitation will be the length of the backwash cycle.

In South Africa, disc/screen filter openings must be $\leq 1/5$ than that of the micro sprayer orifice diameter. The appropriate micro sprayer manufacture's recommendations must be used for flow-path openings of ≤ 1 mm and for drippers (Koegelenberg, et al. 2002). A common rule of the thumb in the USA is to remove all particles larger than 1/10 of the diameter of the smallest passage in drippers.

For micro sprayers, the ratio used is 1/7, if the sprayers have a simple short orifice (Burt & Styles, 1994).

2.3.6 **Filtration flow-rate**

This entails the amount of water to be handled during filtration influences the performance of the filters. The flow-rate through the filter is normally chosen according to a recommended pressure differential of ≤ 10 kPa. For sand filters, a maximum filtration rate is recommended according to the dirtiness of the water and the emitter type. Burt & Styles (1994) suggest the following:

- For average dirty water: 49 m^3/h to 61 m^3/h per m^2 sand surface area
- For extra dirty water: 24 m^3/h to 37 m^3/h per m^2 sand surface area

Minimum values are recommended for drippers while the maximum values are recommended for micro sprayers. Minimum flow-rates are generally accepted if the automatic backwash controller is set to backwash at least once every 24 hours. The low flow-rates provide better filtration than the high flow-rates, but as mentioned previously, the dirt moves further down into the sand bed at low flow-rates and there is no high build-up of pressure differentials because of less compaction at lower pressures.

2.3.7 **Backwashing management frequency, rate and duration**

The backwashing process influences the performance and operation of filters negatively if the following is not done correctly:

- Frequency adjustment. An electrical timer can be used, or a pressure differential switch which monitors the pressure difference over the filters can be installed. The best method is to use the pressure differential switch in combination with a timer.
- Flow-rate adjustment. The backwash flow-rate needs to be set correctly to ensure that none of the filter sand is removed from the filter during backwashing.
- Duration adjustment. The backwash duration must be sufficient to allow complete cleaning of the filter. If the duration is too short or the flow-rate is too low, the clean, filter pressure differential will gradually increase with time (Burt & Styles, 1994).

2.3.8 **Backwashing and filtration efficiencies of filters**

The backwashing efficiency of a filter has major implications on the management of such a filter. If it should be less than 90%, it means that the backwashing cycle will have to be shortened continuously until it becomes impractically short and then the filter will have to be hand-cleaned from time to time. If such an action would not take place in good time, the irrigation system will receive less and less water and its efficiency will get greatly impaired. When the filter gets completely clogged, the system will get no water at all, dirt will be forced through the element, the element can collapse and automatic filters will seize working. It is then extremely difficult to get such an element cleaned again and in most cases, it has to be replaced by a new element or new sand.

Low filtration efficiencies leads to clogging problems in irrigation systems. In such cases, finer elements need to be placed in the filters which can affect the friction losses through them and also reduce their filtration capacities. It is usually then necessary to also increase the number of filters in a filter station in such cases.

2.3.9 Maintenance schedule of filters

Effective filtration of irrigation water is of cardinal importance for the efficient performance of drip irrigation systems. Regular inspection is the key to success, and the maintenance schedule, as shown in Table 2.7, is recommended.

Table 2.6: Maintenance schedule for filters* (Koegelenberg, et al. 2002)

Monitor	With each cycle	Monthly	Annually
Inspect for leakages at filters	✓		
Monitor pressure difference over filters	✓		
Inspect sand level depth (± 360 mm) and add sand if necessary		✓	
Service disc filter		✓	
Monitor duration of backwashing cycle and reset if necessary		✓	
Inspect sand particles and filter elements and replace if necessary			✓
Service backwashing and air valves on filter station			✓
Check hydraulic and electric connections			✓

*If the filter station is automated, the maintenance schedule can be adapted, e.g. the pressure difference over the filters can be verified over a longer period, e.g. weekly.

Where aggressive water occurs, metal parts of the filters must receive epoxy treatment. Lubricants extend the lifespan of synthetic discs in filters where metal and rubber parts are in contact. High viscosity silicon products have proved to be the most suitable product for general usage. Lithium grease, but definitely not oil, is very suitable for valve axles and other moving parts. Pierce and Mancuso (1985) provide a trouble-shooting guide for sand filters which can be seen in Table 2.6.

Table 2.7: Troubleshooting guide for sand filters (after Pierce and Mancuso, 1985)

Probable cause	Solution
PROBLEM: POOR FILTRATION	
Probable cause	**Solution**
1. Excessive flow through filters causing coning and forcing contaminants through filter.	1. Reduce flow-rate or add filters.
2. Air in filters causing disruption of sand bed.	2. Install auto or manual air bleed device.
3. Incorrect sand.	3. Replace with proper sand.
4. Excessive pressure forcing contaminants through filters.	4. Readjust backwash control valve to proper setting.
5. Insufficient sand depth allowing contaminants to pass through.	5. Add sand to achieve depth between 31 cm and 33 cm.
PROBLEM: CONSISTENTLY HIGH PRESSURE DIFFERENTIAL	
Probable cause	**Solution**
1. Filter sealed over with contaminants restricting backwashing flow.	1. Open tanks and remove contaminants from sand surface, close tanks and backwash until filters are clean.
2. Insufficient backwashing flow.	2. Re-adjust backwash flow or partially close field valve.
3. Low filter sand level causing inadequate backwashing.	3. Add sand to correct level.
PROBLEM: SAND APPEARS DOWNSTREAM	
Probable cause	**Solution**
1. Incorrect sand, i.e. too fine.	1. Replace with proper sand.
2. Broken or damaged PVC lateral pipe.	2. Repair or replace pipe.
PROBLEM: BACKWASH VALVES LEAK	
Probable cause	**Solution**
1. Obstruction in valve seat.	1. Remove obstruction.
2. Rubber seating disc worn or damaged.	2. Replace seat disc.
3. Diaphragm damaged (leaking from port of diaphragm chamber at rear of valve).	3. Replace diaphragm.
4. Pinched or worn o-ring.	4. Replace o-ring and lubricate shaft.
PROBLEM: WATER HAMMER	
Probable cause	**Solution**
1. Air in tanks.	1. Bleed off trapped air. Check for leaks in pump suction line.
2. Long vacuum line causing vacuum.	2. Install vacuum breaker on backwash line.
PROBLEM: INCREASING FREQUENCY OF BACKWASH CYCLE	
Probable cause	**Solution**
1. Backwash flow or duration is not adequate to remove all contaminants.	1. Readjust backwash flow and/or increase duration of backwash cycle.
2. Insufficient sand depth.	2. Add sand.
3. Increased concentration of contaminants in water supply (may be seasonal).	3. Add extra filter tanks or reduce flow-rate or increase backwash duration and frequency.
PROBLEM: AUTOMATIC BACKWASH FAILS TO CYCLE	
Probable cause	**Solution**
1. Controller power off, blown fuse or circuit breaker tripped.	1. Turn power on. Ensure wiring is connected. Reset circuit breaker or install new fuse.
2. Improper setting on differential pressure switch.	2. Inspect seal for signs of tampering.
3. Solenoid malfunctioning.	3. Check connections. Clean ports. Check filter screen on water pickup assembly for damage. Clean or replace screen.
4. Loss of sufficient system pressure to actuate valves.	4. Check system for pressure leaks. Check filter screen on water pickup assembly for damage.

2.4 Laboratory Test Results

A literature study did not yield any publications on the infield performance of irrigation filters. Similarly, there were only a few articles that reported the results of laboratory tests. The Agricultural Research Council's Institute for Agricultural Engineering conducted a series of laboratory tests on various filters used for irrigation in 1983 (Van Niekerk, 1983). The performance of the different filters were given in terms of the volume of water that could be filtered for a specific quality of water and a pressure drop of 50 kPa over the filter. The quality of the water was determined using a Dirtiness Index Meter that was developed for this purpose. The head losses versus flow-rate were also determined for the filters.

The Centre for Irrigation Technology (CIT) in Fresno, California, USA has published some results from laboratory tests performed on filters (Norum, 1999). The CIT evaluated screen and disc filters using a graded sample of sand with equal portions of 80 mesh (181 µm) to 100 mesh (142 µm), 100 mesh (142 µm) to 120 mesh (117 µm), etc. particles. The particles were introduced into the supply stream when steady hydraulic conditions were achieved. The sand deposited on the screen or disc and the sand downstream of the filter were collected and dried and re-screened. This method was used to determine the removal efficiency of the rated filter. An example is given for a 150 mesh (92 µm) screen filter and a 150 mesh (92 µm) disc filter. The removal efficiency of the screen filter was 70% whereas the disc filter had a removal efficiency of 95% for particles up to 150 mesh (92 µm) in size. This difference is attributed to the disc filter developing a finer filtering capability because of the trapped solids in gaps between the discs. The removal efficiency of these two filters is shown in Fig. 2.6. If the filter fineness is classified for a removal efficiency of 95%, then the disc filter can claim its rated fineness, whereas the screen filter has a lower than rated fineness of around 110 mesh. Fig. 2.7 shows the removal efficiency of a sand separator at various head losses across the filter. The curve shows that there must be a trade-off between the removal efficiency and the head loss across the sand separator. Thus, the greater the head loss, the greater the energy input and cost thereof (Norum, 1999).

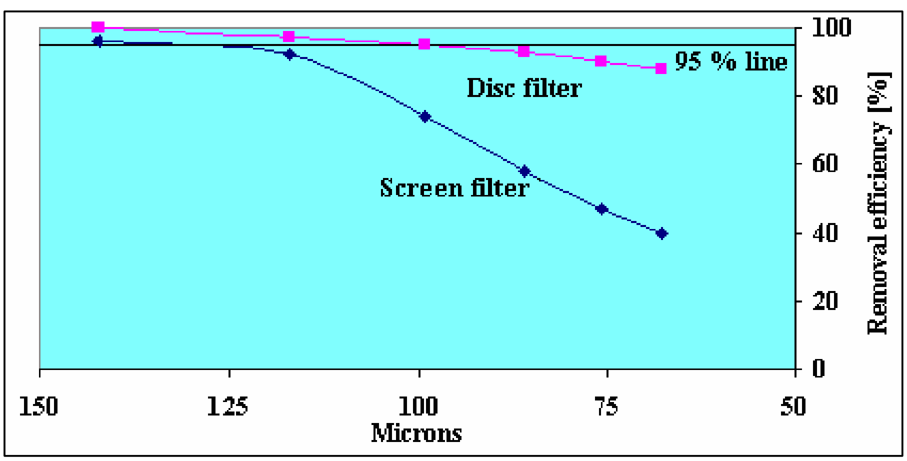


Fig. 2.6: Removal efficiency of a screen and a disc filter (after Norum, 1999)

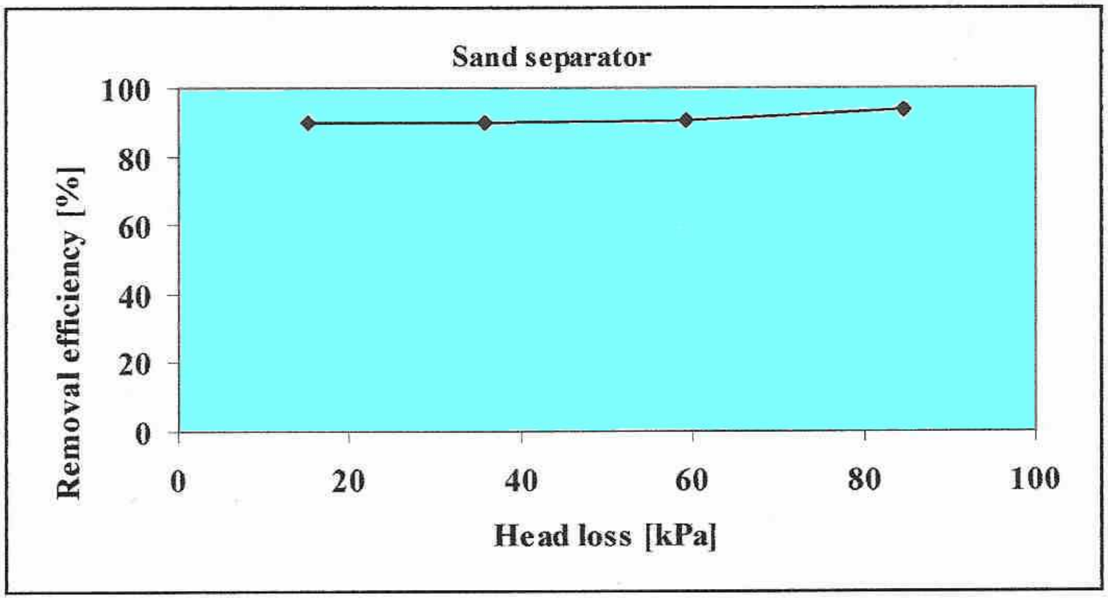


Fig. 2.7: Removal efficiency of a sand separator (after Norum, 1999)

Haman et al. (1994) conducted tests on sand filters with different grades of sands to gauge the filter performance. The maximum particle size removed versus flow per area of sand filter is shown in Fig. 2.8. It can be observed that as the flow-rate per unit area increases, the smallest particle filtered by the specific grade of sand increases in size. It can also be seen that the finer the filter sand (larger grade number), the finer the particle that is filtered.

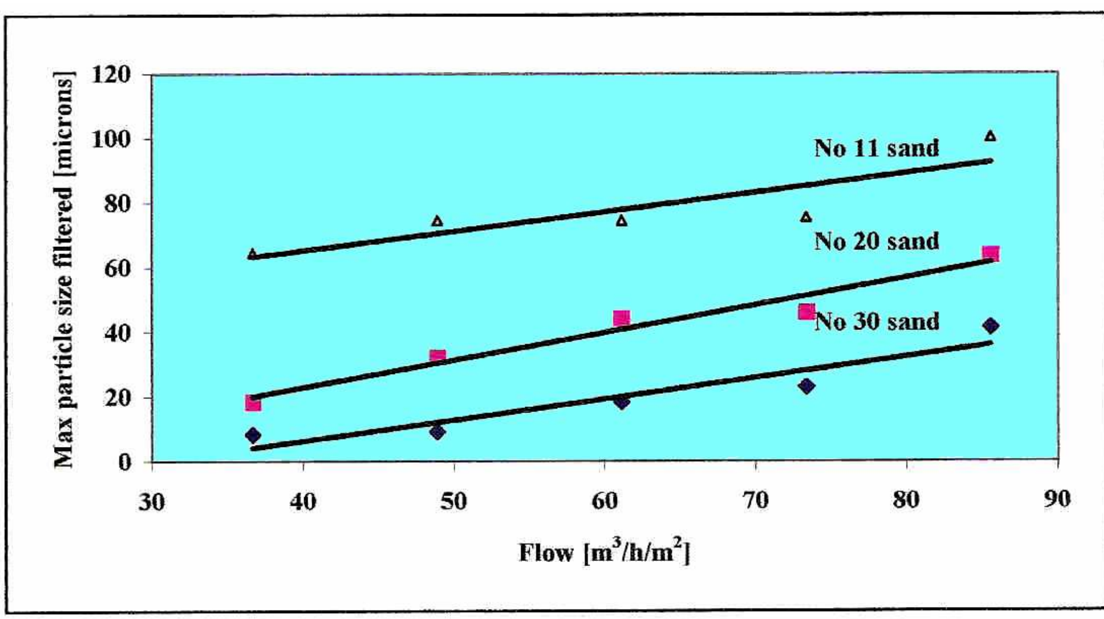


Fig. 2.8: Maximum particle size filtered versus flow per area (after Haman et al. 1994)

Fig. 2.9 (Haman et. al. 1994) shows the head loss versus elapsed time since the last backwash for sand filters with different grades of sand under field conditions. Thus, the coarser the sand, the lower the head loss is across the filter and the longer the backwash intervals can be for a given head loss. These curves were determined for a specific set of filters and water quality conditions and therefore cannot be applied universally (Haman et al. 1994).

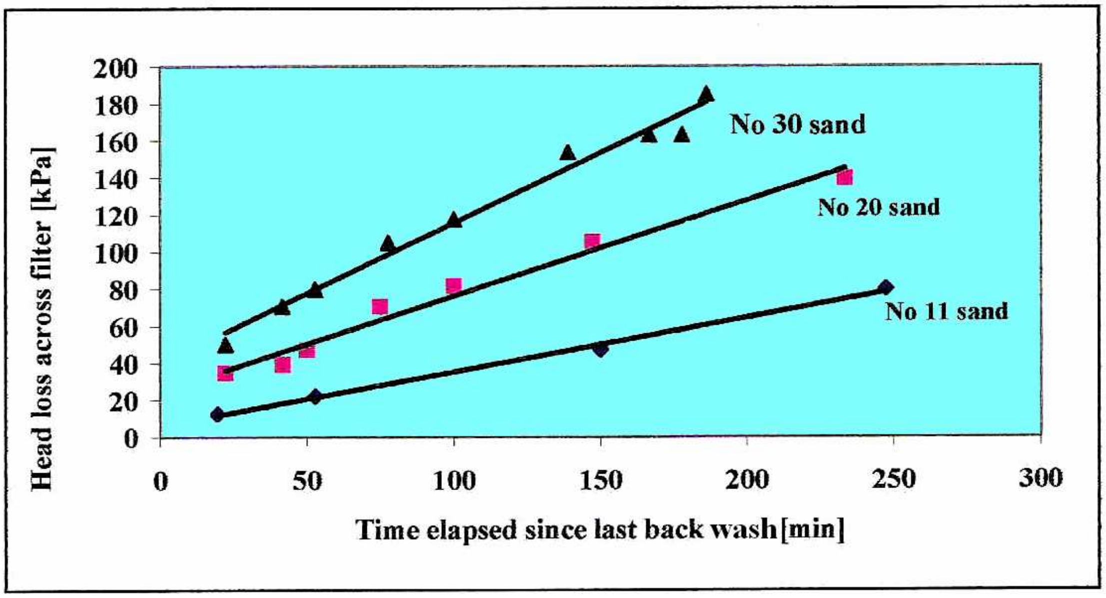


Fig. 2.9: Head losses versus elapsed time since last backwashing (after Haman et al. 1994)

2.5 Conclusion

There are many different types of filters that are best suited for specific applications and water conditions. Although some filters have been tested in the laboratory, there are still questions as to the performance of filters in the field, since a literature study did not yield any sources of such information.

Backwashing of filters is the standard in-field practice to clean irrigation filters. Preliminary studies have shown that the efficiency of backwashing varies for different types of filters. Scientific information regarding the backwashing efficiency is required to manage filtration systems effectively.

3. METHODOLOGY

This chapter describes the methodology that was followed for the evaluation of filter efficiency and backwash management efficiency. The sites at which evaluations took place and the filters that were tested are firstly described. Thereafter, the method used for the field and laboratory tests follows.

3.1 Identification of Filters and Evaluation Sites

After consultation with manufacturers and suppliers of irrigation filters, it was decided to evaluate the following selection of filters (covering about 80% of the market) that are used for the primary treatment of irrigation water. For ease of referring to them in the tables and graphs in the rest of the document, each was given an alphabetical-cum-type-of-filter code:

Table 3.1: Filters and filter codes that are reported on

Code	Type	Name of Filter	Supplier
AS	Sand	Silicon II 41 sand filter (80mm)	Agriplas (Pty) Ltd
BC	Screen	Amiad self-cleaning screen filter (Taf 3) (80mm)	Agriplas (Pty) Ltd
CC	Screen	Amiad self-cleaning screen filter (Saf 3000) (150mm)	Agriplas (Pty) Ltd
DS	Sand	Sandfil 40 / Conn 40 sand (80mm)	Andrag/Agrico (Pty) Ltd / Conns Manufacturing Co (Pty) Ltd
ED	Disc	Arkal Spin Klin® disc filter (Three-Filter unit) (100mm)	Netafim SA
FD	Disc	Arkal 3 disc filter (Arkal 3 Twin) (80mm)	Netafim SA
GD	Disc	Amiad 3 disc filter (80mm)	Agriplas (Pty) Ltd
HD	Disc	Terbus cyclonic disc filter (80mm)	Terbus (Pty) Ltd

The Sandfil 40 and Conn 40 are manufactured by Conns Manufacturing Co and were therefore treated as the same filter. The underdrain construction of the filter consists of slotted plastic piping. The underdrain construction of the Silicon II 41 filter has a number of rosettes mounted on plastic piping. These two types of sand filters were chosen to evaluate the difference between the backwash management efficiency of the different under drain constructions. The different filters were evaluated in five regions around the country where sand/silt or organic contamination was a problem. The areas that were chosen for this study were as follows:

- Orange River Valley, Kakamas – sand/silt problems
- Berg River Valley, Paarl – organic problems
- Breede River Valley, Robertson – organic problems
- Sundays River Valley, Kirkwood and Addo – sand/silt problems
- Kouga River Valley, Patensie – organic problems

In each of these areas, three different filter stations of the filter types that were found in each area were selected. Sufficient numbers of filters in a particular area that were used for primary filtration could not be found for the Amiad 3 disc filter and the Terbus disc filter. Thus, they were not evaluated in the field. In the Sundays and Berg River areas, only two Arkal 3 manual disc filter stations were tested in each area. This was due to a lack of suitable test stations. The areas in which the five different types of filters were tested are shown in Table 3.1 below and there location in South Africa is indicated in Fig. 3.1.

Table 3.2: Location of filter evaluations

Filter type	Sand/Silt problems	Organic problems
Sandfil 40/Conn 40 sand	Orange River Valley	Breede River Valley
Silicon II 41 sand	Orange River Valley	Breede River Valley
Amiad self cleaning screen	Sundays River Valley	Kouga River Valley
Arkal Spin Klin®	Sundays River Valley	Kouga River Valley
Arkal 3 disc	Sundays River Valley	Berg River Valley

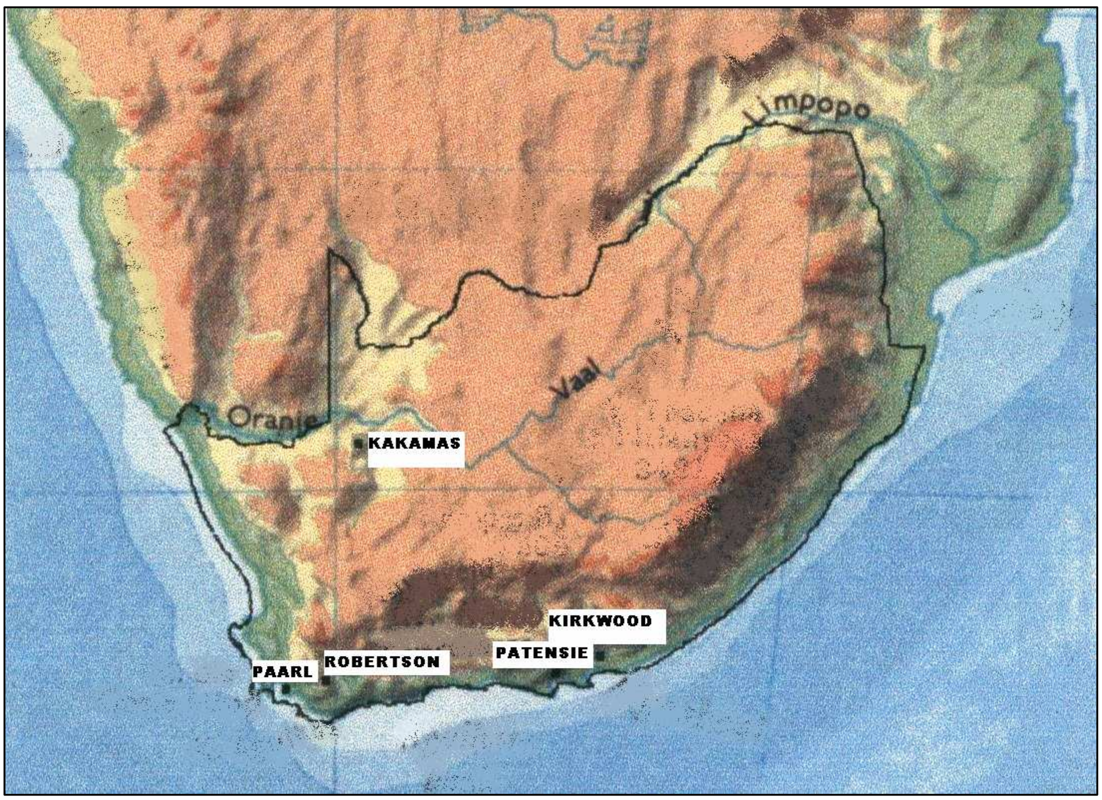


Fig. 3.1: Location of test sites in South Africa

The majority of the filter stations received water from a storage dam that was supplied via the canal system. However, there were some filter stations that pumped water directly out of the canal or river. The set up of each of the filter stations will be discussed in more detail in the results section.

3.2 Field Test Procedures

A questionnaire (Appendix A) was completed at each site in which details of the filter station and the management practises were recorded. The person responsible for the management of the filter station was consulted to obtain this information. The filtration efficiency test and the backwash management test will be described in the following sections. These test procedures were used for all the filter types.

