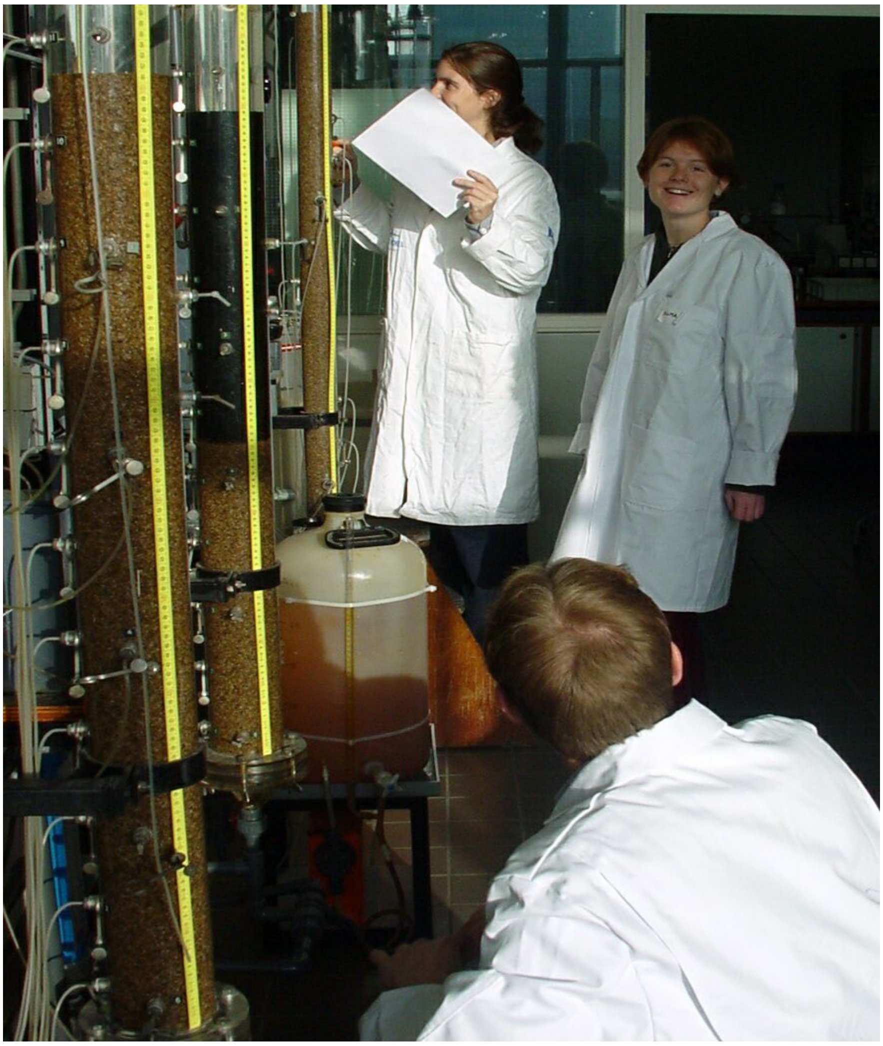
LAB EXPERIMENTS

Granular filtration

Filter run



Framework
This module explains the lab experiment on granular filtration; filter run.

Contents
This module has the following contents:

1. Objective
2. Experiment set-up
3. Theory
4. Procedure
5. Results
6. Design
7. Turbidity measurement

Data Forms

1. Objective

The objective of the filtration experiment is to determine the parameters that are characteristic for a filtration process. In this experiment natural surface water is used. A design of a full-scale filtration plant has to be made with the experimental results.

2. Experiment set-up

The experimental setup consists of two parallel downflow gravity filters and dosing equipment (Figure 1). One filter has a single layer bed of 1 m height of river sand with a particle diameter between 1.0 – 1.6 mm. The other filter has a double layer bed with 0.5 m river sand (1.0 – 1.6 mm) and on top 0.5 m anthracite with a particle diameter between 1.4 – 2.5 mm.

Over the height of the column several sampling points are present by which the hydrostatic pressure can be measured. The filtration columns have a diameter of 90 or 190 mm. The filtration rate is controlled downstream of the filter with a valve. The flow rate is read from a flow meter. The pressure changes within the filter are read with the help of water manometers that are connected to the filter column.