3.2.1 Filter efficiency test

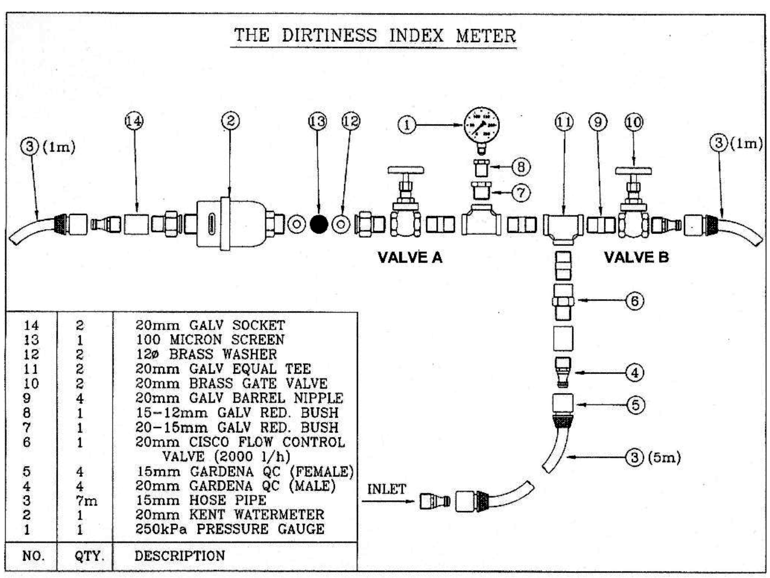
The method for evaluating the removal efficiency of an irrigation filter is described in ASAE EP458 (1997): Field Evaluation of Micro-irrigation Systems in section 3.4.1 of the standard. The removal efficiency(E_r) of a filtration system was calculated from:

$$E_r = 100\left[1 - \frac{TSS_{out}}{TSS_{in}}\right] \tag{3.1}$$

Where: TSS_{out} = the concentration of the total suspended solids at the filter outlet (mg/ℓ)

TSS_{in} = the concentration of the total suspended solids at the filter inlet (mg/ℓ).

According to the standard, water samples are to be collected, before and after the filter, 30 minutes after the start up of the filtration system. The date should be recorded because of the seasonal nature of the water quality. The differential pressure between the inlet and outlet of the filter should be recorded before and after backwashing. Sample and pressure measuring points will be required before and after the filter being evaluated. However, in water that has a high loading of very fine particles (clay, silts and fine organic material); this test can indicate very low or even negative filtration efficiencies (Ravina et al. 1993). For this reason, it was decided to use the Dirtiness Index Meter (DIM) test procedure developed by the ARC-Institute for Agricultural Engineering (Van Niekerk, 1983). The components of the DIM are shown in Diag. 3.1 and the test procedure is as follows:



Diag. 3.1: Components of the Dirtiness Index Meter

Connect a DIM before and a DIM after the filter by making use of whatever available take-off points there are on the manifold (a point can be created by taking off for example a pressure gauge). The fines of the screens (13) used in the DI meters should be the same as the rated fineness of the filter. For each DIM the following procedure is then followed: Valve A is closed at the start of a test. Valve B must be fully open and then being closed slowly until the pressure reading on gauge (1) falls between 110 kPa and 120 kPa. At this point, the reading on the water meter must be noted. Valve A is then opened fully. This will cause the pressure to fall to between 40 kPa and 50 kPa. As the screen becomes more and more clogged, the pressure reading will start to rise again. When it reaches 100 kPa, Valve A is closed fully and the reading on the water meter noted again. The mathematical difference between these two readings gives the volume in litres of the water that has clogged the screen. The screen is then dismantled and examined, and then thoroughly cleaned before the next test.
The dirtiness index (DI) was calculated twice before the filter and twice after the filter. The DI is calculated according to the following equation:

$$\text{DI (\%)} = \frac{\text{Screen Factor (F)}}{\text{Volume through flow} - \text{meter } (\ell)} \tag{3.2}$$

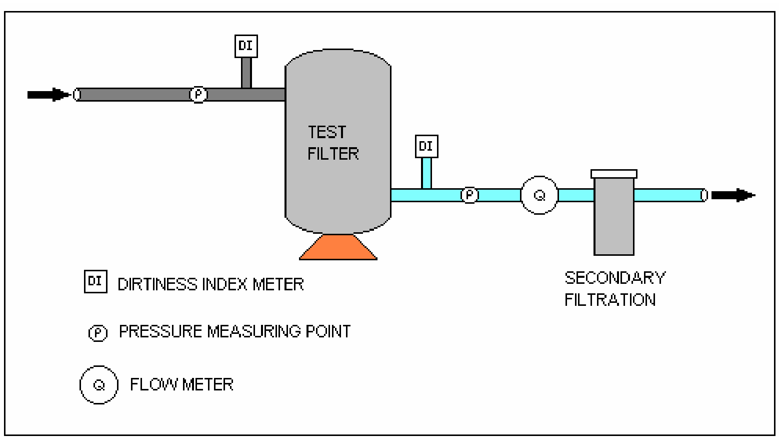
Where: $F = 6{,}32 \times 10^{-3} N^{2.1}$
N = fineness of the screen in microns.

Table 2.3 shows how water can be classified according to the DI method. It also indicates the filter clogging potential of the water.

The results were averaged and used in the following equation to calculate the efficiency of the filter:

$$\text{Filtration Efficiency} = 100\left(1 - \frac{\text{DI after filter}}{\text{DI before filter}}\right)\% \tag{3.3}$$

An example of the set up of a test is shown in Diag. 3.2. A DIM and pressure monitoring point is placed before the filter, and a DIM, pressure measuring point and flow meter are placed after the test filter before any secondary filtration. Water samples were taken before and after the filter and analysed for the TSS using the ASAE standard method so that the results from the different tests could be compared.



Diag. 3.2: Schematic set-up of filter test

The flow-rate through the filter was measured using a clamp-on flow meter. This was done to determine the capacity at which the filter was being used. In order for the meter to operate correctly, the meter required a straight section of pipeline of at least five (preferably ten) times the diameter of the pipe in front of the meter, and at least three (preferably five) times the diameter of the pipe after the meter, to ensure a fully developed turbulent flow profile in the meter. The pressure before and after the filter station was monitored during the DI test to compare the head loss with SABI norms (Koegelenberg, et al. 2002).

3.2.2 Backwash management test

The backwash management cannot be easily determined in the field. Therefore, the following field test was used to evaluate the filters. The filters were first backwashed according to the current practises of the farmer. The head loss over the cleaner filter was recorded. The filters were then backwashed for another cycle and the pressure drop over the filter was recorded. This procedure was repeated until a negligible change in pressure drop was reached.

The flow-rate was measured during the backwashing cycle using the clamp-on flow meter. The backwash pressure was also determined to observe whether it met the manufacturer's requirements. In the case of sand filters, the backwash water was visually inspected for any signs of filter sand.

3.2.3 Water sampling and testing

At each site, three water samples were taken. Two 1-litre samples were taken stream-up of the filter for the total suspended solids (TSS) and for algae characterisation and count. The sample taken for algae analysis was preserved with 1% per volume of tincture of iodine.

The samples for TSS were collected from the bypass outlet of the Dirtiness index meter. The sample taken to determine the algae population was taken from the water source near the pump intake using a 1-litre sample bottle at a depth of 500 mm below the water surface. Bemlab, Somerset West, performed the TSS analyses and the algae samples were analysed by Aquatic Ecosystem Services, Helderberg.

The water at each site was tested for iron and manganese concentrations. The iron was tested using a Hach iron test kit. The manganese was tested using a Visocolor manganese test kit manufactured by Macherey-Nagel. The instructions supplied with the test kits were followed. Both methods utilize a graded colour scale to determine the concentration of iron or manganese in the water.

3.2.4 Other observations

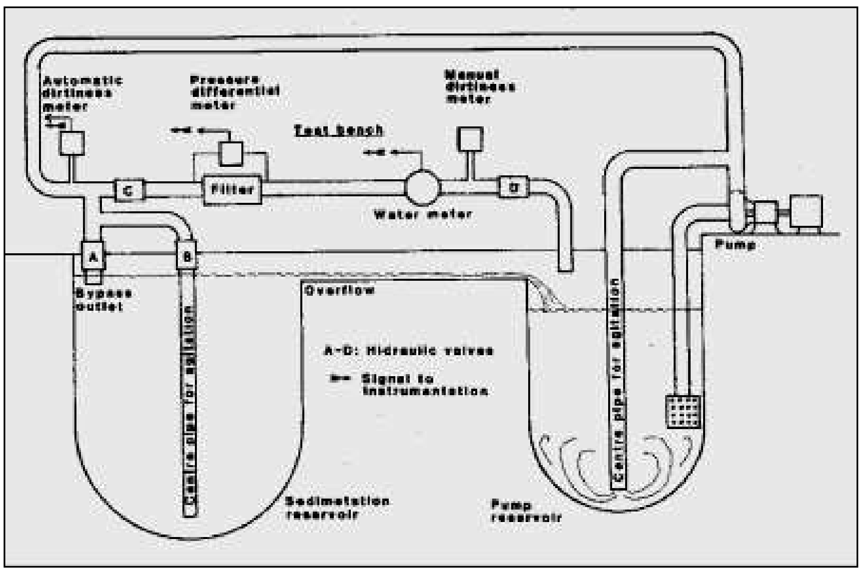
At each site, the filter stations were visually inspected for signs of leaks, for signs of wear of the filter discs or sand, for pressure gauges and backwash control systems. If there were any anomalies at a specific site, these were also noted. The position of the pump suction was noted, as this can have an influence on the performance of the filter station.

3.3 Laboratory Testing

Generally, limited scientific information is available on irrigation filters. To be able to apply filters optimally it is also necessary to have accurately tested information about their performance in practice. The tests that the ILI Hydrolabs perform on irrigation filters are designed to simulate real life situations as close as possible so that the test results can be used directly in practice to make decisions on filters that are based on accurate scientifically proven information. In the Hydrolabs highly accurate electronic measurements are taken on the filters under fully controlled test conditions. The tests are furthermore completely automated and computerised which ensures consistent test results.

3.3.1 The filter test bench

Diag. 3.3 is a simplified diagram of the filter test bench at the ARC-Institute for Agricultural Engineering (ARC-ILI) in Pretoria, South Africa. It is a re-circulating system, consisting mainly of two reservoirs, a pump, pipes, valves, two Dirtiness Index Meters, electronic pressure – and flow sensors.



Diag. 3.3: The irrigation filter test bench of the ILI Hydrolabs (Van Niekerk, 1983)

and instrumentation that display all the signals and that have two-way communication with the controlling computer. Water circulates from the pump to the other side of the test bench. Part of the water circulates back into the pump reservoir through a center pipe, blows onto the floor and keeps the dirt in suspension. On the other side, water is distributed over a large area of the sedimentation reservoir. It moves slowly through the reservoir and the dirt settles out into this reservoir so that clean water returns to the pump reservoir. When the dirtiness of the water in the pump reservoir needs to be increased, the centre pipe in the sedimentation reservoir is activated for a few seconds, blows some dirt into suspension which flows over to the pump reservoir and tops-up the dirt in it. In such a way good control over the dirtiness index of the water in the pump reservoir is achieved. When the desired dirtiness index in the pump reservoir is reached, the water flowing into the sedimentation reservoir is shut off, the valve leading to the filter under test is opened and the filter-clogging test starts.

3.3.2 The filter tests

At first, the dirtiness index of the water in the test bench is lowered to 1% and a friction loss test is done on the filter. Out of this test, the flow-rate that causes a friction loss of 10 kPa is determined. The clogging tests on the filter are going to be done at this flow-rate which in this case is 33 m^3/h as shown in Fig. 3.2.

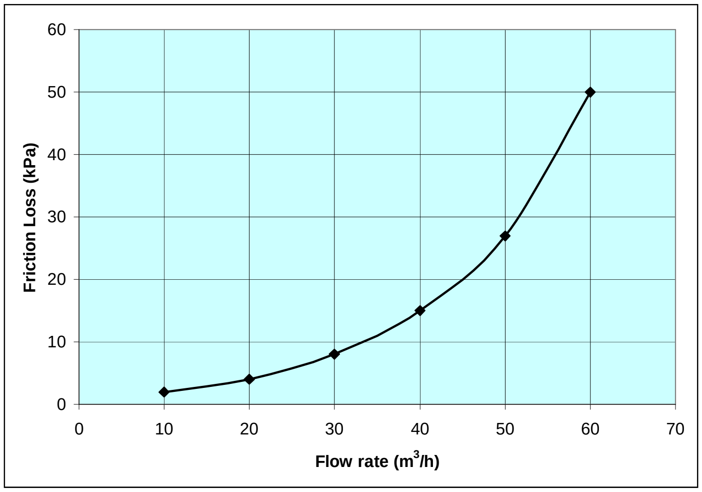


Fig. 3.2: A typical friction loss curve of a filter

Once the clogging test on the filter is initiated, the flow-rate is checked and the pressure difference over the filter is measured and noted. An automatic valve keeps the flow-rate constant for the whole duration of the test. For the rest of the test the computer monitors the Dirtiness Index Meters takes the readings from them and backwashes them after which new readings immediately start again. The dirtiness index of the in-going and out-going water of the filter is measured continuously in this way. These measurements are used to calculate the average filtration efficiency of the filter for each DI setting of the test according to equation 3.3. The readings of the tests of one of the sand filters that were tested are shown in Table 3.3:

Table 3.3: Filtration efficiency measurements on the Silicon ll sand filter

Dirtiness Index (%)	7,1	14,1	27,6	**Average efficiency (%)**
Filtration Efficiency (%)	97	96	98	**97**

The computer also monitors the pressure difference over the filter and at every 5 kPa increase of the pressure difference, the following measurements are noted:

- The total volume of water that was filtered so far since the beginning of the test.
- The flow-rate through the filter at that point in time.
- The pressure difference over the filter.
- The latest dirtiness index measurements before and after the filter. From these measurements, the filtration efficiency of the filter at this point of clogging of the filter is calculated.

This will continue until the total pressure difference over the filter reaches 60 kPa and then the test is terminated and the data stored on the hard disk of the computer. The valve leading to the filter is closed again and the water is circulated again through the sedimentation reservoir. Control of the dirtiness index of the water also stops. It is though important that the pump should keep running to maintain the balance of the test bench until the next test is done.

The Dirtiness Index is measured on a scale of 1 to 100 and can thus be regarded as a percentage of dirtiness of the water compared to the dirtiest condition in nature, which will measure 100, and which will be 100% dirty, like a river in heavy flood. Water in nature is on average 2-3% dirty. Under such conditions, a filter will take more or less one week to clog. With a dirtiness of 15%, it will take about one day to clog; 30% will clog it within one hour or so and 60% will clog it within a few minutes.

For this filter, the clogging tests would be done at ±33 m^3/h for instance. This is also the ILI Hydrolab's recommended working flow-rate for field use of the filter. Five tests are done at different dirtiness indexes, ranging from 2% up to 50% dirtiness of the water, and a graph is drawn of volume water filtered against dirtiness index at a head loss *increase* of 50 kPa over the filter. For these tests, the filter elements are thoroughly hand-cleaned before each clogging test. After these tests, the same tests are repeated, but this time the filters are backwashed and not hand-cleaned.

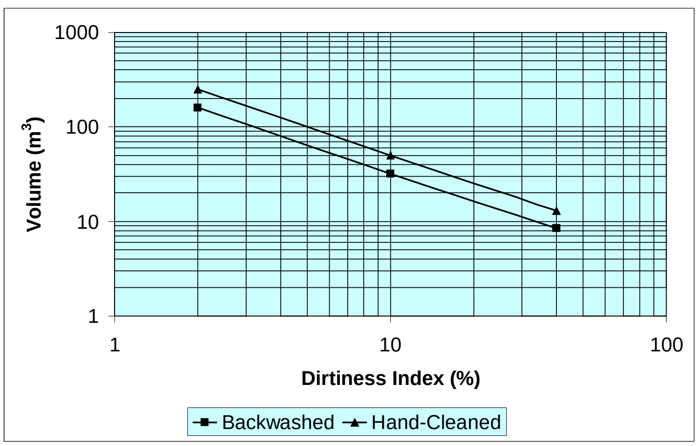


Fig. 3.3: A typical filtration capacity curve of a filter

Usually the results of the two tests do not form perfect straight lines and straight lines have to be fitted on the results like those shown in Fig. 3.3. The volumes that were filtered at the same DI during the two tests (hand cleaning and backwashing) are read from the graph. The volumes are tabled and the backwash efficiencies are calculated according to equation 3.4.

$$\text{Backwash efficiency} = \frac{\text{Volume filtered at } DI_n \text{ with backwashing}}{\text{Volume filtered at } DI_n \text{ by clean filter}} \times 100 \qquad (3.4)$$

Where: DI_n = Dirtiness Index of a specific value.

Table 3.4: Backwash efficiencies for the filter in Fig. 3.3

Dirtiness Index (%)	2	10	40	Average efficiency (%)
Hand-cleaned volume (m^3)	230	50	11	
Backwashed volume (m^3)	150	31	8,5	
Backwash efficiency (%)	65	62	77	**68**

4. RESULTS AND DISCUSSION

The results of the field evaluations and the laboratory tests are presented in this section

Table 4.1: Catchment area codes

Area No.	Catchment
1	Breede River
2	Orange River
3	Kouga River
4	Sundays River
5	Berg River

4.1 Field Evaluation

Each of the sites is referred to by using a code. The code consists of two numbers. The first number refers to the catchment area and the second to the number of the test site in each area. The numbers of the catchment areas are shown in Table 4.1.

A two-letter code is used to refer to the filter that was evaluated. The first letter refers to the filter name and the second letter to the type of filter evaluated for example (S)and, S(C)reen and (D)isc. The filter specifications given by the manufacturers for the filters tested in the field are shown in Table 4.2. The specifications shown are for the primary filters.

Table 4.2: Manufacturer's specifications for filters

Filter code	Maximum flow-rate (m^3/h)	Maximum operating pressure (kPa)	Minimum operating pressure (kPa)	Filtration area (cm^2)	Filtration volume (cm^3)	Minimum backwash pressure (kPa)	Backwash flow-rate (m^3/h)	Recommended backwash time (sec)	Wasted backwash volume (m^3)
AS	41	1 000	100	6 648	332 380	200	50 (max)	180	2
BC	50	800	250	465	NA	200	8 (min)	12	0,026
CC	150	1 000	150	3 000	NA	200	11 (min)	20	0,061
DS	40	1 000	150	7 000	280 000	100	60 (max)	180 – 240	3
ED	30	1 000	NA	1 760	2 640	280	16 (min)	30	0,13
FD	30	1 000	NA	1 900	2 450	250	40 (max)	60	0,67
GD	50	1 000	NA	1 185	NA	NA	NA	NA	NA
HD	50	Not given	NA	2 333	NA	NA	NA	NA	NA

Field tests were carried out on filters AS, BC, CC, DS, ED and FD, while the lab tests were performed on all the filters.

A brief description of the filter stations in the different regions is illustrated in Table 4.3 to 4.7.

Table 4.3: Description of filter stations in the Breede River Valley

Test site	Filter code	Filtration fineness	Number of filters in bank	Water source	Position of extraction point
1.1	DS	Sand – 80 µm	2	Canal to dam	Bottom
1.2	AS	Sand – 80 µm	2	Canal to dam	Bottom*
1.3	DS	Sand – 80 µm	2	River to dam	Bottom
1.4	AS	Sand – 80 µm	2	River to dam	Bottom
1.5	DS	Sand – 80 µm	3	Canal to dam	Float
1.6	AS	Sand – 80 µm	3	River	Bottom

*The extraction point of test site 1.2 was changed from the bottom of the dam to a float off-take point during 2003.

Table 4.4: Description of filter stations in the Orange River Valley

Test site	Filter code	Filtration fineness	Number of filters in bank	Water source	Position of extraction point
2.1	AS	Sand – 80 µm	2	Canal to dam	Bottom
2.2	AS	Sand – 80 µm	2	Canal and settling dam	Float
2.3	DS	Sand – 80 µm	2	River and canal to dam	Bottom
2.4	DS	Sand – 80 µm	4	Canal to dam	Bottom
2.5	DS	Sand – 80 µm	5	Canal to dam	1 m above bottom
2.6	AS	Sand – 80 µm	2	Canal	Bottom

Table 4.5: Description of filter stations in the Kouga River Valley

Test site	Filter code	Filtration fineness	Number of filters in bank	Water source	Position of extraction point
3.1	CC	Screen – 80 µm	1	Canal	NA
3.2	ED	Disc – 130 µm	3	Canal	NA
3.3	ED	Disc – 130 µm	3	Canal	NA
3.4	BC	Screen – 100 µm	1	Canal	NA
3.5	CC	Screen – 100 µm	1	River to dam	Bottom
3.6	ED	Disc – 130 µm	2	Canal	NA

Table 4.6: Description of filter stations in the Sundays River Valley

Test site	Filter code	Filtration fineness	Number of filters in bank	Water source	Position of extraction point
4.1	CC	Screen – 100 µm	1	River to dam	Bottom
4.2	FD	Disc – 200 µm	4	Canal to dam	Bottom
4.3	CC	Screen – 100 µm	1	Canal to dam	Float
4.4	ED	Disc – 130 µm	4	Canal to dam	Bottom
4.5	FD	Disc – 200 µm	4	Canal to dam	1 m above bottom
4.6	CC	Screen – 100 µm	1	Canal to dam	Float
4.7	FD	Disc – 200 µm	4	Canal to dam	Not tested
4.8	ED	Disc – 130 µm	5	Canal to dam	Bottom
4.9	ED	Disc – 130 µm	2	Canal to dam	Float

Table 4.7: Description of filter stations in the Berg River Valley

Test site	Filter code	Filtration fineness	Number of filters in bank	Water source	Position of extraction point
5.1	FD	Disc – 200 µm	4	River to dam	Bottom
5.2	FD	Disc – 130 µm	4	River to dam	Bottom

The results of the field evaluation tests will be discussed in the next section of this report. The reasons for not performing the entire field evaluation, range from farmers not available during the testing period, and the unavailability of irrigation water.

4.1.1 **Filtration efficiency**

The filtration efficiency of the entire filter stations was determined as described in section 3.2.1 of this report. The removal efficiency of some of the sites was also determined. Due to a high loading of very fine particles in the water, negative removal efficiencies were encountered (section 4.1.2). This method was only used during the first evaluation period due to above-mentioned reason.

The dirtiness index method of the Institute for Agricultural Engineering was used to compare the filtration efficiencies of the different filters. The following classification system was used to determine the filtration efficiency:

- ❖ If the cut-off time for the specific screen size was exceeded at the inlet of the filter, the test was terminated (Table 4.8a). The dirtiness index of less than 1% (DI<1) was accepted in this case and thus the water can be classified as clean. In this case, the filtration efficiency cannot be determined.
- ❖ If the pressure gauge of the dirtiness index meter (DIM) at the filter inlet reaches the required pressure <u>quicker</u> than the cut-off time as specified in Table 4.8(a), equation 3.3 was used to determine the filtration efficiency.

Table 4.8(a): Cut-off times at the filter inlet for different screen sizes

Screen sizes (micron)	Cut-off times (min)
60	4
80	7
100	12
130	21
200	52
250	82
300	120

- ❖ In the case of filters with a very high filtration efficiency of 98% or more, it can take up to one full day to get a reading from the dirtiness index meter after the filter, which makes it impractical to try to get the exact reading of the filtration efficiency in practice. It was therefore decided to take a filtration efficiency of 90% as the time-out point in such instances. Table 4.8(b) shows the time-out times (indicated by TO in Tables 4.9 to 4.13) at filter outlet for different DI values before the filter for a 90% filtration efficiency. Appendix C shows a more detailed table for time-out times for different filtration efficiencies and different dirtiness indexes.
- ❖ If the pressure gauge of the DIM at the filter outlet reaches the required pressure almost as quickly as the DIM before the filter, it can be assumed that there is a problem with the filter performance. In these cases, a small or negative filtration efficiency value was obtained.

Table 4.8(b): Time-out times (min) at filter outlet for different DI before filter for a 90% filtration efficiency

DI before filter (%)	2	5	10	15	20	25	30
Screen sizes (micron)							
60	20,6	8,2	4,1	2,7	2,1	1,6	1,4
80	32,8	13,1	6,6	4,4	3,3	2,6	2,2
100	60,0	24,0	12,0	8,0	6,0	4,8	4,0
130	104,3	41,7	20,9	13,9	10,4	8,3	7,0
200	257,7	103,1	51,5	34,4	25,8	20,6	17,2
250	411,7	164,7	82,3	54,9	41,2	32,9	27,4
300	600,0	240,0	120,0	80,0	60,0	48,0	40,0

In Tables 4.9 through 4.13 that follow, the average dirtiness index of the water before and after the filter, as well as the filtration efficiency of the filters for the different regions, are shown. It will be seen that in a number of places in the the tables the words: **Not measured**, are displayed. The reasons why the filtration efficiencies could mostly not be measured are mainly: insufficient measuring points, faulty backwash valves and problems with the screen/washer combination of the dirtiness index meter, which could happen if these were not properly tightened, or if they were wrongly assembled.

The Breede River filter efficiencies are shown in Table 4.9

Table 4.9: Summary of the filtration efficiency results for the Breede River Valley evaluations

Region	Test site	Filter code	Filtration fineness (microns)	10/2002			04/2003			10/2003			04/2004		
				DI before filter (%)	DI after filter (%)	Filtration efficiency (%)	DI before filter (%)	DI after filter (%)	Filtration efficiency (%)	DI before filter (%)	DI after filter (%)	Filtration efficiency (%)	DI before filter (%)	DI after filter (%)	Filtration efficiency (%)
Breede	1.1	DS	80	1,7	TO	>90	1,9	TO	>90	2,8	TO	>90	37,5	TO	>90
	1.2	AS	80	9,6	TO	>90	5,1	1,6	68,2	1,6	TO	>90	4,8	TO	>90
	1.3	DS	80	27,3	3,0	89,0	DI<1			DI<1			43,2	1,5	96,6
	1.4	AS	80	18,4	TO	>90	DI<1			4,2	1,3	68,8	DI<1		
	1.5	DS	80	DI<1			DI<1			1,1	TO	>90	3,5	TO	>90
	1.6	AS	80	10,3	TO	>90	DI<1			5,6	TO	>90	25,5	TO	>90

The results show the following:

The dirtiness index in front of all the filters during the evaluation periods ranged from clean (DI < 1%) to 43,2% (very dirty), for example the dirtiness index of the water in front of the filter of test site 1.1 ranged from 1,7% to 37,5%. The dirtiness index of the filtered water showed an improvement and ranged from 1,3% to 3%. The filtration efficiencies for the filters tested ranged from 68,2% to 96,6%.

- October 2002. All the filters had a high filtration efficiency.
- April 2003. The water during this period was too clean to determine the filtration efficiency in most cases. The reason for the low filtration efficiency of test site 1.2 was due to the clogging of the backwash valve pilot tubes.
- October 2003. The reason for the low filtration efficiency of test site 1.4 was the very high pressure drop of between 40 kPa (after backwash) and 102 kPa (before backwash) over the filter, which was well above the maximum of 30 kPa which is recommended for sand filters. The high clean pressure drop was a result of the high flow-rate through the filter at the time of the test (32,5 m^3/h [84 $(m^3/h)/m^2$] in stead of 20 m^3/h [51 $(m^3/h)/m^2$]which is recommended for that specific filter).
- April 2004. All the filters had a high filtration efficiency.

Similar results were obtained for the Orange River Valley. A summary of the evaluations conducted in this area are shown in Table 4.10.

Table 4.10: Summary of the filtration efficiency results for the Orange River Valley evaluations

Region	Test site	Filter code	Filtration fineness (microns)	10/2002			04/2003			10/2003			04/2004		
				DI before filter (%)	DI after filter (%)	Filtration efficiency (%)	DI before filter (%)	DI after filter (%)	Filtration efficiency (%)	DI before filter (%)	DI after filter (%)	Filtration efficiency (%)	DI before filter (%)	DI after filter (%)	Filtration efficiency (%)
Orange	2.1	AS	80	12,3	TO	>90	DI<1			4,0	TO	>90	DI<1		
	2.2	AS	80	3,0	TO	>90	15,1	2,9	80,5	**Not measured**			DI<1		
	2.3	DS	80	31,3	1.1	96,6	DI<1			1,9	0,15	92,1	DI<1		
	2.4	DS	80	11,6	TO	>90	DI<1			1,6	TO	>90	**Not measured**		
	2.5	DS	80	5,5	TO	>90	**Not measured**			5,4	TO	>90	DI<1		
	2.6	AS	80	12,3	TO	>90	2,3	TO	>90	6,5	1,1	83,1	2,4	TO	>90

The results show the following:

The water quality before the filter illustrated a large difference between evaluation sites, for example the dirtiness index of the unfiltered water for the October 2002 evaluation period ranged from 3% to 31.3%. Thus, the filtration efficiency of all the test sites is very satisfactory with a minimum filtration efficiency of 80%.

- October 2002. The filtration efficiency of all the test sites was ≥ 90% and proved that sand filters have high filtration efficiency.
- April 2003. The relative low filtration efficiency for sand filters of site 2.2 could be attributed to problems with the sand replacement frequency and extremely high pressure drop over the filter station after backwash (120 kPa).
- October 2003. The filtration efficiency of most of the test sites was ≥ 90% and this proved that sand filters had a high filtration efficiency.
- April 2004. The water during this period was too clean to determine the filtration efficiency in most cases.

Table 4.11 shows the dirtiness index before and after the filter, and the filtration efficiencies of the different filters evaluated in the Kouga River region.

Table 4.11: Summary of the filtration efficiency results for the Kouga River Valley evaluations

Region	Test site	Filter code	Filtration fineness (microns)	10/2002			04/2003			10/2003			04/2004		
				DI before filter (%)	DI after filter (%)	Filtration efficiency (%)	DI before filter (%)	DI after filter (%)	Filtration efficiency (%)	DI before filter (%)	DI after filter (%)	Filtration efficiency (%)	DI before filter (%)	DI after filter (%)	Filtration efficiency (%)
Kouga	3.1	CC	80	3,3	1,4	56,5	DI<1			4,3	1,4	67,4	DI<1		
	3.2	ED	130	4,6	0,75	83,7	DI<1			16,6	3,6	78,3	**Not measured**		
	3.3	ED	130	DI<1			DI<1			5,7	3,1	45,6	DI<1		
	3.4	BC	100	2,0	1,4	31,3	DI<1			4,6	3,0	34,8	**Not measured**		
	3.5	CC	100	DI<1			4,4	0,40	90,9	**Not measured**			10,9	2,2	79,7
	3.6	ED	130	DI<1			DI<1			DI<1			DI<1		

The results show the following:

Table 4.11 illustrates that the filtration efficiencies of the filters varied from 31% to > 90%. The dirtiness index of the incoming water varied and ranged from clean (DI<1%) to 16,6%.

- ❖ October 2002. The BC filter at site 3.4 exhibited a poor performance. The filter was opened to inspect for damage to the screen. It was found that the original screen had been replaced after it had been perforated. The replacement screen did not have the same weave pattern as the original. Also the screen gap appeared to be greater than that of the original 100 µm. Another possible reason for the poor filtration efficiency of the screen filters (test sites 3.1 and 3.4) could be that under high-pressure differentials, the organic material in the water is forced through the coarser screen. There was wear on the moving parts of the BC filter which lead to insufficient suction of dirt from the screen.
- ❖ April 2003. The water during this period was too clean in most cases to determine the dirtiness index of the incoming water.
- ❖ October 2003. The screen and disc filters showed lower filtration efficiencies than the sand filters (> 90%). This trend also occurred in the laboratory tests. The reason mentioned under October 2002 for the poor filtration efficiency of the screen filters would also be relevant in this case.
- ❖ April 2004. The water during this period was in most cases too clean to determine the dirtiness index of the incoming water.

The summary of results for the Sundays River Valley is shown in Table 4.12. The results of site 4.7 are not shown, as a test could not be completed at this location for the following reasons:

There was no shut-off valve on the mainline to enable the connection of dirtiness index meters or the inspection of the discs in the filter. Consequently, the discs in this filter station were never cleaned by hand. There was no drainage available in the pump-house to allow the drainage of water. As a result, the filter station was soon flooded to the level of the pumps. The test was discontinued on the upstream side as a result of this flooding. The prescribed straight section of pipeline was not available on which to connect the flow meter to determine the flow-rate through the filter station. Another FD manual disc site could not be found, as site 4.7 was the last FD manual disc site that was found during the visit earlier in the year. Also, the FD manual disc is mainly found in older filter stations, as it is not commonly used for primary filtration any longer.

Table 4.12: Summary of the filtration efficiency results for the Sundays River Valley evaluations

Region	Test site	Filter code	Filtration fineness (microns)	10/2002			04/2003			10/2003			04/2004		
				DI before filter (%)	DI after filter (%)	Filtration efficiency (%)	DI before filter (%)	DI after filter (%)	Filtration efficiency (%)	DI before filter (%)	DI after filter (%)	Filtration efficiency (%)	DI before filter (%)	DI after filter (%)	Filtration efficiency (%)
Sundays	4.1	CC	100	2,2	0,30	86,2	5,8	0,56	90,7	**Not measured**			9,0	1,23	86,4
	4.2	FD	200	1,2	0,93	22,5	3,8	3,1	18,3	13,4	10,0	25,4	1,2	0,96	20,1
	4.3	CC	100	6,7	0,60	91,0	10,6	1,0	90,2	5,1	0,81	84,1	DI<1		
	4.4	ED	130	42,4	3,1	92,7	15,2	1,9	87,7	**Not measured**			7,0	0,94	86,7
	4.5	FD	200	DI<1			5,2	3,88	26,0	6,6	5,4	17,7	DI<1		
	4.6	CC	100	DI<1			DI<1			DI<1			DI<1		
	4.7	FD	200	**Test site unsuitable for tests**											
	4.8	ED	130	3,39	0,71	79,0	4,8	1,7	63,6	**Not measured**			1,38	0,69	50,3
	4.9	ED	130	1,3	0,33	74,9	DI<1			**Not measured**			4,3	0,51	88,0

The results showed the following:

The dirtiness index of the incoming water ranged from very clean (DI<1%) to very dirty (42,4%). This showed that there was a large variation in the quality of the irrigation water before filtration. The dirtiness index of the filtered water ranged from a 0,3% to 10%.

- October 2002. The filtration efficiency of most of the filter test sites was ≥ 80%. The low filtration efficiency value of test site 4.2 could be attributed to the high flow-rate through the filter and the high-pressure drop over the clean filter station after backwashing.
- April 2003. The relatively low filtration efficiency of test site 4.2, 4.5 and 4.8 could be attributed to a combination of factors, for example, the high flow-rate through the filter and the high-pressure drop over the clean filter station after backwashing.
- October 2003. The low filter efficiencies of sites 4.2 and 4.5 were due to design and management problems, for example, a high pressure drop over the clean filter station after backwashing.
- April 2004. The relatively low filtration efficiency of test site 4.2 and 4.8 could be attributed to management problems, for example, the high flow-rate through the filter and the high-pressure drop over the clean filter station after backwashing.

Table 4.13 shows a summary of the results obtained for the two stations under investigation in the Berg River Valley. A third and fourth filter station were identified but could not be tested. This was due to the pressure at one of the stations being too high for the testing equipment to function and the second station was discontinued one week before testing was due to start. No other suitable stations could be found in this area.

Table 4.13: Summary of the filtration efficiency results for the Berg River Valley evaluations

Region	Test site	Filter code	Filtration fineness (microns)	10/2002			04/2003			10/2003			04/2004		
				DI before filter (%)	DI after filter (%)	Filtration efficiency (%)	DI before filter (%)	DI after filter (%)	Filtration efficiency (%)	DI before filter (%)	DI after filter (%)	Filtration efficiency (%)	DI before filter (%)	DI after filter (%)	Filtration efficiency (%)
Berg	5.1	FD	200	5,1	2,7	47,7	DI<1			**Not measured**			DI<1		
	5.2	FD	130	2,6	1,9	29,7	5,7	2,2	61,7	2,2	1,4	39,0	**Not measured**		

The results showed the following:

The filtration efficiency of site 5.2 for the first three evaluation periods was very low. It varied between 29,7% and 61,7%. During October 2002 the discs were covered in silt and had foreign objects between the discs that were creating a larger flow-path than the rated 130 microns. This is shown in Fig. 4.1. A faulty backwash control system and non-operational solenoids were responsible for the state of the filter discs at the time of the test. The relatively low filtration efficiency of test site 5.1 of 47,7% during February 2002 could be due to management problems.

Fig. 4.1: Dirt build-up on discs and foreign objects between discs at site 5.2

4.1.2 **Removal efficiency**

Water samples were taken before and after the filter during the first evaluation period and analysed for total suspended solids. The total suspended solids results were used to calculate the removal efficiency of the filters according to the ASAE standard method (see section 3.2.1). The results of the analyses and the removal efficiency are shown in Table 4.14. The average dirtiness index before and after the filter and the filtration efficiency, is also shown for comparison.

Table 4.14: Water analyses results and removal efficiency (10/2002)

Sample site	TSS Before filter (mg/ℓ)	TSS After filter (mg/ℓ)	Removal efficiency (%)	Average DI before filter (%)	Average DI after filter (%)	Filtration efficiency (%)
1.1	16	0	100,0	1,7	TO	>90
2.1	48	60	**-25,0**	12,3	TO	>90
2.2	74	134	**-81,1**	3,0	TO	>90
2.3	14	70	**-400,0**	31,3	1,1	96.6
2.4	72	82	**-13,9**	11,6	TO	>90
2.5	124	122	1,6	5,5	TO	>90
2.6	82	66	19,5	12,3	TO	>90
3.1	2	3	**-50,0**	3,3	1,4	56,5
3.2	3	4	**-33,3**	4,6	0,75	83,7
3.4	11	2	81,8	2,0	1,4	31,3
4.1	108	99	8,3	2,2	0,3	86,2
4.2	59	51	13,6	1,2	0,93	22,5
4.3	54	49	9,3	6,7	0,6	91,0
4.4	153	138	9,8	42,4	3,1	92,7
4.8	101	89	11,9	3,4	0,7	79,0
4.9	95	92	3,2	1,3	0,3	74,9
5.1	11	6	45,5	5,1	2,7	47,7
5.2	2	1	50,0	2,6	1,9	29,7

Table 4.14 emphasizes that there is a difference between the efficiency calculated, using the two methods. The removal efficiency derived from the water samples ranged from -400% to 100%. Also, many of the filters showed very low efficiencies using this method, whereas the dirtiness index method showed much higher efficiencies. This could be due to the fact that the total suspended solids method does not take the fineness of the filter into account, for example, it can happen that a very high concentration of very fine particles is present in the water. It was sent to ASAE for comments but was not successful in getting a reply from them. The TSS reading will be high in this case. Since a filter has a relatively coarse element inside, this water will have no effect on it. The DI meter will also give a very low reading since it will have a coarse screen inside.

Due to the above facts, the ASAE method for determining removal efficiency was only used for the first evaluation period. However, the TSS was analysed during all the sets of evaluations.

4.1.3 Other water analyses

The iron (Fe), manganese (Mn) and total suspended solids (TSS) before the filter are shown in Table 4.15. The manganese and iron concentrations were determined on site using field test kits, while the total suspended solids and algae contents of the samples were analysed by independent laboratories (see section 3.2.3)

Table 4.15: The iron (Fe), manganese (Mn) and total suspended solids (TSS) determined before the filters

Region	Test site	Filter code	10/2002			04/2003			10/2003			04/2004		
			TSS (mg/ℓ)	Fe (mg/ℓ)	Mn (mg/ℓ)	TSS (mg/ℓ)	Fe (mg/ℓ)	Mn (mg/ℓ)	TSS (mg/ℓ)	Fe (mg/ℓ)	Mn (mg/ℓ)	TSS (mg/ℓ)	Fe (mg/ℓ)	Mn (mg/ℓ)
Breede	1.1	DS	16	0,5	0	26	1,4	0	6	0,6	0	25	0,7	0
	1.2	AS	Not measured	1,1	0	2	1,2	0	3	0,7	0	20	0,5	0
	1.3	DS	Not measured	0,75	0	8	2,4	0	11	1,0	0	28	1,0	0
	1.4	AS	Not measured	0,85	0	8	2,4	0	12	0,5	0	18	0,5	0
	1.5	DS	Not measured	0,5	0	14	0.8	0	17	1,1	0	5	0,9	0
	1.6	AS	Not measured	0,5	0	10	1	0	17	1,1	0	5	0,9	0
Orange	2.1	AS	48	0,6	0,2	24	0,3	0	26	0,5	0	12	0,4	0
	2.2	AS	74	0,7	0	46	0,4	0	Not measured			14	0,4	0
	2.3	DS	14	0,5	0	36	0,1	0	15	0	0,3	11	0,35	0
	2.4	DS	72	0,5	0	56	0	0	43	0	0	Not measured		
	2.5	DS	124	1,1	0	72	0,1	0	41	0,1	0	29	0,45	0
	2.6	AS	82	0,85	0	59	0,5	0	31	0,2	0,1	35	0,35	0

Region	Test site	Filter code	10/2002			04/2003			10/2003			04/2004		
			TSS (mg/ℓ)	Fe (mg/ℓ)	Mn (mg/ℓ)	TSS (mg/ℓ)	Fe (mg/ℓ)	Mn (mg/ℓ)	TSS (mg/ℓ)	Fe (mg/ℓ)	Mn (mg/ℓ)	TSS (mg/ℓ)	Fe (mg/ℓ)	Mn (mg/ℓ)
Kouga	3.1	CC	2	1,4	0,3	6	0,8	0,2	1	0,5	0,2	7	0,6	0,1
	3.2	ED	3	0,6	0	2	**Not measured**	**Not measured**	10	0,5	0,2	9	0,65	0.15
	3.3	ED	6	0,5	0	4	0,8	0,2	9	0,6	0,15	9	0,7	0,1
	3.4	BC	11	0,5	0	2	0,8	0,2	2	0,7	0,15	8	0,65	0,1
	3.5	CC	4	0,7	0,2	9	0,6	0,1	8	0,5	0,1	7	0,5	0,1
	3.6	ED	**Not measured**	0,7	0,2	4	0,8	0,7	2	0,5	0,1	2	0,6	0,1
Sundays	4.1	CC	108	0,5	0	100	0,5	0,3	54	0,5	0,3	100	0,75	0,3
	4.2	FD	59	0,5	0	11	0,5	0,3	54	0,5	0,3	100	0,7	0,3
	4.3	CC	54	0,6	0	107	0,9	0,3	30	0,5	0,1	54	0,4	0,1
	4.4	ED	153	0,7	0	176	1,2	0,4	29	0,5	0,25	120	0,5	0,25
	4.5	FD	118	0,9	0	121	0,9	0,4	50	0,5	0,1	81	0,6	0,1
	4.6	CC	84	0,6	0	42	0,5	0,3	13	0,5	0,15	23	0,4	0,1
	4.8	ED	101	0,65	0	127	0,7	0,4	102	0,6	0,15	56	0,5	0,15
	4.9	ED	95	0,6	0	89	0,6	0,3	146	0,5	0,25	66	0,6	0,3
Berg	5.1	FD	11	0,65	0	18	0,4		0	**Not measured**		6	0,55	0,2
	5.2	FD	2	0,6	0	6	1,6	0,1	3	1,0	0,1	11	0,6	0,1

The total suspended solids (TSS) levels for most of the sites in the Orange and Sundays River regions during all the evaluation periods represent a medium to high blockage potential for drippers (>50 mg/litre), (Heyns et al. 2002). The relatively lower TSS levels in the Orange River region during the third and fourth evaluation periods could be attributed to the low run-off in this region during these periods. The TSS levels of the other regions represented a low blockage potential for drippers (<50 mg/litre). The iron levels measured in the field varied from 0-2,4 mg/litre. The majority of the iron levels during October 2002 were approximately 0,5 mg/litre, while during April 2003 there was an increase in iron levels in all the regions except in the Orange River region, where there was a slight decrease in the Fe levels. The Orange River region had relatively low iron levels during October 2003 in comparison with the other regions. Only 3 sites in all the regions had a high Fe content (>1,5 mg/litre), which represent a high blockage potential for emitters (Heyns et al. 2002). At most of the sites of the Breede, Orange and Berg River regions the levels of manganese were low (< 0,1 mg/litre) during the evaluation periods. From April 2003, there was an increase in the Mn content of especially the sites in the Kouga and Sundays River regions. Most of these manganese levels represent a medium blockage potential (0,1-1,5 mg/litre), (Heyns et al. 2002) with levels between 0,1-0,7 mg/litre.

Two genera of Bacillariophyta (diatoms), namely Fragilaria and Melosira; one genus of Cyanobacteria (blue-green algae) namely, Oscillatoria; as well as one genus of Chlorophyta (green algae), namely Scenedesmus, are normally associated with physical blocking of filters, as well as complicating chemical settling processes (Harding, 2002). In all samples, the algae count of these genera was low and was therefore not likely to cause filter-clogging problems unless it was due to build-up over time. Appendix B shows an algae analysis in the different regions during October 2002.

4.1.4 **Flow-rate evaluation**

The flow-rates of water passing through the filters during the evaluation for all the regions are illustrated in Table 4.16. The measured values are compared with the maximum allowable flow-rates according to the manufactures. All, except the filters of sites 4.2 and 4.8 during the October 2002, sites 4.2 and 4.3 during the April 2003 and sites 2.5 and 4.2 during the April 2004 evaluation periods, had a flow-rate per filter that was less than the recommended maximum flow-rate. The measured flow-rates exceeded the recommended flow-rates marginally (3%) in the case of site 4.8 and by 30% in the case of site 4.3. This can be attributed to bad management by the farmer, for example, by irrigating more blocks than designed for. The flow-rates of test sites 1.1 and 2.2 were not measured due to the turbulence problems of the flow through the filter station during the evaluation (site 2.2) and to an insufficient measuring point on the filter station (site 1.1). The variation in flow-rates during the evaluation period of certain sites are due to the fact that different numbers of irrigation blocks were irrigated simultaneously at the different times.

Table 4.16: The flow-rates of water passing through the filters during the evaluation

Region	Test site	Filter code	Filter fineness (microns)	Number of filters	Flow-rate through filter (m^3/h)								
						10/2002		04/2003		10/2003		04/2004	
					Supplier max/filter	Total measured	Per filter	Total measured	Per filter	Total measured	Per filter	Total measured	Per filter
BREEDE	1.1	DS	75	2	40	**Not measured**							
	1.2	AS	75	2	41	46	23	33	16.5	39	19.5	50	25
	1.3	DS	75	2	40	71.4	35.7	33	16.5	70	35	37.2	18.6
	1.4	AS	75	2	41	35	17.5	65	32.5	61	30.5	61.0	30.5
	1.5	DS	75	3	40	63.5	21.2	45	15	60.5	20.2	57.0	19
	1.6	AS	75	3	41	54	18	85	28.3	74	24.7	65.0	21.6
ORANGE	2.1	AS	75	2	41	53	26.5	50	25	49	24.5	53	26.5
	2.2	AS	75	2	41	**Not measured**							
	2.3	DS	75	2	40	42.5	21.3	45	22.5	43.4	21.7	38	19
	2.4	DS	75	4	40	86.4	21.6	83	20.8	90	22.5	**Not measured**	
	2.5	DS	75	5	40	116.3	23.3	143	28.6	127	25.4	208.3	**41.6**
	2.6	AS	75	2	41	56	28	14.3	7.2	30	15	52	26
KOUGA	3.1	CC	75	1	150	86	86	70	70	70	70	67.5	67.5
	3.2	ED	130	3	30	79	26.3	79	26.3	75	25	70	23.3
	3.3	ED	130	3	30	35.9	12	33.6	11.2	63	21	82	27.3
	3.4	BC	100	1	50	25	25	24.5	24.5	17	17	15.5	15.5
	3.5	CM	100	1	150	94.6	94.6	85	85	86	86	88.5	88.5
	3.6	ED	130	2	30	55.8	27.9	41.5	20.8	50	25	38.5	19.3

Region	Test site	Filter code	Filter fineness (microns)	Number of filters	Flow-rate through filter (m^3/h)									
						10/2002		04/2003		10/2003		04/2004		
					Supplier max/filter	Total measured	Per filter	Total measured	Per filter	Total measured	Per filter	Total measured	Per filter
SUNDAYS	4.1	CC	100	1	150	57.2	57.2	99.3	99.3	78	78	84	84
	4.2	FD	200	4	30	151	**37.8**	141	**35.3**	90	22.5	132.6	**33.1**
	4.3	CC	100	1	150	80.5	80.5	194	**194**	100	100	123	123
	4.4	ED	130	4	30	42.4	10.6	36	9.0	65	16.3	45	11.2
	4.5	FD	200	4	30	86	21.5	78	19.5	84	21	84	21
	4.6	CC	100	1	150	120	120	137	137	128.5	128.5	129.3	129.3
	4.8	ED	130	5	30	155	**31**	96	19.2	86	17.2	124	24.8
	4.9	ED	130	2	30	34	17	30	15	42	21	41	20.5
BERG	5.1	FD	200	4	30	76.6	19.2	31.3	7.8	**Not measured**		80	20
	5.2	FD	200	4	30	40	10	82	20.5	80	20	80	20

4.1.5 **Operating pressure of the system**

The operating pressure of the systems during the evaluation period for all the regions are shown in Table 4.17. The measured values are compared with the minimum and maximum allowable pressure values according to the manufactures. All, except site 3.4, had an operating pressure which adhered to the recommended values. The problem at site 3.4 may be due to an irrigation management fault. The design pressure of the test sites is unknown.

Table 4.17: The operating pressure of the system before the filter during the evaluation

Region	Test site	Filter code	Filter fineness (microns)	Number of filters	Operating pressure (kPa)				
					Manufacturer (min / max)	Measured			
						10/2002	04/2003	10/2003	04/2004
BREEDE	1.1	DS	75	2	150 - 1 000	305	300	290	320
	1.2	AS	75	2	100 - 1 000	290	310	330	280.5
	1.3	DS	75	2	150 - 1 000	360	580	300	317
	1.4	AS	75	2	100 - 1 000	500	600	500	390
	1.5	DS	75	3	150 - 1 000	222	360	310	57
	1.6	AS	75	3	100 - 1 000	465	410	380	478
ORANGE	2.1	AS	75	2	100 - 1 000	340	335	350	340
	2.2	AS	75	2	100 - 1 000	480	575	**Not measured**	440
	2.3	DS	75	2	150 - 1 000	370	420	440	400
	2.4	DS	75	4	150 - 1 000	470	485	500	**Not measured**
	2.5	DS	75	5	150 - 1 000	515	510	450	318
	2.6	AS	75	2	100 - 1 000	215	250	200	250
KOUGA	3.1	CC	75	1	150 - 1 000	300	310	200	282
	3.2	ED	130	3	NA - 1 000	215	260	245	230
	3.3	ED	130	3	NA - 1 000	360	450	250	500
	3.4	BC	100	1	250 - 800	**240**	**242**	**200**	270
	3.5	CC	100	1	150 - 1 000	450	470	500	520
	3.6	ED	130	2	NA - 1 000	200	260	220	300
SUNDAYS	4.1	CC	100	1	150 - 1 000	245	490	400	495
	4.2	FD	200	4	NA - 1 000	560	590	610	570
	4.3	CC	100	1	150 - 1 000	345	315	330	330
	4.4	ED	130	4	NA - 1 000	250	310	290	330
	4.5	FD	200	4	NA - 1 000	200	290	290	290
	4.6	CC	100	1	150 - 1 000	360	335	220	320
	4.8	ED	130	5	NA - 1 000	440	450	410	440
	4.9	ED	130	2	NA - 1 000	430	440	420	410
BERG	5.1	FD	200	4	NA - 1 000	110	285	**Not measured**	290
	5.2	FD	200	4	NA - 1 000	300	230	120	160

4.1.6 **Backwashing management**

The following were measured to evaluate the backwashing management of the farmers for the evaluation period (Table 4.18):

- ❖ The backwash time of the filters by using a stopwatch.
- ❖ The backwashing flow-rate through the filters using the clamp-on flow meter once the flow had stabilised.
- ❖ The backwashing pressure during the backwash process by using a pressure gauge.
- ❖ The pressure drop over the filter station. The filter was backwashed manually until a negligible change in pressure drop over the filter station was reached.