Ferric chloride is dosed to the surface water that has to be treated. Suspended matter is coagulated, flocculated and removed in the filter bed. By measuring the effluent turbidity at certain time intervals the filtration process is monitored. Moreover, the single bed filter is sampled at different heights in the bed. The filtration runtime depends on the surface water quality. The expected run time of the experiment is about 6 hours.

Figure 1 - Filtration installation in the laboratory

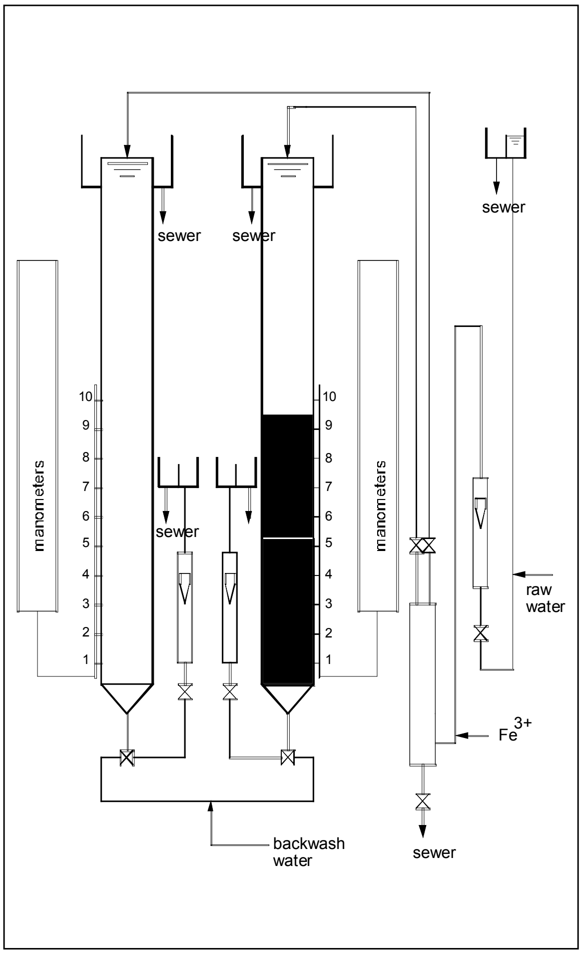


Figure 2 - Filtration experimental set-up

3. Theory

Due to clogging of the bed the pressure losses will increase. In the beginning the effluent of both columns has the same turbidity. After some time the single bed filter breaks through, causing a fast increasing turbidity of the effluent. When the maximum allowable value is exceeded the filtration process is stopped. The double layer filter has a greater accumulation capacity and still has a good effluent quality.

Another criterion to stop filtration is the moment where the pressure losses in the filter exceed the available water height between in- and outflow. Due to such pressure losses the flow rate decreases to unacceptable low values. This happens even if the effluent quality is still acceptable. An important tool for the design is the so-called Lindquist diagram. The pressure losses over the filter are plotted against the height in the bed at several moments from the start. An example is given in figure 3.

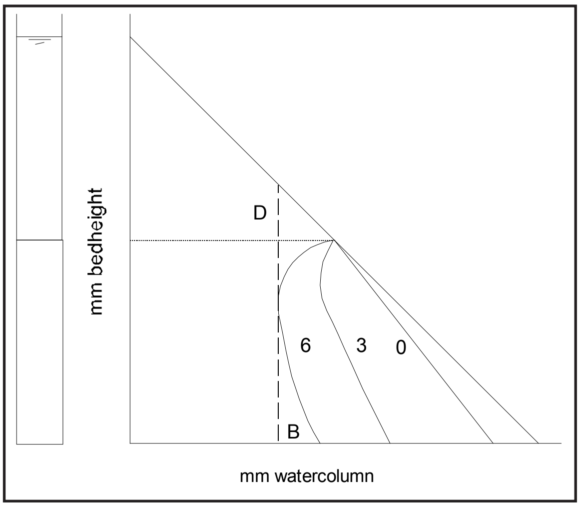


Figure 3 - Lindquist diagram

The moment where the curves reach the vertical line at the left side (Figure 3) the pressure becomes negative. The dashed vertical line indicates that negative pressure can be avoided if the water height above the bed is at least D mm. The pressure with respect to the filter bottom is B mm. In the Lindquist diagram a horizontal line can be drawn at the desired bed height and the values of D and B can be found.

The final design of a filtration plant is based on experiments like this with different filter materials, bed heights and flow rates, giving several runtimes based on effluent quality and/or pressure losses. Other important factors in the design are construction costs, the production per filter unit and the water consumption for backwashing the filters.