The backwashing management for the automatic screen filters (BC and CC filters) were not measured due to the fact that the backwashing process starts automatically once a certain preset pressure differential is reached. There is thus no control over the backwashing process, once it started. These values were, though, measured in the ILI-Hydrolabs during the laboratory tests on these filters and the values that are shown in Table 3.18C are the laboratory measurements whereas the other measurements are the field measurements.

Although the tests were done at specific dirtiness index points, the data can also be interpolated between the points by following the graphs that are displayed in section 4.3 where the laboratory test results are given.

Table 4.18A: Backwashing management test results (Backwash flow-rate)

Region	Test site	Filter code	Filter fineness (microns)	Number of Filters	Backwash time per filter(sec)					Backwash flow-rate(m^3/h)				
					Manufacturer (recommendation)	Measured				Manufacturer	Measured			
						10/2002	4/2003	10/2003	4/2004		10/2002	04/2003	10/2003	04/2004
BREEDE	1.1	DS	80	2	180	270	180	120	240	60 (max)	**Not measured**			
	1.2	AS	80	2	180	120	140	120	240	50 (max)	26.8	22	27.2	26
	1.3	DS	80	2	180	180	250	180	240	60 (max)	53.8	51.5	52.6	40
	1.4	AS	80	2	180	150	120	180	240	50 (max)	**96.5**	**67.5**	47	**57**
	1.5	DS	80	3	180	80	160	180	360	60 (max)	24.1	42.5	31	25
	1.6	AS	80	3	180	80	105	180	540	50 (max)	**Not measured**			
ORANGE	2.1	AS	80	2	180	100	200	90	70	50 (max)	34.8	27	25.9	26
	2.2	AS	80	2	180	80	120	**Not measured**	72	50 (max)	49	48.5	**Not measured**	
	2.3	DS	80	2	180	90	60	85	205	60 (max)	35	17.5	22.1	16
	2.4	DS	80	4	180	90	60	120	**Not measured**	60 (max)	48.7	44.5	49	**Not measured**
	2.5	DS	80	5	180	60	100	120	300	60 (max)	53.1	50.5	49	51
	2.6	AS	80	2	180	120	90	180	180	50 (max)	35.7	19.6	30	34
KOUGA	3.1	CC	75	1	20	-	-	-	78	11	-	-	-	-
	3.2	ED	130	3	30	30	41	30	84.5	16 (min)	18.7	17	18	16
	3.3	ED	130	3	30	20	43.5	30	88	16 (min)	19.8	38	17	17
	3.4	BC	100	1	12	-	-	-	-	8	-	-	-	-
	3.5	CC	100	1	20	-	-	-	-	11	-	-	-	-
	3.6	ED	130	2	30	**Not measured**				16 (min)	**Not measured**			
SUNDAYS	4.1	CC	100	1	20	-	-	-	-	11	-	-	-	-
	4.2	FD	200	4	60	120	120	60	120	40 (max)	16.7	16.6	14	15
	4.3	CC	100	1	20	-	-	-	-	11	-	-	-	-
	4.4	ED	130	4	30	60	60	30	30	16 (min)	**15.2**	16.3	16	16
	4.5	FD	200	4	60	20	180	60	40	40 (max)	**Not measured**			
	4.6	CC	100	1	20	-	-	-	-	11	-	-	-	-
	4.8	ED	130	5	30	40	40	60	40	16 (min)	20	20.5	16	16
	4.9	ED	130	2	30	**Not measured**				16 (min)	**Not measured**			
BERG	5.1	FD	200	4	60	105	60	**Not measured**		40 (max)	5.7	22	**Not measured**	
	5.2	FD	200	4	60	60	110	120	100	40 (max)	27.4	35.5	37	32

Table 4.18B: Backwashing management test results (Backwash pressure)

Region	Test site	Filter code	Filter fineness (microns)	Number of Filters	Backwashing pressure (kPa)				Pressure drop over clean filter station after backwash (kPa)				
					Supplier (min)	Measured			Norm (max)	Measured			
						10/2002	10/2003	4/2004		10/2002	4/2003	10/2003	4/2004
BREEDE	1.1	DS	80	2.0	100.0	300.0	330.0	320.0	40.0	15.0	**Not measured**	**70.0**	**100.0**
	1.2	AS	80	2.0	200.0	238.0	400.0	314.0	40.0	37.0	14.0	**53.0**	40.0
	1.3	DS	80	2.0	100.0	530.0	410.0	365.0	40.0	**70.0**	**70.0**	**48.0**	20.0
	1.4	AS	80	2.0	200.0	455.0	547.0	**Not measured**	40.0	20.0	**100.0**	40.0	**50.0**
	1.5	DS	80	3.0	100.0	270.0	440.0	350.0	40.0	20.0	40.0	**55.0**	40.0
	1.6	AS	80	3.0	200.0	530.0	495.0	500.0	40.0	30.0	30.0	**45.0**	**70.0**
ORANGE	2.1	AS	80	2.0	200.0	305.0	450.0	320.0	40.0	35.0	35.0	10.0	35.0
	2.2	AS	80	2.0	200.0	530.0	**Not measured**	520.0	40.0	**70.0**	**120.0**	**Not measured**	**70.0**
	2.3	DS	80	2.0	100.0	278.0	480.0	370.0	40.0	20.0	40.0	**80.0**	**80.0**
	2.4	DS	80	4.0	100.0	385.0	600.0	**Not measured**	40.0	25.0	25.0	5.0	**Not measured**
	2.5	DS	80	5.0	100.0	385.0	500.0	370.0	40.0	20.0	20.0	**50.0**	**100.0**
	2.6	AS	80	2.0	200.0	275.0	300.0	280.0	40.0	27.0	20.0	5.0	**60.0**
KOUGA	3.1	CC	75	1.0	200.0	-	-	-	30.0	-	-	-	-
	3.2	ED	130	3.0	280.0	**260.0**	300.0	**260.0**	30.0	15.0	**55.0**	5.0	**35.0**
	3.3	ED	130	3.0	280.0	360.0	340.0	517.0	30.0	15.0	10.0	30.0	10.0
	3.4	BC	100	1.0	200.0	-	-	-	30.0	-	-	-	-
	3.5	CC	100	1.0	200.0	-	-	-	30.0	-	-	-	-
	3.6	ED	130	2.0	280.0	**Not measured**	410.0	350.0	30.0	**50.0**	**70.0**	10.0	10.0

Table 4.18B (continued): Backwashing management test results (Backwash pressure)

Region	Test site	Filter code	Filter fineness (microns)	Number of Filters	Backwashing pressure (kPa)				Pressure drop over clean filter station after backwash (kPa)				
					Supplier (min)	Measured			Norm (max)	Measured			
						10/2002	10/2003	4/2004		10/2002	4/2003	10/2003	4/2004
SUNDAYS	4.1	CC	100	1.0	200.0	-	-	-	30.0	-	-	-	-
	4.2	FD	200	4.0	250.0	593.0	610.0	605.0	30.0	**60.0**	**85.0**	**90.0**	**70.0**
	4.3	CC	100	1.0	200.0	-	-	-	30.0	-	-	-	-
	4.4	ED	130	4.0	280.0	**220.0**	300.0	345.0	30.0	15.0	30.0	**80.0**	**50.0**
	4.5	FD	200	4.0	250.0	**200.0**	290.0	315.0	30.0	30.0	**50.0**	10.0	25.0
	4.6	CC	100	1.0	200.0	-	-	-	30.0	-	-	-	-
	4.8	ED	130	5.0	280.0	415.0	420.0	450.0	30.0	25.0	30.0	20.0	20.0
	4.9	ED	130	2.0	280.0	495.0	560.0	**Not measured**	30.0	30.0	**40.0**	**45.0**	**40.0**
BERG	5.1	FD	200	4.0	250.0	**80.0**	**Not measured**		30.0	20.0	25.0	**Not measured**	
	5.2	FD	200	4.0	250.0	275.0	**180.0**	**220.0**	30.0	23.0	**40.0**	**40.0**	30.0

The results demonstrated the following:

The backwash time per filter varies from 20 seconds to 540 seconds depending on the water quality. Most of the filters are backwashed either on pressure differential or on a fixed time cycle. Only site 5.1 is backwashed manually. The volume of water used per filter during the backwash process can be determined by multiplying the backwash flow-rate with the backwash time. The most noticeable difference between the sand, the screen and the disc filters is the volume of water used for each backwash. From Table 4.18C follows that the average volume of water per backwash per filter resulted in 0,15 m^3 for screen filters, 0.37 m^3 for disc filters and 1,63 m^3 for sand filters.

Table 4.18C: Backwashing management test results (Backwash volume)

Region	Test site	Filter code	Filter fineness (microns)	Number of Filters	Screen filters: Average Volume/filter/backwash (m^3)	Disc filters: Average Volume/filter/backwash (m^3)	Sand filters: Average Volume/filter/backwash (m^3)
BREEDE	1.1	DS	80	2			
	1.2	AS	80	2			1,10
	1.3	DS	80	2			2,92
	1.4	AS	80	2			3,21
	1.5	DS	80	3			1,66
	1.6	AS	80	3			
ORANGE	2.1	AS	80	2			0,91
	2.2	AS	80	2			1,35
	2.3	DS	80	2			0,69
	2.4	DS	80	4			1,19
	2.5	DS	80	5			2,05
	2.6	AS	80	2			1,18
KOUGA	3.1	CC	75	1	0,17		
	3.2	ED	130	3		0,22	
	3.3	ED	130	3		0,29	
	3.4	BC	100	1	0,04		
	3.5	CC	100	1	0,17		
	3.6	ED	130	2			
SUNDAYS	4.1	CC	100	1	0,17		
	4.2	FD	200	4		0,45	
	4.3	CC	100	1	0,17		
	4.4	ED	130	4		0,20	
	4.5	FD	200	4			
	4.6	CC	100	1	0,17		
	4.8	ED	130	5		0,23	
	4.9	ED	130	2			
BERG	5.1	FD	200	4		0,32	
	5.2	FD	200	4		0,89	
Overall average backwash volume per filter type					**0,15**	**0,37**	**1,63**

The amount of water used during the backwashing process for the screen and disc filters are less than the volume used for sand filters. However, the screen and disc filters backwash more regularly than sand filters. If the total volume of backwash water is compared to filter 1000 m³ of water at a dirtiness index of 5, the screen filter will use 13,3 m³; the disc filter 1,7 m³ and the sand filter 15,6 m³. Generally, the backwash time per filter is less for the non-sand filters. Most of the filter stations discharges the backwash water back into the water source.

The backwash flow-rates through the sand filters were within the manufacturer's recommendations, except site 1.4 where it seems to be a design problem, for example, wrong choice of equipment. The backwash flow-rate (16 m³/h, April 2004) of site 2.3, is marginally lower than the recommended minimum guideline for sand filters of 25 m³/h per m² sand area of the filter (which corresponds to 17,5 m³/h for a DS filter), which may lead towards insufficient backwashing. Test site 4.4 backwash flow-rate (15,2 m³/h) is marginally lower than the manufacturer's recommendation (16 m³/h).

The main reason for the low backwash pressure of some of the test sites is insufficient provision for extra pressure and flow-rate for the backwash process in the design of the pump for the system. Some systems run on gravity and no compensation can be made in this case, except to run a smaller irrigation system or to run a smaller number of blocks at the same time. In some cases, faulty valves were the reason for low pressures. During the first round of measurements in 10/2002, uncertainty existed about where exactly these measurements were to be taken. Some measurements were taken at the backwash valve where near-to-atmospheric conditions existed and where pressures were low. The right position is at the entrance to the filter station, except otherwise specified by the manufacturer.

The pressure drop over some of the filter stations after the backwash, were above the SABI norms. The main reasons for the high pressure drops over the filters were faulty pressure gauges (site 2.2b), the wrong choice of valves on the filter station (site 3.2), filters which discs were so dirty that they needed to be cleaned manually (site 3.6 and 4.9) and faulty backwash valves (site 4.5). Another reason was that some filters were over exploited by running too high flow-rates through them. This also caused high pressure drops over them, even when they were well cleaned (sites 2.5 and 4.2).

The main reasons for not performing certain measurements were faulty backwash systems, unavailability of the farmer during test periods, lack of water from the water source, insufficient measuring points, malfunctioning of the ultrasonic flow meter, and turbulence flow problems during the measuring period.

4.2 Observations from Field Tests

The following trends were observed during the filtration efficiency tests:

- As the pressure difference over the filter increases, there was a reduction in the filtration efficiency.
- When the flow-rate through a filter was reduced, the filtration efficiency increased.
- With a low dirtiness index of the water before the filter, the filtration efficiency was lower than with a high dirtiness index.
- There was a large variation in the water quality, at the different sites, on the same water supply system.

The extraction point of water that enters the filter station influences the performance of the filters. In systems where the water is pumped from a storage dam that uses a float system for the pump suction pipe, the water is less dirty than systems where the off take is at the bottom of the dam.

In the Breede River Valley, one farm installed a CC filter, but replaced it with sand filters after three months. The high inorganic materials load in the water would rapidly clog the screen in the filter resulting in low downstream pressure. The filter would then have to be dismantled and cleaned with a high-pressure washer. This was repeated every four hours during peak demand periods.

In the Berg river area, FD filters are being replaced with sand or ED as primary filters. The FD filters are being used as secondary filtration equipment and not for new primary treatment systems.

4.3 Laboratory Test Results

Three disc filters, two sand filters and three automatic filters were intensively tested in the ILI-Hydrolabs over a period of one and a half year. Friction loss tests, filtration capacity tests and other performance tests like filtration efficiency, backwash efficiency; the efficiency of different cleaning operations on sand filters and the difference between the different types of discs, were the focus points of the tests.

In the following discussions there will be separately looked at the three different types of filters. The filters will be discussed under the following main headings: general performance characteristics of the filters, the results of the filtration efficiency tests, the results of the backwash efficiency tests and some comments where applicable. Although the tests were done at specific dirtiness index points, the data can also be interpolated between the points by following the graphs that are displayed.

4.3.1 Disc filters

In South Africa, mainly three types of discs are available. The three types of discs were firstly placed consecutively in the same filter casing and a series of tests performed on them to be able to compare only the different discs against each other. After that, the discs were placed in their original filter casings and the different filters were tested for filtration efficiency and backwash efficiency.

4.3.1.1 Comparison of the three different filter discs

General performance characteristics

A large number of micro irrigation filters make use of grooved plastic discs as a filtration medium. There is a need to know what the performance differences of these discs are and therefore, on the recommendation of one of the manufacturers, the three different types of discs were firstly tested in the same filter casing and compared.

Thereafter they were tested in the casings of their original filters and the test results of these filters were compared. Fig. 4.2 to Fig. 4.4 illustrates the different discs:

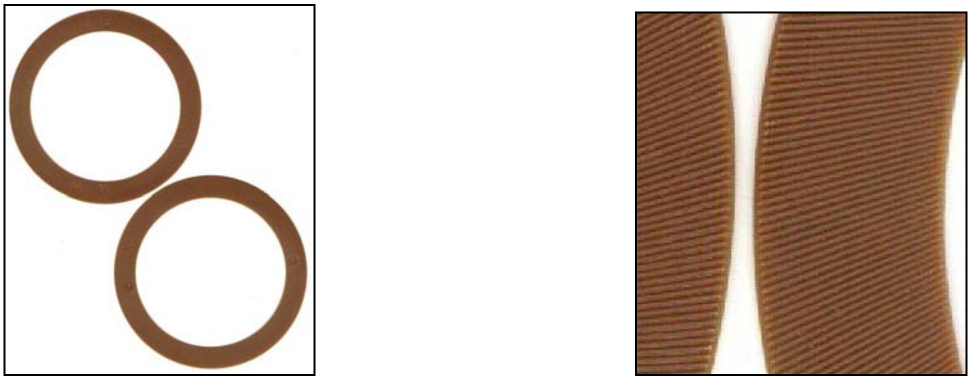


Fig. 4.2: The discs of the GD filter

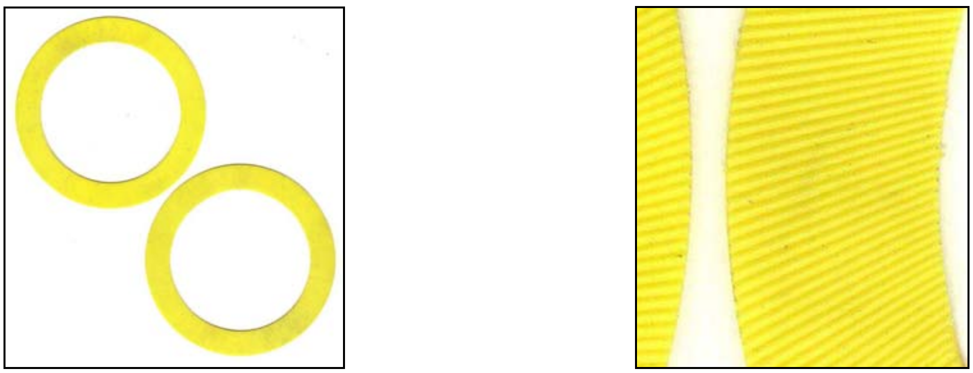


Fig 4.3: The discs of the FD filter

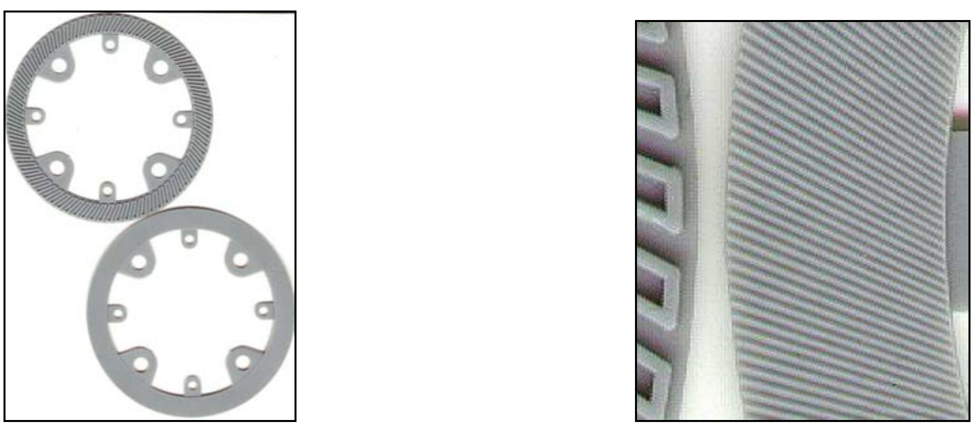


Fig. 4.4: The discs of the HD filter

It was found that the cleaning method (hand-clean vs. backwash) had an effect on the filtering and backwash efficiencies of disc filters. The results of both cases are presented.

It was also found that during the clogging process of a disc filter, as the pressure drop across the filter increases, that the filtration efficiency did not stay the same and that the dirtiness index of the water also had an effect as illustrated in Fig. 4.5 which is a summary of the FD filter test results.

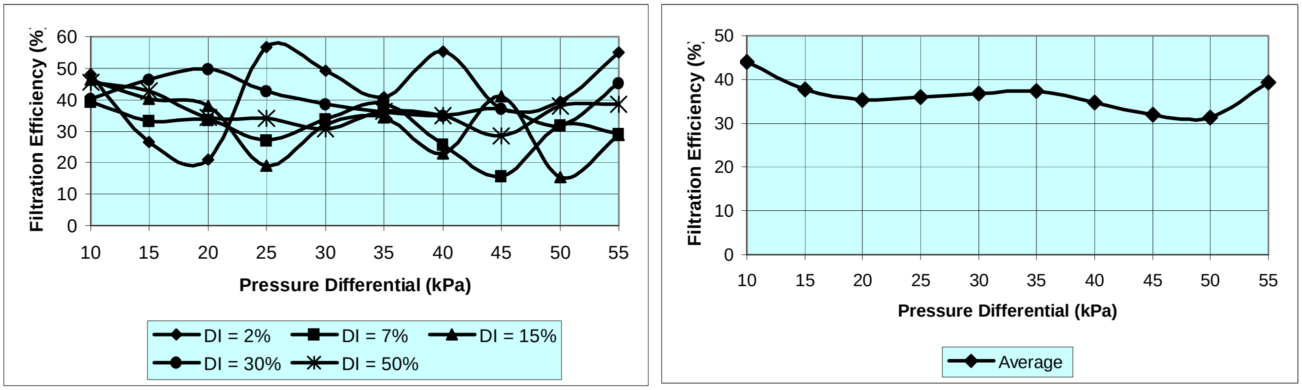


Fig. 4.5: Filtration efficiency during the clogging of a disc filter

It is important to understand that the filtration efficiency is always related to a certain maximum particle size and it is an indication of how efficiently the filter removes that size and bigger than those size particles. The particles with a smaller size than that size are allowed to pass through the filter. At first there is a decrease in filtration efficiency because some dirt particles are forced through the openings as the pressure differential across the filtration area of the disc increases. Then a slight increase happens because the dirt is forming a cake on the outside of the discs which is finer than the passages of the element and the particles for which the element is rated are held back more efficiently. If the pressure differential increases more, again some dirt is forced through the element when the cake cracks and the filtration efficiency decrease. When the element approaches complete clogging so that not even water can pass though it, then the filtration efficiency increases because nothing is let through the element.

From this discussion, it is clear that the filtration efficiency of a disc filter does not have a constant value, and if a value is quoted, then one must know that it is an average value. This characteristic of a disc filter means that if filtration efficiency on a filter is measured, it depends on what stage of clogging the filter is to what value one will measure and this makes it very difficult to compare values that are measured in the field with laboratory values. The filter that was used as an example had only slight changes in the filtration efficiency while clogging. There are though filters that showed much more drastic changes.

Another aspect that must be emphasized is the filtration efficiency as a function of the dirtiness of the water. When water is fairly clean, the filtration efficiency is low, because the filter can not make clean water more clean than it is. One can see this also clearly in the Fig. 4.6.

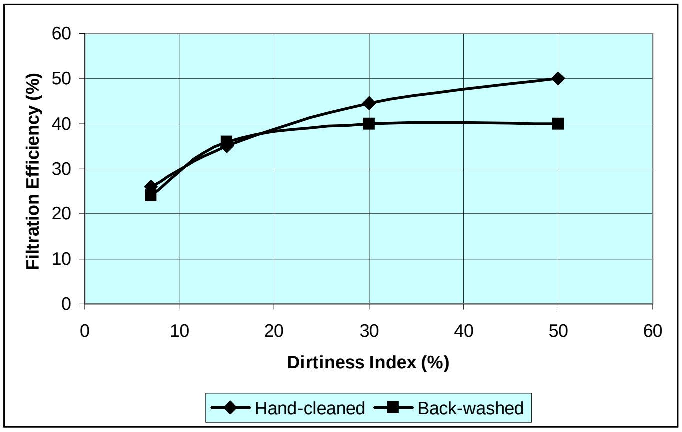


Fig. 4.6: Filtration efficiency as a function of the dirtiness of the water

Results of the filtration efficiency tests

The three types of discs were consecutively placed in the casing of filter HD because it could be converted the easiest to accommodate the other filter's discs and the normal complete range of tests were performed that are normally performed with any filter test viz. the friction loss test to establish the 5 kPa friction loss flow-rate at which the clogging tests are done. Two series of clogging tests are performed: one where the filter is hand-cleaned before a following test and the other where the filter is backwashed before a following test. Each series of clogging tests consists of five tests at the following dirtiness indexes: 2, 7, 15, 30 and 50 (the highest dirtiness that could on average be found in nature is 100 and that will be something like a river in heavy flood). From experience, it was found that very few filters can handle a dirtiness index of 60 and that is why the tests were only performed up to a dirtiness index of 50. During these clogging tests, the filtration efficiency and the backwash efficiency of the filter were measured. In Fig. 4.7, 4.8 and 4.9 the results of the friction loss test, filtration efficiency and backwash efficiency tests of the discs in the same casing are summarised.

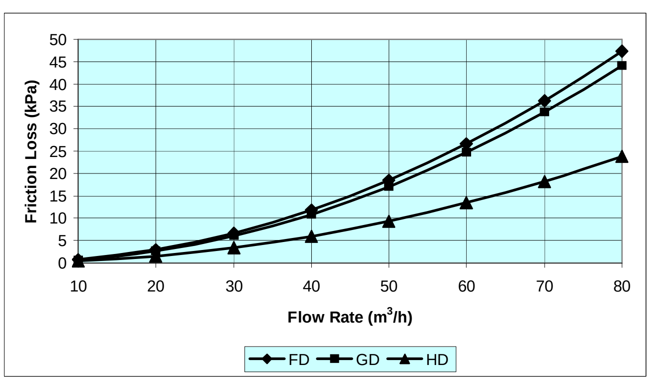


Fig. 4.7: Friction loss curves for the three different filter discs in the same casing

From the graph, it is clear that the design of a filter disc can have a noticeable effect on the friction loss of a filter.

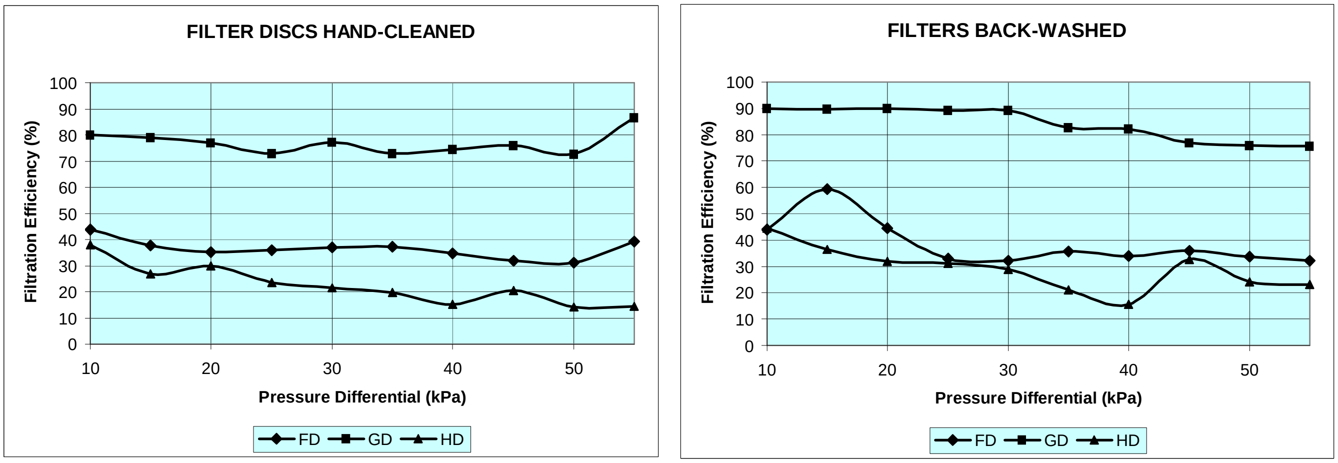


Fig. 4.8: The filtration efficiencies of the three different filter discs

Results of the backwash efficiency tests

The backwashing of the filter on the test bench is done by routing water that was filtered by sand filters on the test bench in the reverse direction through the filter. The flow-rate that was used was equal to twice the recommended filtering flow-rate of the filter with the lowest rate. The same backwash flow-rate and backwash volumes were used for all three discs to have an equal base of comparison. The results of the backwash tests are showed in Fig. 4.9.

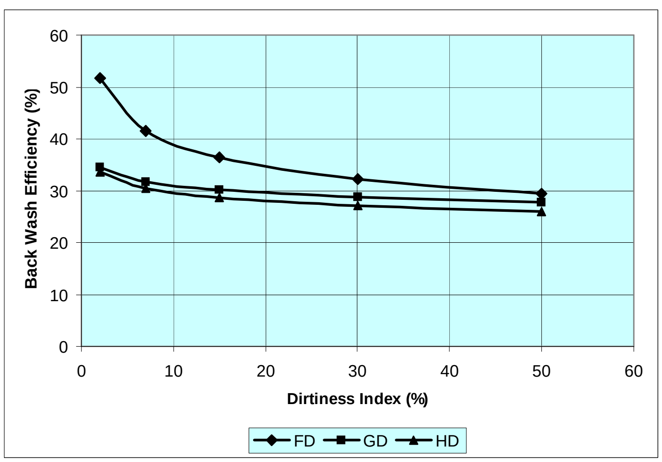


Fig. 4.9: The backwash efficiencies of the three different filter discs

Comments on the comparative tests of the three different filter disc elements

In Fig. 4.8, it can be seen that there was a general trend of lower filtration efficiencies when the pressure differential across the element was more than 30 kPa. This signals a message that it was not good practise to let a filter clog to that point and that the filter should preferably be cleaned before it reaches that point. Many filter stations are equipped with pressure differential measuring devices that can be set so that the filter station will start backwashing when that set pressure differential is reached. A good point to set such a device is obviously 30 kPa as shown by the test results (most of them are set to 50 kPa, which could be good enough, but if a farmer experiences clogging problems in his irrigation system, it could be advisable to lower it to 30 kPa).

In Table 4.19, the results of all the tests on the three different filter disc elements are summarised.

Table 4.19: Comparison between the discs of three different disc filters in the same casing

Type of disc	Average filtration efficiency (%)		Average backwash efficiency (%)
	Hand-cleaned	Backwashed	
Disc FD	36,4	38,4	38,3
Disc GD	76,4	84,1	30,6
Disc HD	22,4	29,0	29,2
Averages	**45,07**	**50,5**	**32,7**

In Table 4.19 it can be seen that the filtration efficiency for all three discs was better when they were backwashed compared to hand cleaning. The reason for that was that not all dirt was removed from the discs through backwashing. The remaining dirt between the discs mace the passages smaller, not-allowing larger particles to pass through the element and therefore the filtration efficiency, relatively to the rated particle size of the element, increased.

One alarming result in the information in Fig. 4.9 is the fact that the backwash efficiency of filter discs is only about 30%. This means that only 30% of the element is cleaned during backwashing, which means that a filter can clean only one third of the volume of water after it is backwashed, compared to when it is hand-cleaned. This fact must surely not be overlooked when the filtration capacity for a filter station is designed.

4.3.1.2 **Comparison of the three different disc <u>filters</u>**

General performance characteristics

The same commentary given in the previous section is greatly applicable to this section. In this section, the test results of the three different filter discs are shown with the discs in their own filter casings.

Results of the filtration efficiency tests

In Fig. 4.10, 4.11 and 4.12 the results of the friction loss test, filtration efficiency and backwash efficiency tests of the three different filters are summarised. For ease of comparison the graphs with the discs in the same casing are placed next to the results of the individual filters' tests.

From the friction loss, graphs (Fig, 4.10) one can see that the casing of filter FD must almost had the same friction as the casing of filter HD, because their friction loss curves were almost the same with the same discs. The curves for filter HD are also the same in the two graphs because it was the same casing and the same discs. The casing though of filter GD must have had much more friction than the casing of filter HD because the same discs in it produces a much higher friction loss at any flow-rate.

This shows that the friction loss of a disc filter can be minimised with the correct design of the casing of the filter. One sometimes gets the feeling that filter manufacturers are not always worried that much about this.

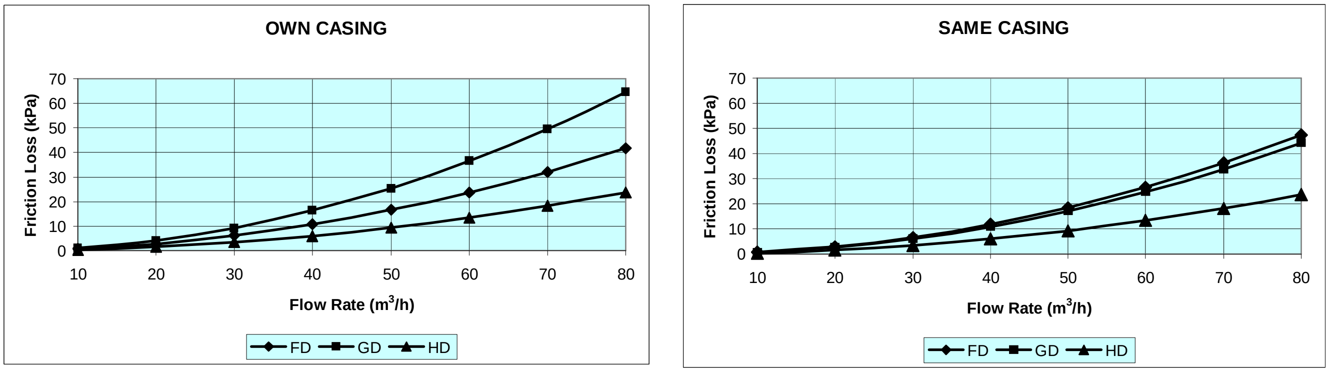


Fig. 4.10: Friction loss curves for the three different filter discs in their own and same casing

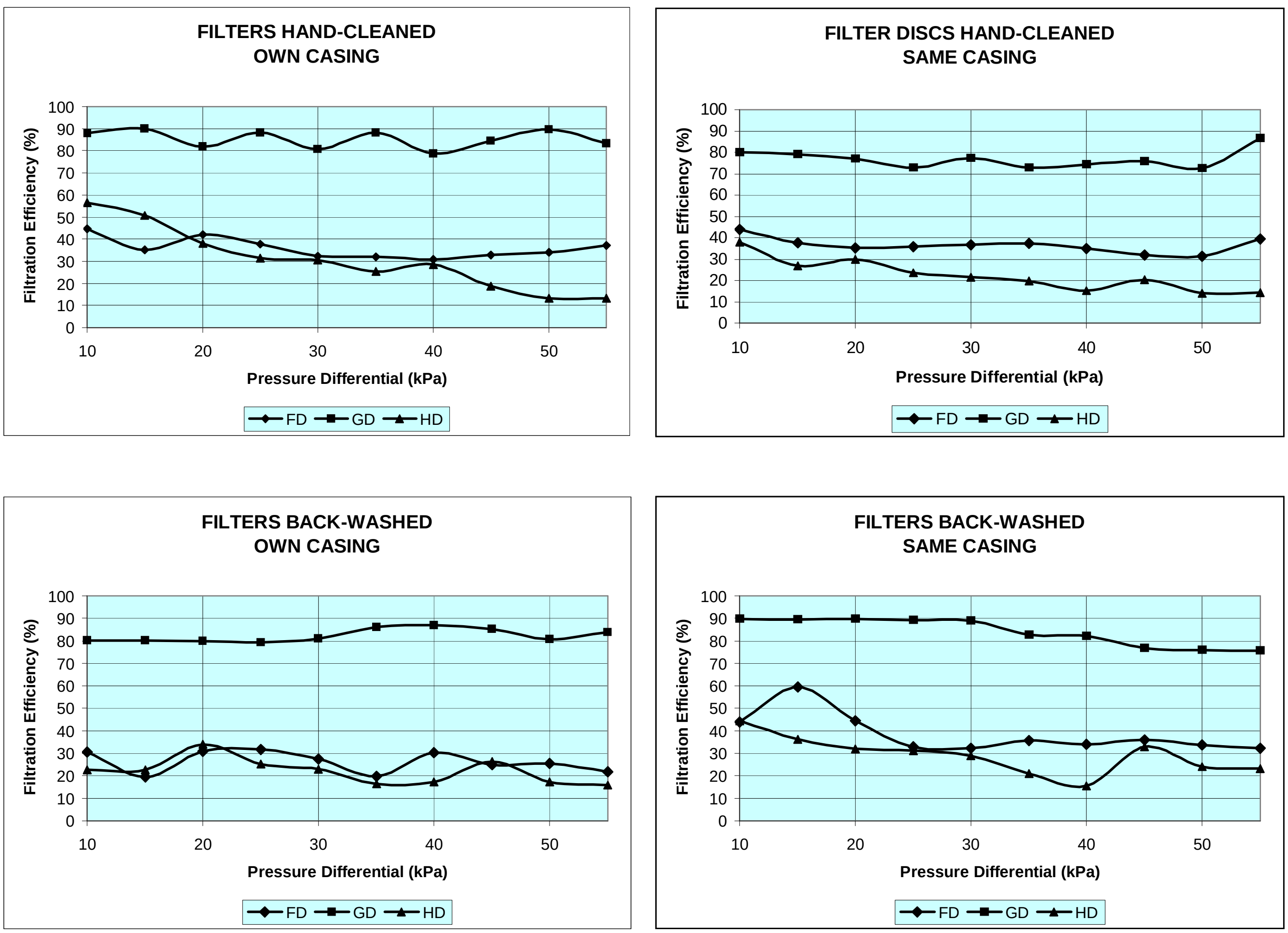
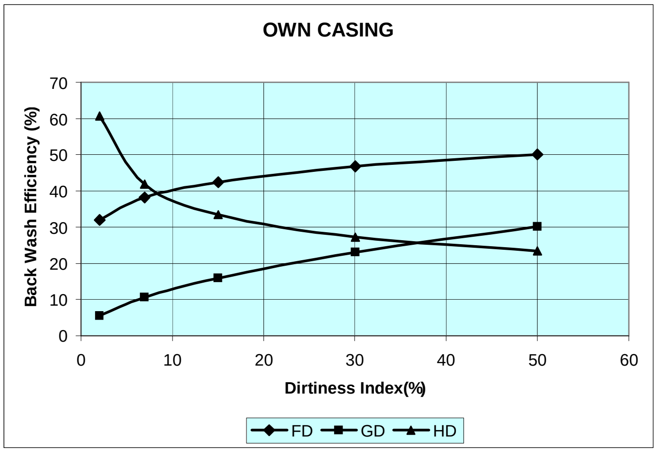


Fig. 4.11: Filtration efficiencies for three different filter discs in their own and same casing

The results in the four graphs are much the same except for filter GD where the average filtration efficiency of the discs in their own casing was about 85% compared to 75% in the HD casing. The discs in their own casings showed on average lower filtration efficiencies when backwashed than when they were hand-cleaned.

Results of the backwash efficiency tests



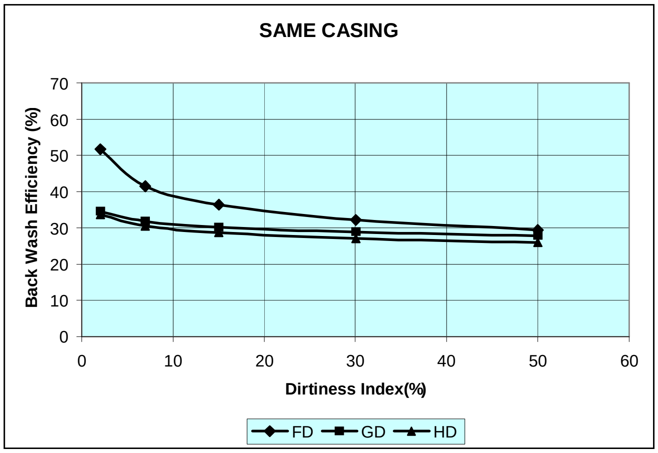
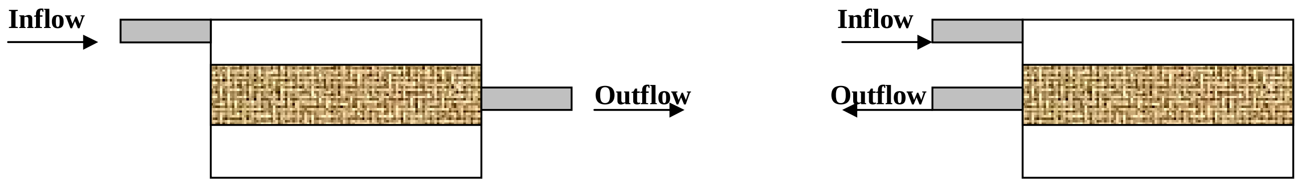


Fig. 4.12: Backwash efficiencies for three different filter discs in their own and same casing

The flow-rate that was used was equal to twice the recommended filtration flow-rate of the filter with the lowest rate. The same backwash flow-rate and backwash volumes were used for all three filters to have an equal base of comparison.

Comments on the comparative tests of the three different disc filters

In the last two graphs, complete differences prevail. The main difference between these tests is the different filter casings and it pointed out that the design of a filter casing plays a major role in the backwash efficiency of the filter at the end. An important aspect to look at is the distribution of the flow patterns inside the casing. Diag. 4.1 might illustrate it better:



Diag. 4.1: Different ways of water flow through filters

The arrows show the direction of flow during filtration. With backwashing of a disc filter, these directions are simply reversed. In the left diagram, it is clear that the water will flow backwards through across the whole length of the element and the whole element will be cleaned. In the right diagram, the water will take short cut through about the left quarter of the length of the element and only about 25% of it will be cleaned.

Table 4.20: Comparison between the three different disc filters in their own casing

Filter code	Average filtration efficiency (%)		Average backwash efficiency (%)
	Hand cleaned	Backwashed	
Filter FD	35,8	26,2	41,9
Filter GD	85,1	76,4	20,1
Filter HD	30,6	22,1	37,3
Averages	**50,5**	**41,5**	**33,1**

4.3.2 Sand filters

4.3.2.1 Filtration and backwash efficiency tests on two sand filters

Sand filters AS and DS were intensively tested and much time was spent to make a study of the effect of different backwash flow-rates and volumes on the backwash efficiencies of the filters and to check the generally accepted norm against the tests' results. The use of compressed air for the thorough cleaning of the filters was also evaluated and it was found that with not much air blown into the backwash water before it enters the filter a sand filter can be 100% cleaned again.

General performance characteristics

From Fig. 4.13 it can be seen that on a macro scale there is no change in the filtration efficiency of the sand filters (AS and DS) when the pressure differential increases across the element, as long as they are well managed. One problem with a sand filter is that it has a loose filtration medium which can easily be disturbed by poor working conditions and then the so-called tunnels are formed through the sand with the result that total collapse of the filtration could happen. This is in strong contrast with the disc filter's performance characteristics.

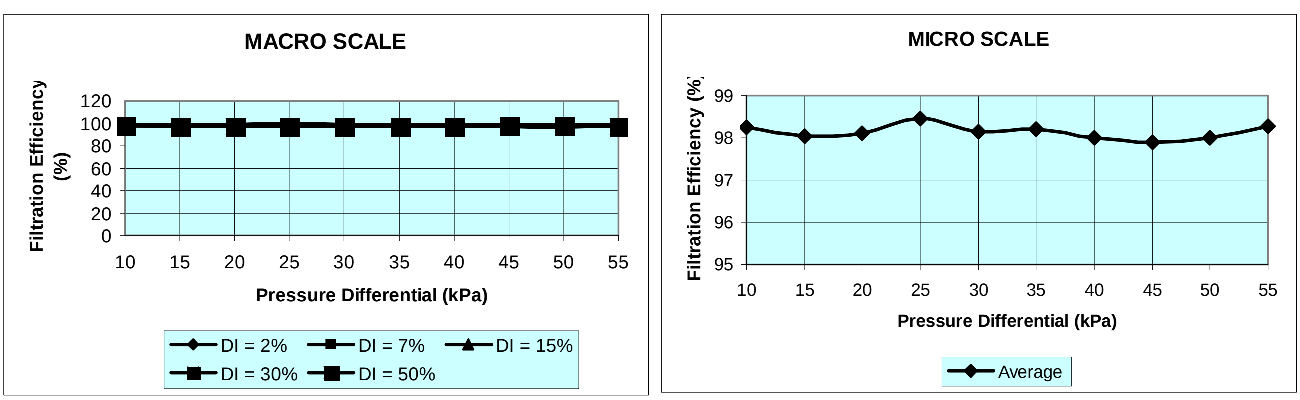


Fig. 4.13: Filtration efficiency of sand filters AS and DS

Only on a micro scale, it can be seen that there are changes in the filtration efficiency with increasing pressure differential across the filter and that more or less the same pattern is followed as was discussed with Fig. 4.5.

Results of the filtration efficiency tests

The biggest problem with a sand filter is the cleaning of the sand when the filter has clogged. It is impractical and actually impossible to clean the sand by hand and the only option next to replacing the sand is to backwash it. A very universally accepted norm is that the backwashing should take place at a flow-rate of 60 $(m^3/h)/m^2$ sand surface area. The tests done by the ILI-Hydrolabs was in the first place to check if this flow-rate does get a filter clean and in the second place to see at what minimum backwash flow-rate does one not get 100% cleaning of the filter any more. It was thus chosen to use the flow-rates and volumes that are tabled in Table 4.21 on both the sand filters that were tested for this project.

Results of the backwash efficiency tests

In Table 4.21, it can be seen that there is a slight difference between the results of the backwash efficiency tests of the filters. For instance can it be seen that the one filter needed a flow-rate of 60,2 $(m^3/h)/m^2$ sand surface area to maintain a backwash efficiency of 91% whereas the other filter needed only 43,2 $(m^3/h)/m^2$ sand surface area to get the same.

The way the tests were done was by lowering the backwash flow-rate until a decrease in backwash efficiency was observed. At that flow-rate, compressed air was added to the backwash water to see if the backwash efficiency would turn back to 100%. This flow-rate was established for each filter and in the table; it is shown what the backwash efficiency at this flow-rate will be with and without air for each filter. It can thus be assumed that all flow-rates above that one will clean the filter 100% with or without air and all flow-rates below that will not clean the filter 100%, even with air.

Table 4.21: Backwash test results on the two sand filters AS and DS

Backwash flow-rate [$(m^3/h)/m^2$]		**Backwash flow-rate (m^3/h)**		**Backwash volume (m^3)**		**Air (yes/no)**		**Backwash efficiency (%)**	
AS	**DS**	**AS**	**DS**	**AS**	**DS**	**AS**	**DS**	**AS**	**DS**
	86.5	60	60		6		Yes		100
60.2	57.6	40	40	4	4	**Yes**	Yes	100	100
60.2	43.2	40	30	4	3	**No**	**Yes**	91	96
45.1	43.2	30	30	3	3	No	**No**	87	91
30.1	28.2	20	20	2	2	No	No	63	69
15.0	14.4	10	10	1	1	No	No	35	33
Surface (m^2)		0.665	0.694						

Comments on the comparative tests of two sand filters

The only actual difference between the two sand filters is their under drains. Filter AS uses rosettes mounted on a network of drainage pipes while filter DS uses a network of perforated fingers as under drain. It can be assumed that the efficiency of backwashing is equal to the uniformity of water movement through the sand and that is mainly determined by the type and construction of the under drain.

4.3.2.2 **The effect of the sand depth in the filter on its filtration and backwash efficiencies**

Uncertainty exists on what the minimum sand depth in a sand filter should be to still have good filtration and backwash efficiencies on a sand filter and what the influence of the pilot disc filter after the sand filter is on the filtration efficiency of the combination. A test was designed to look into these questions. The general standard in South Africa with sand filters is that a sand depth of about 360 mm is used. For this test, sand was placed in the filter to one-third, two thirds and to its full depth and a series of tests were conducted.

Table 4.22: The effect of sand depth and a pilot disc filter on the filtration and backwash efficiencies of a sand filter

Factor	**Efficiency (%)**					
	One third depth		**Two thirds depth**		**Full depth**	
Pilot filter	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**
Filtration	97	96	98	98	99	98
Backwash	74	85	71	84	71	89

From Table 4.22 it is clear that the depth of sand has a small effect of about 2% on the filtration efficiency of the filter (from 97% to 99%). At full sand depth there was a reduction in the backwash efficiency (71% compared to 91% in Table 4.21). There are two reasons for that. One reason is that a lower backwash flow-rate was used during the tests and because of the fact that sand was “added onto a used sand surface”, dirt got trapped at a deeper depth as would have been the case if a full sand depth would have been used from the start (out of a practical viewpoint the tests were started with a third sand depth in the filter, then filled to two thirds and lastly with full depth). There was no difference in the filtration efficiency with or without the pilot filter witch is correct because it has a 200 µm element compared to the 80 µm of the sand filter.

The backwash efficiency also stayed the same for the different sand depths, but the pilot filter had, contrary to the filtration efficiency, a positive effect on the backwash efficiency (71% as opposed to 85%). A possible explanation for that is the following: when the air that is used to help with the backwashing of the filter is introduced, it stays in big bubbles that do not mix effectively with the backwash water. In these tests, the air was introduced at the far end of the pilot filter from the sand filter, which means that it has first to go through the element of the pilot filter before it reaches the sand filter. During this process, the big bubbles burst and while passing through the element of the pilot filter it gets mixed with the backwash water. When reaching the sand, the air is much better distributed in the backwash water and the backwashing is done more efficiently.

Another big difference that different sand depths make is in the friction loss of the filter. Fig. 4.14 illustrates it clearly.

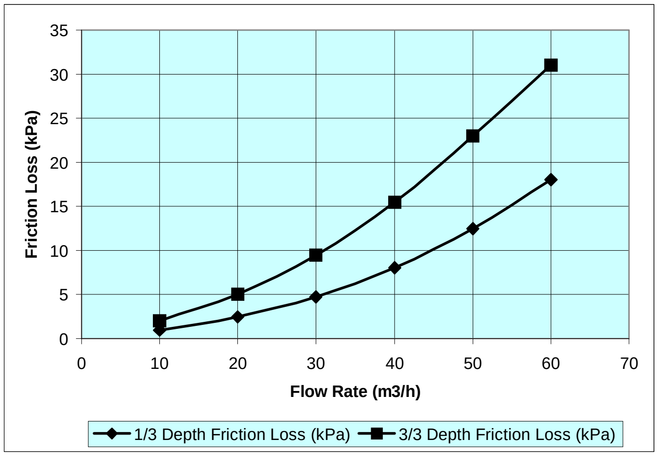


Fig. 4.14: The effect of the sand depth in a sand filter on its friction loss

4.3.3 **Automatic (screen) filters**

Three automatic filters were supplied for lab tests for this project. One was a specially adapted disc filter to act as an automatic filter when used in a filter bank of two or more filters. The model that was supplied contained three filters. The other two were full automatic screen filters that make use of a sucking mechanism inside the screen to clean it.

General performance characteristics

With automatic filters, the filtration efficiencies can be measured in the same way as for the other filters. The problem comes when backwashing efficiency must be measured. For the non-automatic filters, a series of tests can be done where the filters are firstly hand-cleaned and then backwashed and the results of these two sets of tests can be used to calculate the backwash efficiency. With automatic filters this method is not possible because of the fact that an automatic filter can not firstly be treated as a manually operated filter and then as an automatic filter. A different method to compare the backwashing efficiencies of the filters had to be found and it was decided to calculate the volume of water that the filter has used to backwash over a period of time as a percentage of the volume of water that the filter has cleaned over the same period of time and to use these figures of the filters to compare the backwash efficiencies of the filters.

Results of the filtration efficiency tests

In Fig, 4.15 the filtration efficiency results of the three automatic filters are summarised. Filters BC and CC are screen filters and Filter ED is the adapted disc filter.

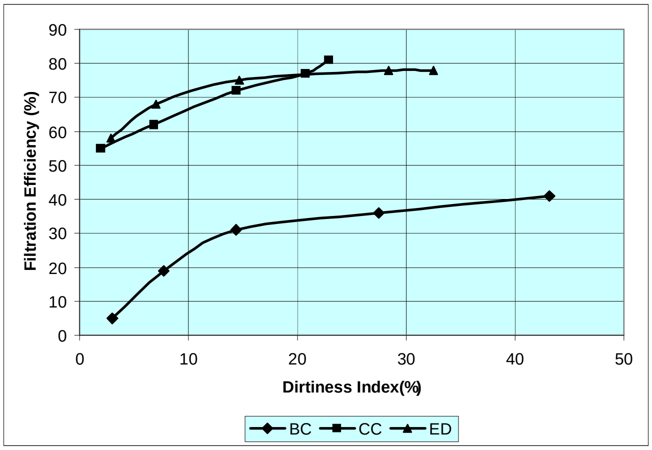


Fig. 4.15: Filtration efficiency test results on the automatic filters

The filtration efficiency of filter BC is typical of screen filters; although filter CC shows that, there can be extreme exceptions. The average filtration efficiency of filter BC was 26,4%; filter CC was 69,4% and filter ED was 71,4%.