Filtration and accumulation of solids can also be described in a mathematical form. Ives derived the following form:

$$\frac{\partial c}{\partial t} = -v_p \cdot \frac{\partial c}{\partial y} - \lambda \cdot v_p \cdot c$$

$$\frac{\partial \sigma}{\partial t} = -v \cdot \frac{\partial c}{\partial y}$$

$$\lambda = \lambda_0 (1 + n_1 \cdot \sigma_v - n_2 \frac{\sigma_v^2}{p_0 - \sigma_v})$$

in which:

c	= concentration suspended solids	(g/m^3)
v	= filtration velocity	(m/s)
v_p	= pore velocity	(m/s)
y	= depth filterbed	(m)
λ	= filtrationcoefficiënt	(m^{-1})
λ_0	= clean bed filtration coefficient	(m^{-1})
n_1, n_2	= constants	(-)
σ	= pore filling	(g/m^3)
σ_v	= volume concentration in pores	(m^3/m^3)

In the Stimela model (www.stimela.com) the Ives formulae are used.

4. Procedure

The procedure below should be followed to execute the experiment:

- adjust the raw water supply rate at 250 l/h.
- determine for both filters the effluent flow rate to maintain a filtration velocity of 8 m/h.
- adjust for both filters the desired influent flow rate with the help of the flow meters.

- measure the pressure loss of the clean beds by reading the water manometers.
- measure at certain time intervals the water temperature and give the values in the report.
- switch on the dosing pump and adjust to the desired flow rate. Determine this flow rate based on a required dosing concentration of 4 to 8 mg Fe^{3+}/l (the exact value is dependant of the water quality and will be given during the experiment). Check the dosing rate from time to time.
- read the water manometers every half hour.
- take effluent samples after 15 minutes and then every half hour and measure the turbidity.
- take samples from the single layer bed over the total bed height, starting after 30 minutes and then every hour and measure the turbidity.
- the filtration process is stopped as soon as a filter breaks through or when the maximum pressure loss is reached. After the experiment the filters have to be backwashed one by one with an expansion of 30%. Backwashing is continued until the supernatant water is completely clear. Close the backwash valve slowly.

5. Results

The results should consist of:
- draw the Lindquist diagrams of both filters. Discuss graphs and explain the differences.
- draw one graph of the total pressure losses and effluent turbidity against time for both filters. Give your conclusions on these graphs.
- make a table and a graph of the turbidity in the single bed for the different depths as a function of time. Give your comments.
- calibrate the Stimela model on the obtained data.

6. Design

Design a filtration plant for a supply of surface water similar to that used in the experiment, using the Stimela model.

Flow rate: 2500 m^3/h
Required turbidity removal: 80 %
Filter type: gravity, down flow, single layer
Filter control: constant level supernatant, constant filtration rate (downstream control)

Use in your design the Lindquist diagram and the turbidity graphs.

Suggest a number of filtration units and determine the dimensions. Have in mind the water depth above the bed, the thickness of the bed, the freeboard, the thickness of the supporting layers and the construction height of the bottom.

Part of this design is the backwash unit, thereby using the results of the experiment “Hydraulics of filtration”. The required backwash rate can influence the size of the filter units.

Give the hydraulic gradient of the clean filter, the clogged filter and during backwashing.

7. Turbidity measurement

Take the following steps:
- stir the sample thoroughly and fill the glass cell.
- clean and dry the outside of the cell carefully.
- place the glass cell in the meter and read the turbidity.

Data forms

Data form 1

Group number: Date:

Pressure measurements on a uniform filter bed

Readings water manometers												
Time	Runtime	1	2	3	4	5	6	7	8	9	10	11

Bed resistance / Pressure differences between measuring points												
Time	Runtime	1	2	3	4	5	6	7	8	9	10	11

Data form 2

Group number: Date:

Pressure measurements on a double layer filter bed

Readings water manometers												
Time	Runtime	1	2	3	4	5	6	7	8	9	10	11

Bed resistance / Pressure differences between measuring points												
Time	Runtime	1	2	3	4	5	6	7	8	9	10	11

Data form 3

Group number: Date:

Turbidity measurements (NTU)

Turbidity measurements of filtrate												
Runtime												
Uniform												
Double												

Turbidity measurements uniform bed												
Runtime												
Filtrate												
6												
5												
4												
3												
2												
1												
Inflow												