Results of the backwash efficiency tests

In Fig, 4.16 the backwash water percentages are given for the three automatic filters. Filters BC and CC are screen filters and Filter ED is the adapted disc filter.

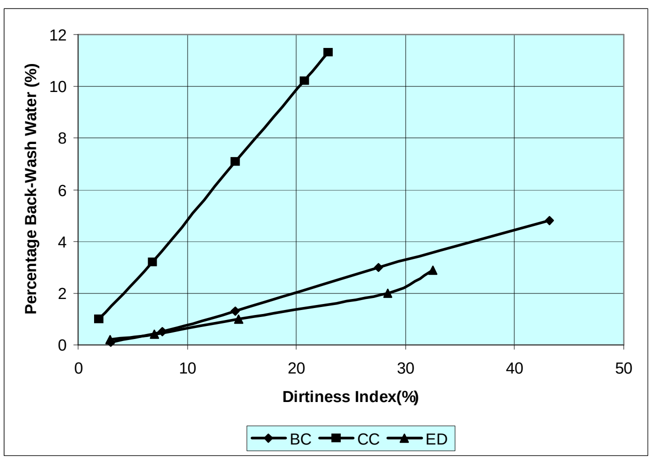


Fig. 4.16: Backwash water percentages test results for the automatic filters

Comments on the comparative tests of the three automatic filters

As seen in Fig. 4.16 not all the filters could be tested to the same level of water dirtiness in the water because they stopped operating at those dirt levels and this is especially true for the full automatic filters. Filter CC shows a very high usage percentage of backwash water, but it can very well be explained by its very high filtration efficiency. Because of this, it removes more dirt from the water than the other filters with the lower filtration efficiencies and therefore it has to use more water for backwash. The average backwash water percentage of filter BC was 1,94% ; filter CC was 6,56% and filter ED was 1,30%.

4.3.4 **Other observations during the laboratory tests**

During the tests on the disc filters, some other aspects were also looked at. Although these tests were only done on one disc filter (Filter HD), experience has shown that these observations are generally applicable to any other filters.

4.3.4.1 **The effect of the flow-rate through a filter on its filtration efficiency**

If the flow-rate through a filter is increased to more than the recommended flow-rate at a friction loss of 5 kPa (30 m^3/h), the filtration efficiency is reduced. In Fig. 4.17 it is illustrated what happened when the flow-rate was increased to the 10 kPa friction loss flow-rate level (50 m^3/h).

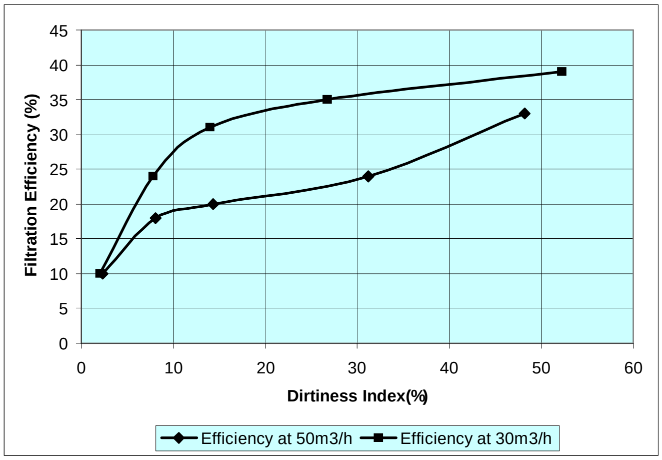


Fig. 4.17: The effect of flow-rate on filtration efficiency

4.3.4.2 **The effect on the filtration efficiency of a filter when its rated fineness is changed**

All the filtration efficiencies that were tested and illustrated so far during the discussions were all tested against <u>the manufacturers of the filters' rating</u> of the fineness of their filters. Different manufacturers have different ways of establishing the fineness of their filters' elements and there is no standard procedure available according to which these ratings can be established. The HD filter that was tested is rated at 225 µm. If the manufacturer would have rated it at 300 µm, then the filtration efficiency would have been tested against 300 µm and then the filtration efficiency of the HD filter would have been the same as is illustrated in Fig. 4.18.

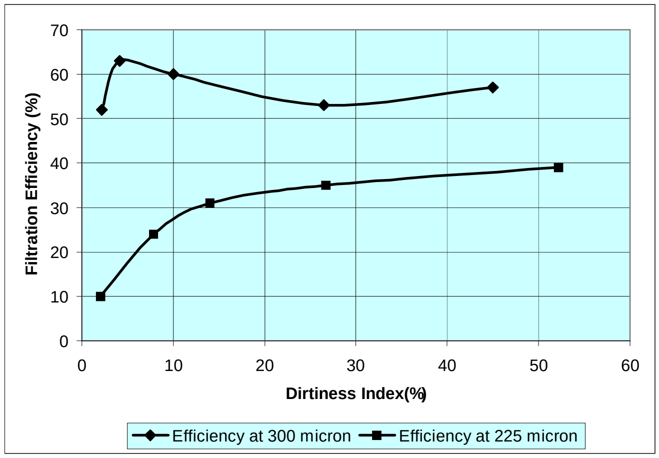


Fig. 4.18: Effect of different ratings of the fineness of a filter's element on its filtration efficiency

Comments on the rated fineness of filter elements

Throughout the world, irrigation test laboratories are presently searching for a standard test method according to which the actual fineness of filter elements could be established. The methods that are being researched will also only be applicable to disc and screen elements and possible on sand filters. The ILI-Hydrolab can at this moment already render a method according to which such a service could be given to manufacturers. It comes down to testing the filtration efficiency of a filter with increasing or decreasing fineness of the screens that are used in the dirtiness index meters until such a test is reached where the filtration efficiency is equal to or more than 95%.

4.4 **Matching the laboratory test results with the field test results**

As was discussed in section 4.3.1.1 under general performance characteristics one could see that it is very difficult, especially with disc filters, to compare test values. In Table 4.23, a comparative summary is given of the field measurements and the laboratory measurements on the different filters.

Table 4.23: Comparing the field test results and the laboratory test results

Filter	Dirtiness Index	Filtration efficiency (%)		Comments on reasons why field values differ from lab values
		Field	Lab	
AS	0 – 5	87	99	Too high pressures over field filters.
	5 – 10	83	99	
	10 – 15	90	99	
	15 – 20	87	99	
BC	0 – 5	33	5	Filter operated at a lower pressure than prescribed. Backwash do not clean element completely. Element largely clogged. Read section 4.3.1.1.
	5 – 10	–	18	
	10 – 15	–	28	
	15 – 20	–	35	
CC	0 – 5	75	55	Manufacturer's fineness rating might differ from the rating it was tested against. Read section 4.3.4.2.
	5 – 10	88	72	
	10 – 15	85	76	
	15 – 20	–	76	
DS	0 – 5	>90	98	Good correlation because the field tests were stopped out of practical considerations before the actual readings could be taken. (Time-out).
	5 – 10	>90	98	
	10 – 15	>90	98	
	15 – 20	94	98	
ED	0 – 5	73	63	Good correlation seeing that this is a disc filter. Read section 4.3.1.1.
	5 – 10	66	77	
	10 – 15	–	80	
	15 – 20	86	80	
FD	0 – 5	26	41	Good correlation seeing that this is a disc filter. Read section 4.3.1.1.
	5 – 10	38	37	
	10 – 15	25	39	
	15 – 20	–	41	

5. CONCLUSIONS

5.1 Reaching the Project Objectives

The purpose of this project was to determine the filtration efficiency and backwashing management of the different types of filters under different water quality conditions, as found under the different on-farm irrigation practices as the producer operates it to maintain the irrigation system, including the filter station. The filters performance was therefore tested in the ARC-Hydrolab, as well as in the field. The end result was the creation of guidelines for the choice and operation of filters with regard to water quality and maintenance requirements. The guidelines give specific information regarding to:

- Matching the filter type with the water quality and the irrigation system
- Choice of equipment
- Upstream side of the filter station
- Design principles with respect to:
  - Filtration
  - Backwashing
  - Sizing of a filter
- Commissioning of filters
- Operation of filters
- Maintenance of filters

The Dirtiness Index Meter was used to determine the dirtiness index (DI) of the water. The DI of the different water sources ranged from clean (DI < 1) to very dirty (DI = 43%). The field evaluation results proof that sand filters have higher filtration efficiencies than disc and screen filters. The operating pressure of the irrigation systems adhered to the minimum and maximum allowable pressure values according to the manufacturers. The measured flow-rates exceeded the recommended flow-rates only by six occasions due to management problems.

When low filtration efficiencies of the sand filters are experienced in the field, it can normally be due to problems with the sand replacement frequency and management problems, for example, extremely high pressure drop over the filter station after backwash. When screen filters are found with low filtration efficiencies it are in some cases an indication that the screen is damaged. Disc filters with a low filtration efficiency value can be attributed to design problems, for example, a too high flow-rate through the filter, management problems, for example, a high pressure drop over clean filter station after backwashing and faulty backwash control system, as well as non-operational solenoids.

The backwashing management results proofed that the amount of water used during backwashing for the screen and disc filters were less than the volume usage for sand filters (Table 4.18C). The average volume of water per backwash per filter resulted in 0,14 m^3 for screen filters, 0.37 m^3 for disc filters and 1,63 m^3 for sand filters. However, the screen and disc filters backwash more regularly than the sand filters. The backwash flow-rate through the sand filters were in most cases within the manufacturer's recommendation. The pressure drop over some of the filter stations after the backwash, were above the SABI norms. The main reasons for the high pressure drop over some filters are faulty pressure gauges, the wrong choice of valves on the filter station, filters with discs that were so dirty that they needed to be cleaned manually with an effort and faulty backwash valves.

The following maintenance practices are considered very important:

- ❖ The weekly inspections for leaks on filter stations and the measurement of the pressure difference over filters are very important.
- ❖ The backwashing of filters on a pressure differential basis in order to prevent dirt from exiting the filter as a result of a too high pressure differential.
- ❖ The regular replacement of sand in sand filters to ensure a high filter efficiency at all times.

Many uncertainties about the real efficiencies of filters were cleared by the tests that could be performed under controlled conditions in the ILI-Hydrolabs on the major different types of filters. On average the filtration efficiency in the laboratory of the sand filters was 98.5%, the disc filters 57.3% and the screen filters 45.6% (from Table 4.23)

Much new knowledge that could be applied with great success when dealing with irrigation filters was gained. This includes:

- ❖ The actual filtration efficiencies of the different types of filter elements.
- ❖ The actual backwash efficiencies of the different types of filters which is influenced by:
  - The casing of the filter
  - The use of a pilot filter with a sand filter
  - The use of air with sand filters
  - The backwash flow-rate through a sand filter
  - The type of under drain of a sand filter

For the first time can the performance of filters be explained scientifically and the good correlation that was found with the field tests proved that the right tracks were followed during this project. It further proved that the test methods applied by ILI were correct and efficient. By executing so many series of tests on the filters the tests procedures were also refined and expanded and in this way, a very good basis was laid for future irrigation filter tests.

The uniqueness of irrigation filters was also demonstrated to show the big difference between irrigation and domestic filtration of water in that during irrigation filtration only the harmful part of the dirt is removed and the rest led through by an irrigation filter whereas a domestic filter has to remove all the dirt in the water. This basic difference between the two types of filtration is the reason why a completely different approach has to be followed for irrigation filtration in comparison with domestic filtration for which man in general has a much better understanding.

It was also clear from the testing of the total suspended solids (TSS) that it can not be used with confidence to determine the removal efficiency. The unique dirtiness index meter as developed by ARC-ILI give excellent results to quantify the dirt in the water in a practical way and to design the filtration system to cope with the specific water quality.

5.2 The Way Forward

A few aspects that were identified need attention:

- ❖ Irrigation technology exchange sessions should be presented in every region where the investigation was performed to reveal the research results. The sessions must include practical demonstrations to show the different filters filtration and backwashing abilities.
- ❖ A self-explanatory manual for farmers regarding the operation and maintenance of the different filters. The manual must include practical examples and photographs to practically demonstrate the maintenance schedules.
- ❖ A great need exists for the compilation for compiling of a code of practice, which describes the complete development process of an irrigation system at farm level and prescribes minimum acceptable standards for irrigation equipment and services.
- ❖ The fact that the filtration efficiency of the disc filters showed widely varying results, points actually to incorrect ratings by the manufacturers of their filters. Discussions will be needed with them on this subject and some form of standardisation will have to be found.

6. GUIDELINES

A huge amount of information was gathered with this project. Especially during the field visits, it became clear that too high pressure differences occur over the filters which in some cases is a result of flow-rates through the filters which are too high or in other cases attributable to poor backwash management of the filters. It is thus appropriate that guidelines should be given for the selection of the right size of filter for the system and the right backwash procedures and methods.

6.1 Guidelines for the Choice of Filters and Accessories

6.1.1 Matching filter type with water quality and irrigation system

The primary factor that determines what kind of filter must be used is in the first place the kind of system. Usually more than one type of filter will then be suitable and the choice between the possible filters is then based on the dirtiness of the water and the kind of dirt in it. With a mobile Dirtiness Index Meter, it is easy and advisable to go out and do a measurement of the water. Such a measurement will in the first place tell one what the dirtiness of the water is, but because of the fact that one can observe what kind of dirt was caught by the screen of the meter, it is also possible to know what kind of dirt is present in the water. Another factor that plays a role is the kind of backwash management that will be done on the filters once they are installed. From the dirtiness measurement and the filtration capacity tests, a filter station can be designed that has enough filtration capacity to match the kind of backwash management.

The type of filter and the fineness of the element will depend on the type of irrigation system for which it will be used.

- **Drip systems**

  Use sand filters with secondary disc filters, also known as control filters. The control filters serve as monitors of the sand filters to ensure that they operate efficiently and to act as safety filters if things should go wrong with the sand filters. If one irrigates from a borehole, disc filters with a filtration fineness of not more than 100 µm can substitute the sand and control filters.

- **Micro sprayer systems**

  Use disc and screen filters with a filtration fineness of not more than 15 of the outlet size of the micro sprayers. Disc filters typically have a filtration fineness of 200 µm, and is thus suitable for most micro sprayers.

- **Floppy systems**

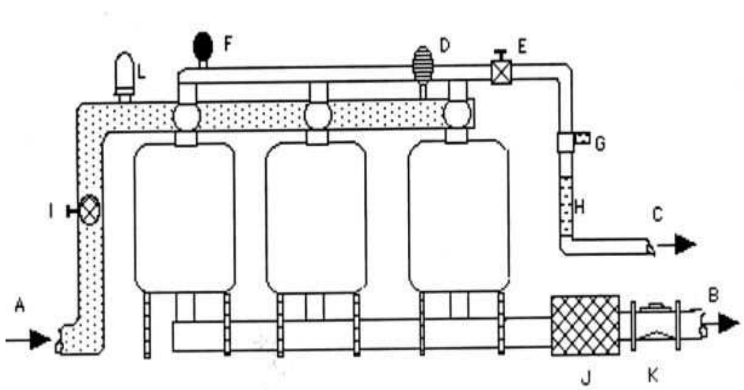
  The smallest model of the Floppy sprinkler has a discharge flow-rate of 700 ℓ/h, which places it in the same category as a large micro sprayer. All Floppy sprinklers are equipped with flow regulators. At no pressure, the minimum flow area size is 2,8 mm, but at 300 kPa it reduces theoretically to 0,8 mm and at 700 kPa to 0,6 mm, which is less than that of a dripper. This means that if Floppy sprinklers were used at high pressures, it would be recommended that sand filters should be used.

6.1.2 **Choice of equipment**

Only irrigation filtration units from reputable irrigation companies must be used and preferable those filtering units that have been tested by an independent testing laboratory. Full specifications and design parameters must accompany the equipment.

6.1.2.1 **Accessories for the sand filter station**

Large particles present in the water content will usually be inorganic sands or organic materials such as algae. Inorganic particles are usually heavy and can easily be removed by a settling basin. Organic materials are lighter and must be removed by sand filters. Floating materials may be skimmed from the water surface. Accessories for the filter station must be reliable to ensure the protection of the filter station and the irrigation system.



A – Irrigation water source
B – Clean water to irrigation system
C – Backwash water disposal
D – Combination Air valve
E – Backwash flow-rate adjustment valve
F – Vacuum release valve
G – Sighting port
H – Clear plastic tube
I – Rinse valve
J – Disc / screen filter (200 µm)
K – Pressure sustaining valve
L – Pressure release valve

Fig. 6.1: Typical layout of three sand filters with accessories (adopted ed. From Burt & Styles, 1994)

Some of the accessories for the sand filter station are essential, and others are optional. Essential accessories referred to in Fig. 6.1 are:

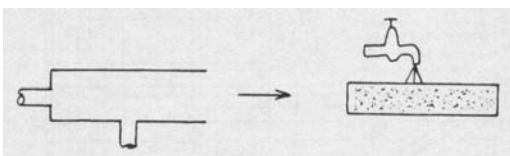
- Backwash flow-rate adjustment valve, E
- There are ways to determine if the backwash water is dirty or clean and if there is sand loss during backwash. This may include:
  - A backwash discharge line end, C, which is exposed to the air and is accessible. If the discharge line is too long, too small or goes uphill to the extent that it is impossible to develop enough backwash flow, the backwash valve must be re-adjusted.
  - A specially designed sighting and sampling port, G, which continually passes a portion of the backwash flow through a small attached glass jar which allows the operator to view if the backwash water is dirty or clean.
  - A section of clear plastic in the backwash line, H, which should be covered to protect it from sunlight damage.
- A secondary disc/screen filter, J, located downstream of the sand filter to prevent dirt from clogging the emitters if the sand filter should fail.

- A combination air valve, D, located at the downstream end of the supply manifold. The combination air valve has a kinetic as well as automatic function, so it releases small, as well as large volumes of air when necessary.
- A vacuum release (kinetic) valve, F, located at the upstream end of the backwash manifold. This valve will release large quantities of air during the filling of the system.
- A pressure release valve, L, located upstream of the filters discharges excessive pressure to the atmosphere and thereby protecting the filters against sudden pressure increases.
- A pressure sustaining valve, K, located downstream of the filters. The function of the valve is to maintain a minimum pre-set upstream pressure irrespective of changes in pressure and flow through the system to ensure that enough pressure is available for the filter to backwash and to meet the minimum pressures specified by the manufacturers.

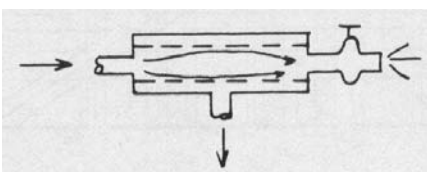
6.1.2.2 **Screen filter stations**

Screen filters can be cleaned in three ways (Van Niekerk, 1983):

- **Removal of the element**

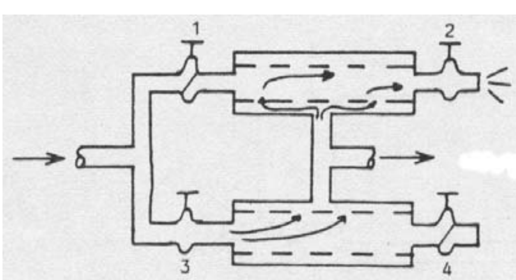


- **Flushing of the filter**



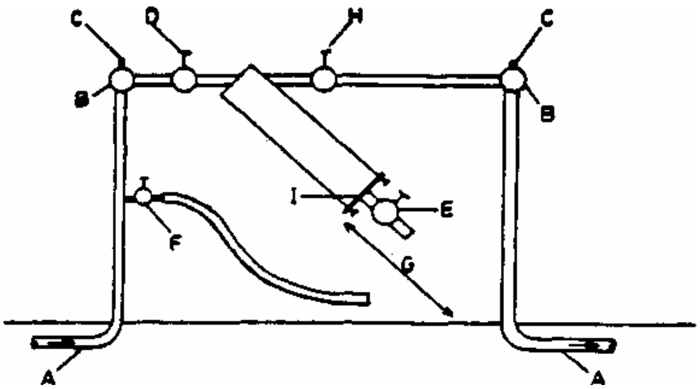
- **Backwashing of the filter**

To backwash the other filter, open valves 1 and 4 and close valves 2 and 3.



6.1.2.3 **Disc filter stations**

The casings of some disc filters are not equipped with backwash valves and to clean them, as in the case of the screen filters, their elements must be removed. To ensure that no dirt enters the irrigation system when the filters are cleaned, the following installation method and cleaning procedure is recommended (Van Niekerk, 1983):



A = Pipe line
B = Manifold for parallel installation of filters
C = Pressure measuring points
D = Cut-off valve
E = Waste water valve for flushing or back washing water
F = Small tap and hose pipe for cleaning the elements
G = Leave enough room so that the element can be removed beneath the filter
H = Cut-off valve
I = Removable lid

Management of the filters

A. Filters that can be flushed
1. Open valve E and close valve H. (The filter is flushed with unfiltered water.)
2. When the water form valve E is clean, close E and open valve H.
3. Repeat the process for the other filter(s) and continue with filtration.

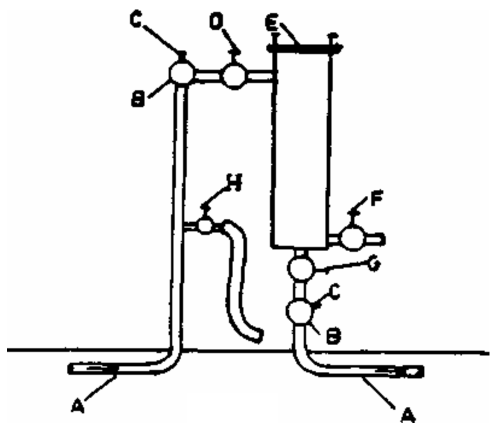
B. Filters that can be backwashed
1. Open valve E and close valve D. (The filter is backwashed with the filtrated water from the other filters.)
2. When the water from valve E is clean, close E and opens valve D.
3. Repeat the process for the other filter(s) and continue with filtration.

C. Removal of the filtering element
1. Open valve E and flush out the worst dirt.
2. Close valves D and H (The filter is totally isolated)
3. Loosen lid I and remove the element.

4. Clean the element with the hose or replace it with a clean element if available.
5. Put the element back, close valve E, open valves D and H and continue with filtration.
6. Repeat the process for the other filter(s).

Remark: If valves D, H and E are replaced with hydraulic valves procedures A and B can be done automatically with additional equipment.

In the cases where the filters are equipped with backwash valves:



A = Pipe line
B = Manifold for parallel installation of filters
C = Pressure measuring points
D = Cut-off valve
E = Removable lid
F = Drainage valve and waste water valve for flushing or backwashing water
G = Cut-off valve
H = Small tap and hose pipe for cleaning the elements

Management of the filters

A. Filters that can be flushed
1. Open valve F and close valve G. (The filter is flushed with unfiltered water)
2. When the water from valve F is clean, close F and open valve G.
3. Repeat the process for the other filter(s) and continue with filtration.

B. Filters that can be backwashed
1. Open valve F and close valve D. (The filter is backwashed with the filtrated water of the other filters.)
2. When the water from F is clean, close F and open valve D.
3. Repeat the process for the other filter(s) and continue with filtration.

C. <u>Removal of the filtering element</u>

1. Open valve F and flush out the worst dirt.
2. Close valves D and G.
3. Loosen lid E, let all the water in the filter drain through valve F and remove the element.
4. Clean the element with the hose or replace it with a clean element if available.
5. Put the element back, close valve F, open valves D and G and continue with filtration.
6. Repeat the process for the other filters.

Remark: If valves D, F and G are replaced with hydraulic valves, procedures A and B can be done automatically with additional equipment.

6.1.3 **Upstream side of the filter station**

6.1.3.1 **Pumps**

- ❖ The suction pipe of the pump must be deep enough beneath the water level to prevent a vortex being formed and air sucked in. In cases where surface water is utilised, suction pipes must be attached to a float to ensure that the higher quality water for irrigation is withdrawn near the water surface. Directives are given in Table 6.1, for the minimum water depth above the suction pipe inlet, according to the inlet flow velocity of the water in the suction pipe.

Table 6.1: Minimum water depth above suction pipe inlet

Inlet flow velocity (m/s)	Minimum water depth (m)
1,0	0,5
2,0	1,1
3,0	2,0

- ❖ It is also important that the distances, as shown in Fig. 6.2 are maintained in the pump hole.

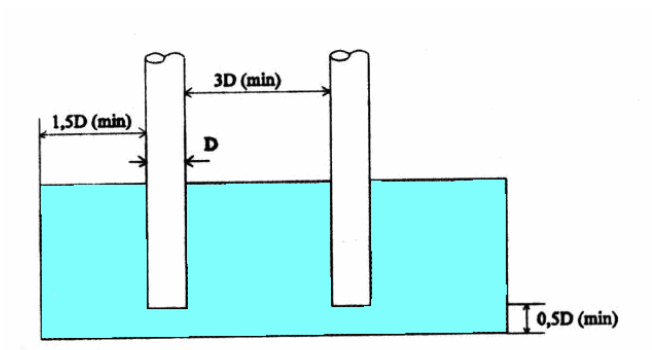


Fig. 6.2: Minimum distances between suction pipes and sides, and bottom of pump hole

- ❖ Bell-shaped inlets are recommended, because they have the benefit that the flow speed at the inlet is low and that sand and stones cannot be sucked in as easily.
- ❖ Free-area of foot valves must be at least 1½ times the suction pipe diameter. Where suction head is a limiting factor, foot valves, which usually result in a high friction loss, must be avoided.

- ❖ The free area of the screen before the suction pipe must be at least four times that of the suction pipe to prevent alien materials from blocking the foot valve. Guide screens must be mounted at least eight times the suction pipe diameter in front of the suction eye of the pump to prevent turbulence causing cavitations. If it is necessary to mount the screen closer to the pump, a stream aligner must be mounted.
- ❖ Screens must have holes with a diameter of 6 mm to 12 mm and the total area of the holes must be six times that of the suction pipe area.
- ❖ Water supply to the pump hole must also be such that it does not cause the suction pipe to suck in air. It is especially a problem where the pump hole is fed by another pipeline. In that case the supply pipeline must be placed away from the suction pipe, so that the suction pipe does not suck in air bubbles that form when the water enters the pump hole.
- ❖ Suction pipes or drainage pipes must fit naturally and not be forced in by means of flange bolts. It must also be supported independently near the pump so as not to place stress on the pump casing.
- ❖ A foot valve's open area must be four times that of the open area of the suction hose, thus ensuring that the velocities through the foot valve does not exceed those of the suction hose by more than 25%. The following is proposed:

Suction hose (absolute maximum)	$\leq$ 1,5 m/s
Suction strainer	$\leq$ 0,4 m/s
Maximum permissible velocity in filter station manifold	$\leq$ 0,5 m/s

6.1.3.2 **Sedimentation and aeration**

In cases where the irrigation water contains solid particles in suspension in excess of 200 parts per million (DI = 900%), it is advisable to have a settling basin where the particles can be sedimented before the water is filtered. This will prevent an overload on the filter as well as excessive backwashing of them.

The following points are important when settling basins are used.

- ❖ The outlet of the basin should be as far as possible from its inlet.
- ❖ The backwash water from the filters should be dumped as far as possible from the inlet (preferably not back into the basin)
- ❖ It must be possible to clean the basin with the minimum effort.
- ❖ Water for filtration should be drawn from the upper layer of the dam (suction pipe mounted on float).
- ❖ A long, narrow settling basin is more effective than a square one.

Where there is iron in the water, it necessary to aerate the water so that the iron may oxidise. The iron oxide will then sedimented in the basin and the water for irrigation may be drawn off from the surface of the basin.

6.2 Design Principle Guidelines for Filters

6.2.1 Filtration

The following design guidelines are recommended:

- ❖ Filtration degree
  - – If a sand filter is used, there must be a 200 µm control screen/disc filter downstream of the sand filter.
  - – For micro sprayer irrigation, it is recommended that disc/screen filters openings must be 1/5 of the micro sprayer orifice diameter. The appropriate micro sprayer manufacturer's recommendations must be used for flow-path openings of ≤ 1 mm.
- ❖ The maximum allowable flow-rate through a clean sand filter must be ≤ 50 m^3/h per m^2 of the filter sand surface.
- ❖ The recommended maximum allowable pressure difference over the different types of filter/filter station, are as follows:

Table 6.2: Maximum allowable pressure differences over the filters/filter stations

Type	Clean water (kPa)		Maximum pressure build-up (kPa)	Pressure difference before backwashing (kPa)	
	Filter	Filter station		Filter	Filter station
Disc/Screen filter	10	30	40	50	70
Sand filter	10	40	20	30	60

The filter station includes all the fittings, valves and in the case of a sand filter-station, the secondary filter as well.

6.2.2 Backwashing

- ❖ At least 50% of the maximum filtration rate (50 m^3/h per m^2 sand surface) is necessary to backwash sand filters effectively. The maximum backwashing rate must not be more than 1,2 times the filtration rate.
- ❖ A minimum inlet pressure of 6 m (60 kPa) during backwashing is required.

6.2.3 The size of a filter

The size or number of filters required for a specific irrigation system in a certain area under a particular type of management depends on the following factors:

- ❖ The flow-rate which each filter will have to handle
- ❖ The dirtiness of the irrigation water
- ❖ The total pressure drop which can be allowed across the filter (consisting of the pressure drop across a clean filter plus the additional pressure drop for possible blocking of the element)
- ❖ The minimum cycle required for the cleaning of the filters

6.2.3.1 **The allowable flow-rate through a filter**

The faster the water flows through the filter, the more friction loss will occur across the filter. For economic and physical reasons, this loss obviously has to be restricted. The following guidelines can be followed:

- For dirty water (DI > 1%) – a maximum loss of 10 kPa across a clean filter. This loss can be allowed to increase to a **maximum** of 50 kPa (30 kPa for sand filters) due to blocking of the element, but the actual allowable increase will be determined by the hydraulics of the irrigation system, as will be discussed later on. If the 50 kPa limit is exceeded, it could lower the efficiency of filtration drastically.
- For clean water (DI < 1%, like borehole water) - a maximum loss of 30 kPa across a clean filter and the maximum limit of 50 kPa across a dirty filter.

To determine what the loss across a clean filter will be when a specific irrigation system's water moves through it, the friction loss curve of the filter should be consulted. Please note that where two or more parallel filters are used, the total flow-rate of the system must first be divided by the number of filters. The friction loss resulting from this flow-rate can then be read from the friction loss graph. If the friction loss exceeds the above limits, it means that the flow-rate is too high for the filter and that a larger filter or additional filters should be chosen.

6.2.3.2 **The dirtiness of the irrigation water**

Fig. 6.3 is the friction loss graph of the Silicon ll sand filter. According to the previous paragraph, the recommended flow-rate for this filter would be 33 m^3/h because this is the flow-rate that gives a friction loss of 10 kPa over the clean filter.

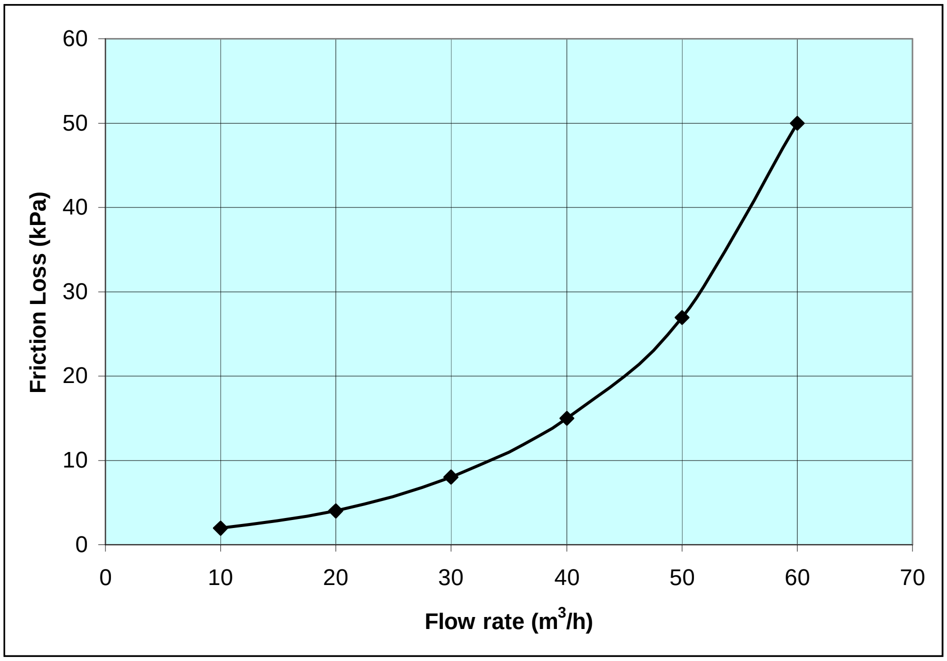


Fig. 6.3: Friction loss graph of the Silicon ll sand filter

Fig. 6.4 is the dirty water capacity graph of the Silicon ll sand filter. It must be interpreted as follows: If a pressure difference increase of only 20 kPa is allowable over the filter (as is the case for sand filters) and if the irrigation system can supply it (see 6.2.4.3 hereafter), then it means that the filter can clean only 30 m^3 of water before it must be cleaned again with a DI of the water equal to 10% for example.

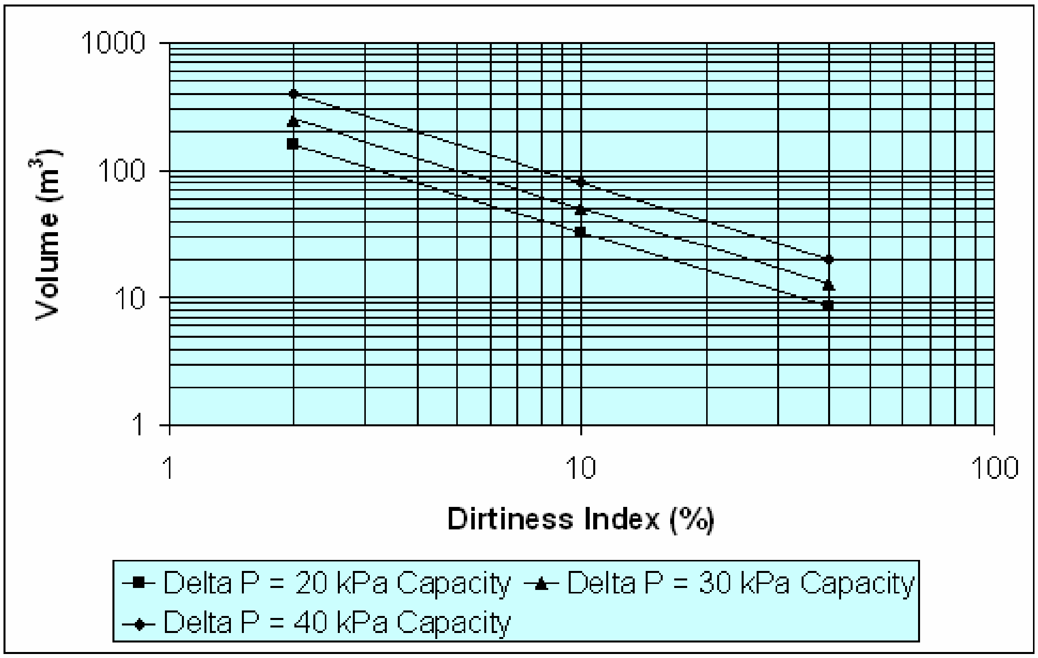


Fig. 6.4: Dirty water capacity graph for the Silicon ll sand filter

With an allowable volume of 30 m^3 and an allowable flow-rate of 33 m^3/h, it means that this filter will be clogged in less than one hour. If the farmer has to clean his filters manually (his type of backwash management), it can be very impractical if he has to clean his filters every hour. It might be more practical to clean the filters every six hours. If this is the case, he will need six Silicon ll filters in his filter station to give him enough filter capacity for his backwash management style.

6.2.3.3 **The total pressure drop allowed across a filter**

When the internal losses of an irrigation system increase, for e.g. due to a filter starting to block, the delivery of the system will start decreasing. The delivery should not be allowed to decrease too much, and a maximum decrease in delivery of 10% can be taken as a good norm. As soon as it decreases with more than 10%, one will find that the distribution is disproportionate. The size of the internal losses, which accompany the 10% decrease in flow, is unique to each system and can be calculated from the system's hydraulics, as illustrated in Diag. 6.1.

To determine what additional losses the irrigation system can absorb without impairing the efficiency of the system, the pressures of the system are calculated from the pump up to the filter, and then again from the dripper (if it is a drip system) backwards until directly behind the filter. (In the graph, it would thus be from left to right up to the filter, and then from right to left up to the filter.

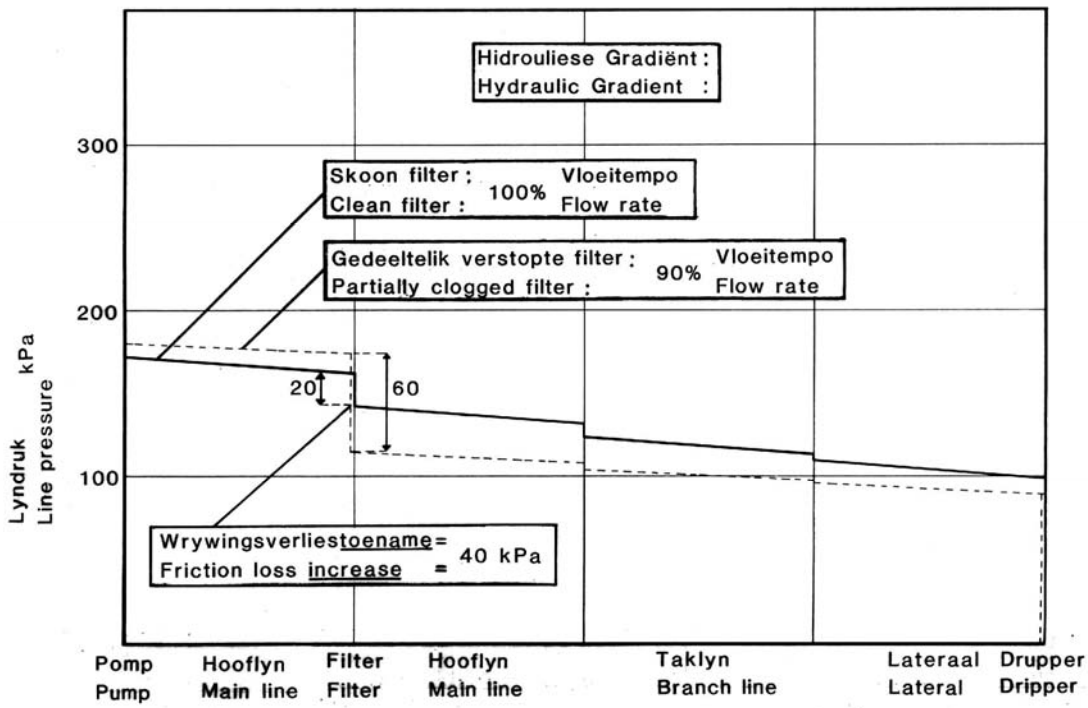


Diagram 6.1: Permissible friction loss increase over a filter

The calculation is done for 100% flow (clean filter) and for 90% flow (dirty filter). The first calculation will thus, for e.g., show a pressure drop of 20 kPa across the imaginative filter, and the second calculation a pressure drop of 60 kPa. This means that the system can absorb an additional 40 kPa pressure drop across the filter without affecting the efficiency of the system adversely. Keeping in mind that the total recommended pressure drop across the filter is only 50 kPa, it means that only 30 of the 40 kPa can be utilised by the filter because the initial loss was already 20 kPa, as can be seen in the diagram.

6.2.3.4 **The cleaning cycle of a filter**

As a filter filtrates dirty water, the pressure drop across the filter increases, as was previously indicated. The more the pressure drop across a filter can be increased, the more water will be filtrated. This pressure drop cannot, however, be increased to an unlimited degree and should preferably be limited to 50 kPa (30 kPa for sand filters) for the following reasons:

- If the pressure drop increases too much, the dirt will after a while be forced through the element and the efficiency of filtration will start decreasing.
- With certain filters, the element may give way if the pressure drop becomes too much, and a concentration of dirt (which has in the meantime built up in the element) will enter the system and most likely immediately block the system.
- Elements that get often blocked under a too high pressure drop become more difficult to clean, and the efficiency of backwashing is drastically reduced.

If the dirtiness of the water is known, as well as the additional pressure drop, which can be allowed across the filter for blockage, then the dirtiness capacity graph of the filter can be used to determine how much water a filter will clean under the given circumstances. If the quantity of water that a filter can clean is known, as well as the flow-rate at which the filter operates, the time it will take the filter to filtrate this given quantity, can be calculated, and this time constitutes the cleaning cycle of the filter.

With very dirty water it can however happen that if a filter is chosen on the basis of what has been discussed up till now, it will result in a very short cleaning cycle. The only way to elongate an impractical short cleaning cycle is to make use of larger or additional filters in parallel so that their common cleaning cycle can be lengthened to a practical time, and **this decision will mainly have to be made by the farmer or the manager of the filters**. It will also lower the flow-rate per filter, and the friction loss across each individual clean filter will be less than 10 kPa, as was previously advised. This, however, is not of importance in this case because **the dirty water capacity of the filter now becomes the main consideration and not the flow-rate through the filter any more.**

In the case of very dirty water, combinations of different filters are many time necessary and Table 6.3 gives guidelines of how to choose and combine them.

6.3 Guidelines for the Commissioning of Filters

During the commissioning of a new filter station, some specific steps have to be followed in a definite sequence and one step can not be taken before another is finished. For every situation, its own set of steps is valid, but in general, the following order of steps will be mostly the correct approach:

- See that all pipe connections, hydraulic pipe and electrical connections are in place.
- When electronic meters are used, they must be tested manually first for operationality. Remove the pressure sensor from where it is mounted and put pressure on to it by blowing it up with your mouth and check if the display reacts. Take the flow meter mechanism out of its casing, blow onto the impellor, and check if the display reacts.
- When a computer or any other electronic device is connected to the instrumentation, check if there is communication between them.
- Check if the elements of the filters are in place and well fastened.
- Check if all pipe and electrical connections are in place at the pump and if the water supply is in place.
- Close the valve after the pump and start the pump.
- Open the valve very slowly and only partially at first so that the system can fill up slowly.
- Check for water leaks and if there are leaks, close the valve first, switch off the pump, and repair the leaks first.
- Try again and let the water flow slowly for a while whilst the functionality of the station is tested in full.
- Open the valve fully, bring the system to full pressure, and do all checks again. Leave it on for an hour or so to check its stability.
- Put the system in use and check if all controls and programmes work, as they should.
- Keep a close eye on it for at least a month to make sure, if everything is working well in the long run.

Table 6.3: Filter selection guide – Quick reference (Adopted from Bruce, 1985)

Flow-rate	Solids concentration		Product (s) recommendation
	Inorganic	Organic	
Less than 11,4 m^3/hr	L	L	A
	L	M	C + A or B
	L	H	C + A or B
	M	L	D + A
	M	M	C + D +A or B
	M	H	C + D + A or B
	H	L	D or D + A
	H	M	C + D + A or B
	H	H	C + D + B
11,4-45,4 m^3/hr	L	L	B
	L	M	C + B
	L	H	C + B
	M	L	D or B or D + B or <u>D + B</u>
	M	M	C + D or F or <u>D + F</u>
	M	H	C + F or C + D + F or <u>C + D + F</u>
	H	L	D + B or F or <u>D + F</u>
	H	M	C + D + F or C + F or <u>D + E</u>
	H	H	C + D + F or <u>C + D + F</u>
Greater than 45.4 m^3/hr	L	L	B
	L	M	C + F or E <u>only</u>
	L	H	C + F or E <u>only</u>
	M	L	D + B or D + F or E <u>only</u>
	M	M	C + F or C + D + F or E <u>only</u>
	M	H	C + B or C + D + F or <u>C + E</u>
	H	L	D + B or D + F
	H	M	C + D + F or C + F or <u>D + E</u>
	H	H	C + D + F
Solids Concentration Code: L – Less than 5 ppm M – 5-50 ppm H – More than 50 ppm		Recommendation Product Code: A – Strainer B – Screen/Disc Filter C – Suction Screen Filter D – Suction or Discharge Separator E – Gravity Screen Filter F – Sand Filter	

<u>Underlined options</u> above indicate potential Pump Protection systems to minimize abrasive pump wear.

6.4 Guidelines for the Operation of Filters

The theoretical backwashing cycle can be calculated as shown in par. 6.2.4.2. This is, however, just a theoretical time and it must be monitored at first to see if it is applicable in practice. The cycle can change during the season as the water quality changes and this can easily be established by taking regular DI measurements of the water throughout the year. The same tools that were used to establish the theoretical cycle, can be used to make corrections to it. If the water is very clean, backwashing should be done once daily to prevent sedimentation of the sand-bed. Stirring the sand with the hand can elevate sedimentation. It may sometimes be necessary to replace the sand. Bacterial growth on the sand sometimes leads to sedimentation of the sand, resulting in tunnel forming. The bacteria growth can be prevented by means of chemical treatment of the water.

The backwashing duration must be lengthy enough to remove all impurities from the filter. A backwashing duration of at least 60 seconds is mostly recommended. It is, however, good practice to physically backwash the filter, and monitoring the time, it will take until all the discolouring and alien material disappears from the water. It is also very important to take a sample of the backwashing water with a clean container before the backwashing process is completed and to inspect it to ensure that it is clean. The evaluation and setting of sand filter backwashing times must be done regularly. If the duration is too short, or the flow-rate is too low, the pressure differential over the filter station after backwash will gradually increase with time.

Backwashing usually takes place while irrigation continues. To operate both the backwashing and irrigation system simultaneously, the flow-rate to the irrigation system must be reduced to build-up the pump pressure and to allow backwashing by using a pressure-sustaining valve. It is, however, beneficial to backwash the system from time to time (bi-weekly), with all blocks closed, so that a greater volume of water can flow through the filters to accomplish a more effective backwashing action. A pressure of ±5 m higher than the normal functioning pressure, before the filters, during this action is sufficient. The use of compressed air, to assist with the backwashing action, is recommended if problems are experienced with tunnelling in the sand. This is effective to break up clods in the sand. Discolouration of water during backwashing is normal and indicates the effective functioning of the filters.

The backwashing flow-rate is very important and must be set to ensure effective backwashing. A too-high flow-rate will cause the sand to wash out, while a too low flow-rate will prevent impurities from being washed out. Backwashing can be performed on a time, volume, or pressure difference basis. The backwashing on a pressure difference basis is recommended, since it takes water quality changes into consideration.

6.5 Guidelines for the Maintenance of Filters

The following maintenance schedule for filters is recommended:

Table 6.4: Minimum maintenance schedule requirements for drip irrigation systems

Monitor	Weekly	Monthly	Quarterly	Annually
Inspect filters for leaks.	✓			
Check pressure difference across filters	✓			
Monitor filter backwash cycle and adjust if necessary		✓		
Check the hydraulic and electrical connectors		✓		
Service screen filters. Replace screen element if necessary		✓		
Inspect sand level (± 360 mm) and shape of sand grains. Add sand or replace if necessary*			✓	
Service disc filters. Replace filter discs if necessary.				✓
Service backwash and air valves				✓

*The sand should have sharp edges to be effective. If the sand particles become round due to frictional wear, the effectiveness of the filter is reduced.

Where aggressive water occurs, metal parts of the filters must receive epoxy treatment. Lubricants extend the lifespan of synthetic discs in filters where metal and rubber parts are in contact. High viscosity silicon products have proved to be the most suitable product for general usage. Lithium grease, but definitely not oil, is very suitable for valve axles and other moving parts.

6.5.1 Replacing sand in filters

The rule of thumb is to replace the sand annually. However, it may be necessary to replace the sand by investigating the condition of the sand. When sand is rubbed between the fingers, it must not feel smooth, because this will mean that the sand has been worn down and will no longer filter effectively. When replacing sand, sand particles must be angular and not round.

Sand particle sizes that vary from 0,71 mm to 1,85 mm are recommended. When replacing the sand in the filter, it is essential to half-fill the filter with water before filling it with sand to prevent damage to the underdrain system in the filter. The water forms a cushion and protects the internal parts. Sand filters normally have a sand depth of ±360 mm. Always use prescribed graded sand from a reputable supplier.

A layer is sometimes formed on the sand that becomes dirty or blocked and even causes sedimentation. It is not necessary to remove all the sand from the filter. The layer can be scraped off and removed and the correct amount of sand can be replaced. It is usually as a result of a low backwashing flow-rate or a too long backwashing cycle.

6.5.2 **Replacing filter discs**

Any disc/discs that show signs of mechanical damage should be replaced. Discs with chemically blocked channels must be removed and cleaned chemically. If the discs cannot be cleaned effectively, they must be replaced. Always replace discs with the same colour, and from the same manufacturer, to ensure that the degree of filter disc remains the same. It is strongly recommended that the discs should be removed periodically and be cleaned manually.

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Appendix A

FILTER EVALUATION QUESTIONNAIRE: **Test number: _________**

VERIFY FARM INFORMATION

Farm name: ____________________

Irrigator: ____________________

Address: ____________________

Contact number: ____________________

Catchment area: ____________________

Evaluator(s): ____________________ Date: ____________

DISCUSS THE FIELD EVALUATION RESULTS OF OCTOBER 2003 WITH FARMER

VERIFY FILTER INFORMATION

DESCRIPTION OF SYSTEM:

Pump (i.e. KSB/ETA 50-315)

Irrigation system (Area under irrigation, type of system/emitters, emitter spacing, lateral spacing and delivery rate)

System flow meter (type and size)

CURRENT PRACTISES:

Maintenance practises

Schedule (i.e. how often: sand replacement, hand cleaning of discs, replacement of seals, etc.):

Is chlorination practiced?

Are any other chemicals used to clean the filters?

General comments of irrigator on any problems experienced during the operation and maintenance of the filter station and system e.g. blockages:

____

____

____

EVALUATION SECTION:

Visual assessment:

Are there any signs of wear of the sand or filter discs or filter screen?

____

____

Any visual obstructions in the filters or dirt build up on filter discs or screen?

____

____

Are there any leaks in the filter station?

____

____

Location of pressure gauges on the filter station:

____

____

Describe position of water source relatively to pump station and filter station:

____

WATER SAMPLING AND TESTING:

Determination	**Sample size (mℓ)**	**Preservation**	**Sampling position / number**
Total suspended solids	500	Refrigerate	One per site at bypass outlet of DIM at inlet of filter station
Algae	1000	Preserved with 1% per volume of iodine (10 mℓ)	One at water source per drainage region at depth of 500 mm below the water surface
Iron and manganese (separate measurements)	According to test kits	–	One per site at filter inlet

Iron (mg/ℓ): ______________________

Manganese (mg/ℓ): ______________________

<u>QUANTITATIVE ASSESSMENT</u>

Backwash management efficiency test:

	Pressure before filter	Pressure after filter	Pressure drop	Back wash time	Flow meter reading	Backwash flow-rate	Backwash pressure*
	[kPa]	[kPa]	[kPa]	[sec]	[m^3]	[m^3/h]	[kPa]
Before first backwash:				–	–	–	–
After first backwash:							
After second backwash:							
After third backwash:							

NB: Repeat backwash management test until a negligible change in pressure drop over filter is reached. The SAF / TAF filters don't have a backwash action.

* System backwash pressure is defined as the system pressure during backwash on the inlet side of the filter backwashing.

Position of flow meter (distances from obstruction before and after flow meter, diameter of pipe being tested):

Backwash water of sand filter: Are there any signs of filter sand being carried out?

When last was the filter cleaned/backwashed? (How many days ago)

FILTER EFFICIENCY TEST:

Size of screen in dirtiness index meter: ______________

Position of DI meter	V_{start} [ℓ]	V_{end} [ℓ]	$V_{through}$ [ℓ]	Time start (min)	Time end (min)	Duration (min)
Before filter						
After filter						

Where DI is the dirtiness index and V is the volume reading of the DI meter

NB: Tests before filter are repeated until test after filter ends.

The following classification system must be used to determine the filtration efficiency:

- If the cut-off time for the specific screen size is exceeded **at the inlet of the filter**, the test must be terminated.

Cut-off times at the filter inlet for different screen sizes	
Screen sizes (micron)	**Cut-off times (min)**
60	4.1
80	6.6
100	12
130	20.9
200	51.5
250	82.3
300	120

- In the case of filters with a very high filtration efficiency of 98% or more, it can take up to one full day to get a reading from the dirtiness index meter after the filter, which makes it impractical to try to get the exact reading of the filtration efficiency in practice. It was therefore decided to take a filtration efficiency of 90% as the time-out point for such cases. The table below shows the **time-out times at the filter outlet** for different DI values before filter for 90% filtration efficiency.

Time-out times (min) at filter outlet for different DI before filter for a 90% filtration efficiency							
DI before filter (%) / **Screen sizes(micron)**	**2**	**5**	**10**	**15**	**20**	**25**	**30**
60	20.6	8.2	4.1	2.7	2.1	1.6	1.4
80	32.8	13.1	6.6	4.4	3.3	2.6	2.2
100	60	24	12	8	6	4.8	4
130	104.3	41.7	20.9	13.9	10.4	8.3	7
200	257.7	103.1	51.5	34.4	25.8	20.6	17.2
250	411.7	164.7	82.3	54.9	41.2	32.9	27.4
300	600	240	120	80	60	48	40

- If the pressure gauge of the DIM at the filter outlet reaches the required pressure almost as quickly as the DIM before the filter, it can be assumed that there is a problem with the filter performance. The filter must be opened to identify possible problems with the performance of the filter. **The farmer must be advised accordingly.**

System flow-rate and pressure measurements during DI test:

DI Test number:	**Pressure before filter (kPa)***	**Pressure after filter (kPa)***	**Flow-rate [m^3/h]**	
			Clamp-on flow meter	**System flow meter**
1				
2				
3				
AVERAGE				

***If the DI measurements are taken close to the filter and if the rating of the pressure gauges of the DI meters are high enough, these pressures can be measured with them in between tests by closing both valves of the DI meters**

Appendix A

DESCRIPTION OF CLOGGING AGENT ON SCREEN

Mark appropriate clogging agent in table.

Physical, chemical and biological factors involved in emitter clogging (Bucks et al. 1979)		
Physical	**Chemical**	**Biological**
• Inorganic materials Sand (50 – 250 μ*m*) Silt (2 – 50 μ*m*) Clay (< 2 μ*m*)	• Alkaline earths heavy metals Cations Calcium Magnesium Iron Manganese Anions Carbonate Hydroxide Silicate Sulphide	• Algae • Bacteria Filament Slime
• Organic materials Aquatic plants Phytoplankton Algae Aquatic animals Zooplankton Snails Bacteria (0,4 – 2 μ*m*) Plastic cuttings Lubricant residues	• Fertilizer sources Aqueous ammonia Iron Copper Zinc Manganese Phosphorus	• Microbial activities Iron Manganese Sulphur

In case of slimes:

Is only one side of the screen slippery? Yes/No __________________

Are both sides of the screen slippery? Yes/No _____________

Appendix B

ALGAE ANALYSIS IN THE DIFFERENT REGIONS DURING OCTOBER 2002

Sample site	Bacillariophyta (diatoms)							Cryptophyta	Chlorophyta (green algae)				Cyanobacteria (blue-green algae)		Euglenophyta	Dinoflagellates
	Asterionella	Melosira (fragments)	Cyclotella	Nitschioid diatoms	Tabellaria	Pennate diatoms	Fragilaria	Cryptomonas	Scenedesmus	Krichneriella	Ankyra	Pediastrum	Anabaena*	Oscillatoria	Trachelomonas	Ceratium
	Cells or filaments or filament fragments or colonies per millilitre of sample															
1.1	0	125	0	0	0	0	125	0	0	0	0	0	0	0	0	0
1.5	0	625	0	0	0	0	625	0	0	0	0	0	0	0	0	0
2.1	0	0	125	0	0	0	0	0	0	0	0	0	0	0	0	0
2.2	0	250	500	0	0	250	0	0	0	0	0	0	0	0	0	0
2.4	0	250	2500	500	0	0	0	0	0	0	0	0	0	0	0	0
2.5	0	0	1000	0	0	0	0	750	0	0	0	0	0	0	0	0
2.6	0	0	2750	750	0	0	0	0	0	0	0	0	0	0	0	0
3.1	250	250	0	250	250	0	0	0	0	0	0	0	0	0	0	0
3.2	0	0	500	0	0	0	0	0	0	0	0	0	0	0	0	0
3.3	0	175	175	250	0	0	0	0	0	0	0	0	0	0	0	0
3.4	0	500	250	0	0	0	0	0	0	0	0	0	0	0	0	0
3.5	0	125	0	0	0	0	0	0	0	0	0	0	250	0	0	0
4.1	0	75	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.3	0	0	1250	0	0	0	0	0	75	250	0	0	0	0	0	0
4.4	0	0	0	0	0	0	0	0	0	0	0	0	175	0	0	0
4.5	0	0	175	0	0	0	0	0	250	0	0	0	0	0	0	0
4.6	0	0	0	0	0	0	0	0	0	0	0	0	500	0	0	0
4.8	0	0	0	0	0	0	0	0	0	0	500	0	0	0	0	0
4.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2500	0
5.1	0	1	0	0	0	0	0	0	0	0	0	10	1	0	0	1
5.2	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0

TIME-OUT TIMES FOR DIFFERENT FILTRATION EFFICIENCIES AND DIFFERENT DIRTINESS INDEXES

Dirtiness Index:		2	5	10	15	20	25	30
Screen:	Measurement:	(min)	(min)	(min)	(min)	(min)	(min)	(min)
60µm	Before filter:	2.1	0.8	0.4	0.3	0.2	0.2	0.1
	After filter for efficiency of:							
	30%	2.9	1.2	0.6	0.4	0.3	0.2	0.2
	60%	5.1	2.1	1.0	0.7	0.5	0.4	0.3
	90%	20.6	8.2	4.1	2.7	2.1	1.6	1.4
80µm	Before filter:	3.3	1.3	0.7	0.4	0.3	0.3	0.2
	After filter for efficiency of:							
	30%	4.7	1.9	0.9	0.6	0.5	0.4	0.3
	60%	8.2	3.3	1.6	1.1	0.8	0.7	0.5
	90%	32.8	13.1	6.6	4.4	3.3	2.6	2.2
100µm	Before filter:	6.0	2.4	1.2	0.8	0.6	0.5	0.4
	After filter for efficiency of:							
	30%	8.6	3.4	1.7	1.1	0.9	0.7	0.6
	60%	15.0	6.0	3.0	2.0	1.5	1.2	1.0
	90%	60.0	24.0	12.0	8.0	6.0	4.8	4.0
130µm	Before filter:	10.4	4.2	2.1	1.4	1.0	0.8	0.7
	After filter for efficiency of:							
	30%	14.9	6.0	3.0	2.0	1.5	1.2	1.0
	60%	26.1	10.4	5.2	3.5	2.6	2.1	1.7
	90%	104.3	41.7	20.9	13.9	10.4	8.3	7.0
200µm	Before filter:	25.8	10.3	5.2	3.4	2.6	2.1	1.7
	After filter for efficiency of:							
	30%	36.8	14.7	7.4	4.9	3.7	2.9	2.5
	60%	64.4	25.8	12.9	8.6	6.4	5.2	4.3
	90%	257.7	103.1	51.5	34.4	25.8	20.6	17.2
250µm	Before filter:	41.2	16.5	8.2	5.5	4.1	3.3	2.7
	After filter for efficiency of:							
	30%	58.8	23.5	11.8	7.8	5.9	4.7	3.9
	60%	102.9	41.2	20.6	13.7	10.3	8.2	6.9
	90%	411.7	164.7	82.3	54.9	41.2	32.9	27.4
300µm	Before filter:	60.0	24.0	12.0	8.0	6.0	4.8	4.0
	After filter for efficiency of:							
	30%	85.7	34.3	17.1	11.4	8.6	6.9	5.7
	60%	150.0	60.0	30.0	20.0	15.0	12.0	10.0
	90%	600.0	240.0	120.0	80.0	60.0	48.0	40.0

MEASURING THE DIRTINESS OF IRRIGATION WATER FOR MICRO-IRRIGATION FILTERS

A.S. van Niekerk*

ABSTRACT

An easy to build instrument that measures the dirtiness of irrigation water regardless of the kind of dirt, or its concentration, was developed and tested in South Africa. With a constant dirtiness of the water, the instrument produces a repeatable numerical value for the dirtiness of the water which stays in the same order of magnitude. Different mesh sizes may be used in the instrument to measure the dirtiness of water with regard to other particle sizes, for filters with different mesh sizes.

The instrument can be used to produce better filtering station designs and to manage them better. Controlled blocking tests can be done on all filters under a wide range of dirtiness conditions to forecast how quickly they will block under given conditions. Filtering efficiency tests can be easily and effectively done under laboratory and field conditions on all filters. This is especially valuable because it can help identify faults in any micro-irrigation system. The construction, measuring theory, operation, test results and applications of the Dirtiness Index Meter will be described herein.

Keywords: Measuring dirtiness, Dirtiness Index Meter, Filter efficiency, Irrigation water, Blocking tests on filters.

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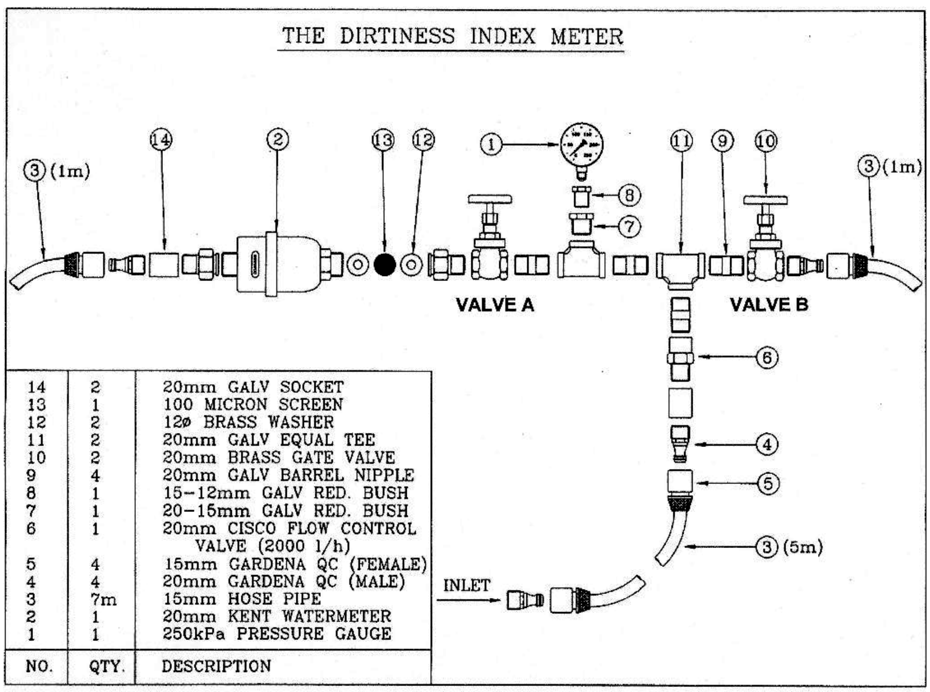
CONSTRUCTION AND BASIC WORKING PRINCIPLE

<u>Construction of the Dirtiness Index Meter (DIM)</u>

The DIM is assembled using 20 mm galvanized pipe fittings. The basic components of the meter are: a water meter that can measure low flow-rates, e.g., a household municipality meter, with a small screen mounted on the inlet side, two brass gate valves, a 250 kPa pressure gauge and a 2000 L/h flow control valve. In Fig. 1, detailed information is given on all the components and how they are assembled. The only component that must be manufactured is the small screen in the water meter and this is done as follows:

Two brass washers, with a thickness of approximately 1.5 mm, and a 12 mm hole in each of them must be made in such a way that they fit neatly, though not too tightly, into the mounting nut of the water meter. A nylon screen of appropriate mesh size is cut to the same size as the washers and clamped between them with the mounting nut of the water meter.

All components are screwed tightly together with sealing tape, except for the mounting nut on the inlet side of the water meter, which is only tightened by hand to enable easy access to the small screen (it is not critical if water leaks at this point).



NO.	QTY.	DESCRIPTION
14	2	20mm GALV SOCKET
13	1	100 MICRON SCREEN
12	2	12ø BRASS WASHER
11	2	20mm GALV EQUAL TEE
10	2	20mm BRASS GATE VALVE
9	4	20mm GALV BARREL NIPPLE
8	1	15-12mm GALV RED. BUSH
7	1	20-15mm GALV RED. BUSH
6	1	20mm CISCO FLOW CONTROL VALVE (2000 l/h)
5	4	15mm GARDENA QC (FEMALE)
4	4	20mm GARDENA QC (MALE)
3	7m	15mm HOSE PIPE
2	1	20mm KENT WATERMETER
1	1	250kPa PRESSURE GAUGE

Fig. 1: Construction of the Dirtiness Index Meter

<u>Basic Working Principle of the Meter</u>

The instrument works on the principle that a quick blocking test is done under controlled conditions on a screen similar to that of the filter for which the dirtiness of the water is measured. This is determined by measuring how many litres of water can be forced through the small screen by a pressure rise of 50 kPa against the screen.

MEASURING THEORY

Background

When, in 1980, it was decided to perform filter tests, nothing could be found in the literature on how to conduct such tests, or on what equipment to use. One of the needs that arose was to conduct blocking tests on filters, but these would have been meaningless if the condition of the test water couldn't be evaluated and stated together with the test results. Some of the things that were tried unsuccessfully were:

- **Using a standard filter as a measure:** Many filters blocked even faster than the standard filter, and since the dirtiness of the water was not constant, no representative measurement could be taken.

- **Measuring the dirtiness of the water in parts per million:** If the total concentration of the dirt is measured, and the distribution of particle sizes in the water is uneven, the tests of the filters with the fine elements can't be compared with the tests of the filters with the coarse elements. What is needed, is a selective measurement, based on particle size, of the dirtiness of the water. When the dirtiness of the water was thus being measured on a selective basis, and filters were being tested at concentrations higher than one percent, it was found that the filters blocked long before a dirtiness measurement could be taken. Similar problems to those of the standard filter were also experienced in this case.

- **Test all the filters simultaneously:** The small filters blocked faster than the large filters. In spite of the large reservoir that was used, a continuous decline in the dirtiness of the water occurred, which means that the large filters were tested with water that was on average cleaner than that of the small filters, making the tests incomparable.

USING A SMALL SCREEN AS A MEASURE

To see what particle sizes passed through filters, the filtered water was sampled through very fine small screens and the screens examined under a microscope. It was found that these screens blocked must faster, and it only became possible to use such a screen to measure the dirtiness of the water after a lot of development, research and testing had been done. The prerequisites that were set for a dirtiness meter were as follows:

- It should produce an increasing value for the dirtiness of the water when the dirtiness of the water increases.
- It should be capable of repeatable measurements.
- It should consider the fineness of the filter's element and still give about the same dirtiness value for the same water.
- It should be as fast, simple and cheap as possible.

There were two problems with the small screen:

- As the water got dirtier, the volume of water blocking the screen got smaller.
- The 300 µm screen filtered about ten times more water than the 100 µm screen before it blocked. (Although this was found in practice first, it could be shown theoretically that an opening of 300 by 300 µm is almost ten times larger than an opening of 100 by 100 µm, which confirms the practical observation.)

Fortunately, two solutions could be found:

- If the inverse is taken of the number of litres that blocked the screen, it produces an increasing value when the dirtiness of the water increases.
- If a factor is built into the dirtiness index formula that can be changed in accordance with the fineness of the screen in the meter, it can compensate for the variation in the volume of each screen. (The standard screen for the DIM was empirically taken as 100 µm with a screen factor of 100.)

From the two solutions just mentioned, equations (1) and (2) were empirically derived for the dirtiness index (DI) of the water:

$$DI = \frac{1}{L} \times F \qquad (1)$$

LEGEND:	DI	=	Dirtiness index.	
	L	=	Number of litres that blocked the screen.	
	F	=	Screen factor (Table 1).	
		=	$0.00632 \times M^{2.1}$	(2)
Where:	M	=	Micron size of the screen used in the meter.	

Table 1: F-factors for the Most Popular Screen Sizes

Finess of Screen µm	Screen Factor [a] F
50	23
100	100
200	430
300	1 000

[a] Equation (2).

OPERATION OF THE DIRTINESS INDEX METER

Taking a Dirtiness Index (DI) Reading

The DIM should be prepared as follows: take the reading on the water meter (=X), close valve A (Fig. 1) and fully open bypass valve B. Install the right screen in the DIM, see that it is clean and choose the correct F-factor (Eq. (2), Table 1).

Connect the DIM to a pump with a pressure of at least 200 kPa and slowly close valve B until the reading on the pressure gauge reaches 110 kPa. Open valve A fully. This will cause the pressure to drop to ± 50 kPa. As the screen becomes blocked, the pressure will start rising again. When it reaches 100 kPa, close valve A and take the new reading on the water meter (=Y). Subtract X from Y and use Eq.(1) to calculate the DI of the water.

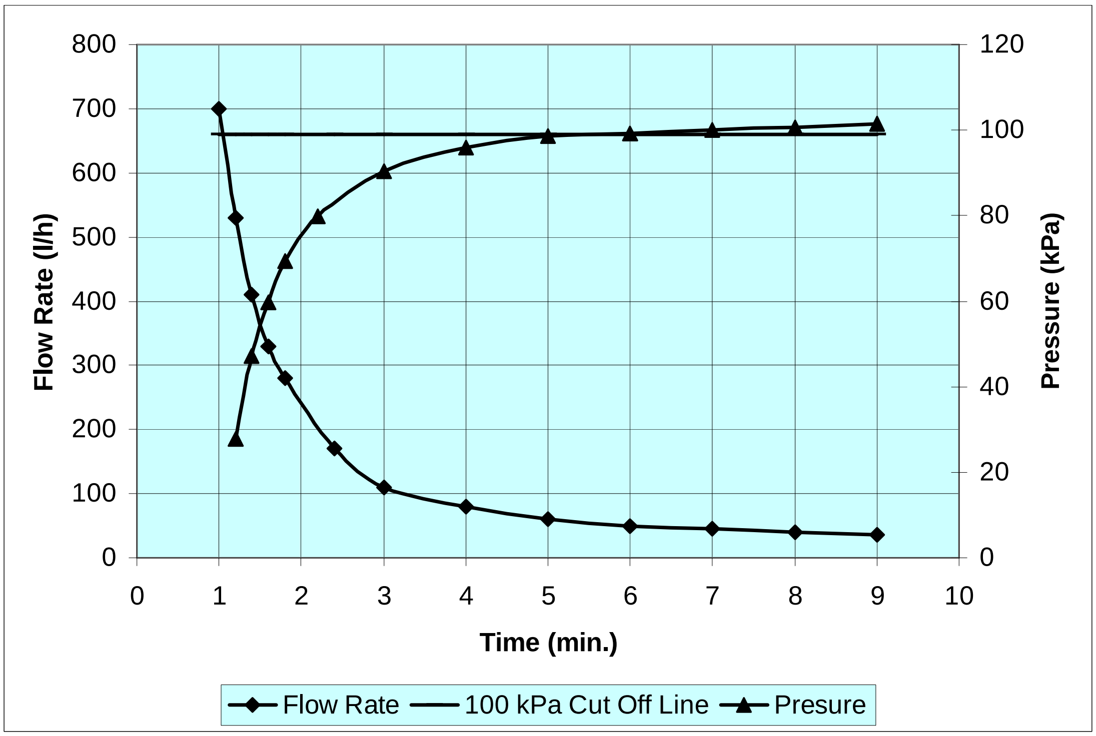


Fig. 2: Flow-rate and pressure build up characteristics of the Dirtiness Index Meter

Remove the screen and examine the dirt on it to determine its type, which is what will block the filter. If it is algae or iron oxide, it means the irrigation system will have to be treated with chlorine and acid from time to time. Clean and reinstall the screen. The DIM is now ready for another measurement.

The reason for setting the pressure at 110 kPa and taking the water meter reading at 100 kPa can be illustrated by Fig. 2. This Fig. shows what happens in a DIM with a 100 µm screen and a DI of 10 of the water during a DI measurement. When valve A is opened, the pressure drops below 50 kPa and the initial flow-rate through the water meter is 700 L/h. As the screen becomes blocked, Fig. 2 shows what happens with the flow-rate and the pressure. The area under the flow-rate curve is the volume measured by the water meter. In the beginning the DIM was left until the water meter stopped, but being a mechanical meter subject to vibration it would, for e.g. stop once after 6 minutes and then again after 10 minutes. This led to readings that could differ by 10% or even more from each other. Monitoring the pressure and taking the readings at 100 kPa made much more exact and repeatable readings possible.

Getting the Average Dirtiness Index of the water

If water is measured over a period of time during which the dirtiness index varies substantially, it is not correct to take the numerical average of the measurements for the average dirtiness of the water, because lower values take longer to measure. To get the correct average DI in this case, it was found that the average of all the volumes of the readings should be taken, and this volume used to calculate the real average DI.

TEST RESULTS AND APPLICATIONS

In the laboratory

It was found that blocking tests could be done very successfully on all types of micro-irrigation filters. The result is that blocking curves can be drawn for all the filters that are tested (Van Niekerk, 1983). An interesting application is to determine the dirtiest water an automatic filter can handle. Most of these filters make use of internally filtered water to clean them, but if the water is so dirty that the elements of the filters get blocked before they themselves are clean, they cannot function any longer. This point is reached at a dirtiness index of about 60.

In general, Table 2 gives a good overview of expected filter performance at different dirtiness indexes:

Table 2: Filters and the Dirtiness Index of water

Dirtiness Index	Expected blocking times
< 1	Usually **very long**.
5	Mostly **a few days**.
30	Mostly **a few hours**.
60	Mostly **a few minutes**.

The times given in Table 2 apply to filters running continuously. If a filter is stopped in between, it was found that it can carry on longer before it gets blocked.

In the Field

After numerous field runs with the DIM, it was found that natural water generally has a dirtiness index of 2 and that the dirtiest water on average has a dirtiness index of 100 (like a river in flood).

When surface water occasionally gets dirty, it becomes about five times dirtier than its long-term average dirtiness, and also only for a relatively short period, as can be seen in Fig. 3.

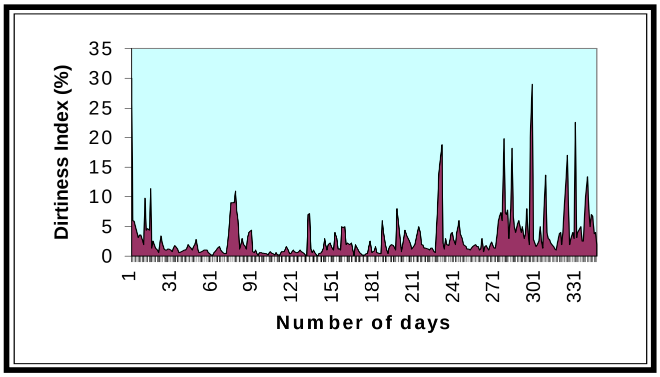


Fig. 3: Yearly Dirtiness Indexes of an Irrigation Reservoir

One application of the DIM is to set standards: When the natural water has a DI of less than 1.5 and there is no possibility of this changing (like a borehole), then a filter can be used at its highest flow-rate (30 kPa friction loss over the clean filter instead of the normal 10 kPa), or if the natural water has a DI of 60, it may not be pumped through a micro-irrigation filter before it is precleaned in other ways.

CONCLUSION

Different methods of measuring the dirtiness of irrigation water for micro-irrigation filters were discussed. Normal measuring methods were unsuccessful and something special and unique had to be developed. The Dirtiness Index Meter that was developed fulfilled all the requirements that were set for it, and proved itself adequate to quantify the dirtiness of irrigation water for the purpose of testing, evaluating, comparing, designing, and managing micro-irrigation filters.

REFERENCE

VAN NIEKERK, A.S. 1983. Filters for micro-irrigation: Manual and test report. Directorate Irrigation Engineering, Pretoria, SA. 55p.

Appendix E

CAPACITY BUILDING

A project of this kind brought about a greater understanding and insight of the working principles and performance of all the different kids of irrigation filters.

Over the research period of three years, the know-how and knowledge of the research team was enhanced tremendously. The industry and producers that participated in the research also benefited through the interaction and transfer of technology.

One student in the person of Mr M.J. Makgae, a postgraduate student of University of Pretoria, Department of Civil and Biosystems Engineering took part in in-field testing of irrigation filters and he did a write-up of this work in fulfilment of his degree Baccalaureus Honoures Institutuonis Agraria.

New methods and test procedures had also been developed to test the different irrigation filters and the upgraded filter test bench is now a world-class facility for testing of any kind of irrigation filters.