Start-up of a drinking water biofilter

Physical, chemical and bacteriological changes

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INTRODUCTION

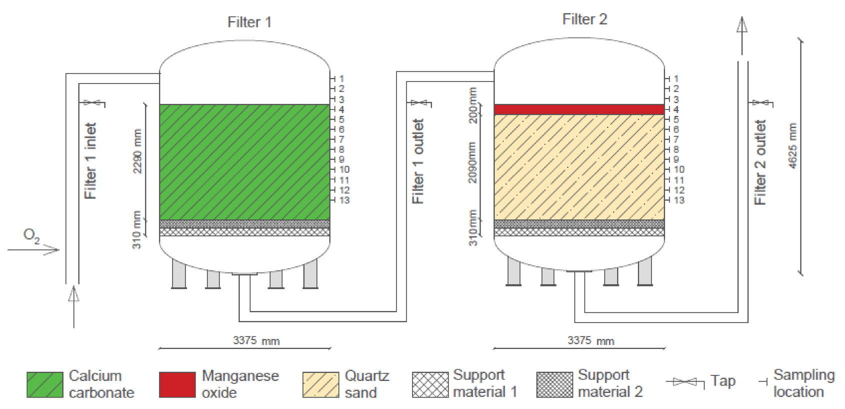
When producing drinking water from groundwater, some waterworks use biofilters as the heart of the treatment process. In biofilters, microorganisms are allowed to populate granular filter media and to carry out the work of purifying the water (de Vet, 2009). This process is gaining attention because of a number of attractive features including 1) low price, 2) no addition of chemicals and 3) increase in the microbiological stability of the finished water.

One drawback of biofilters is the long start-up period when new filter medium is commissioned. During the start-up period, an inorganic coating and a biofilm are established on the filter medium, after which the treated water complies with drinking water criteria. This period typically lasts two or more months (Cai, 2015; Stembal, 2004; Zeng, 2010). Disadvantages of a long start-up period include: 1) the need to discharge water to the environment since the finished water does not comply with drinking water standards, 2) the use of energy and the waste of a precious resource, and 3) the need for an alternative drinking water source for the consumers for the duration of the start-up period. If the start-up process is to be optimized, a thorough knowledge of the development of fully-functioning biofilters is required.

This poster elucidates the start-up process through a holistic monitoring approach at a newly-constructed full-scale waterworks in Denmark. This poster documents a natural start-up, using only inherent inoculation from microorganisms that are present in the raw water and the water used for backwash (no pro-active inoculation with old filter media or backwash water sludge was utilized).

METHODS

Filtration



One of the production lines at Truelsbjerg waterworks, Denmark (Søborg *et al.*, 2015).

Raw water quality

Parameter	Average	Std. Dev.
Oxygen	0.22 mgL^{-1}	0.12
Iron	1.40 mgL^{-1}	0.19
Manganese	0.45 mgL^{-1}	0.07
Ammonium	0.21 mgL^{-1}	0.04
Magnesium	7.6 mgL^{-1}	0.3
pH	7.3	0.06
Conductivity	58 mS/m	0.8
Temperature	8.9°C	0.1

Shading indicates concentrations not in compliance with Danish drinking water criteria.

Sampling

- **Water samples** (unfiltered) were collected from stainless steel taps at 16 locations: 13 different depths on Filter 1 as well as raw water, water between filters and finished water.
- **Filter media samples** were collected from 4 different depths in Filter 1 using a hollow stainless steel probe.
- **Backwash water samples** were collected at one minute intervals during selected backwash events.

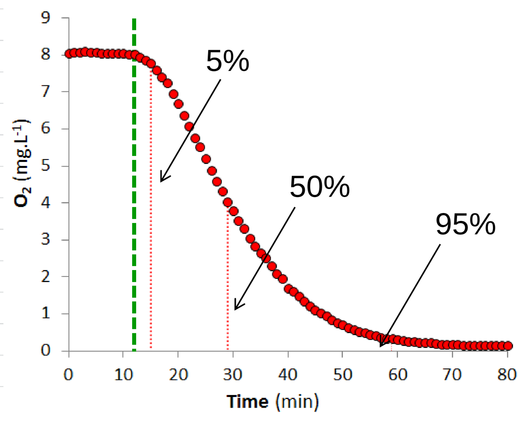
Analyses

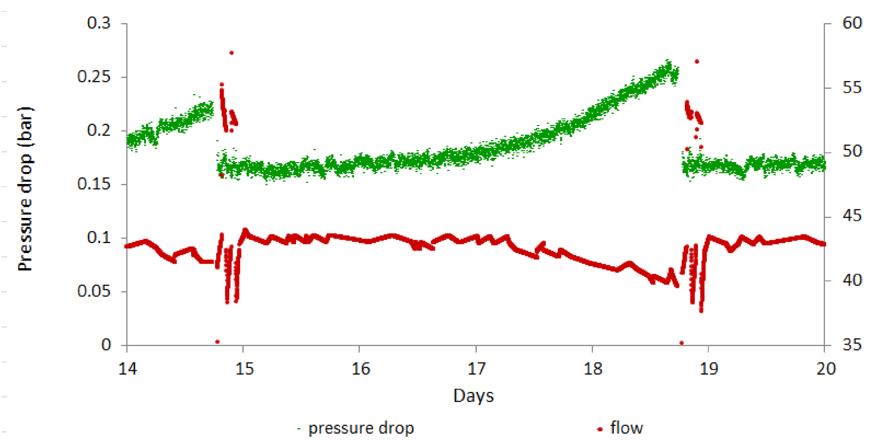
Physical	Chemical	Microbial
Continuous measurements • Flow • Temperature • Pressure • Turbidity	Continuous measurements • Dissolved oxygen • In-line pH • Conductivity • At-line ammonium	Continuous measurements • Bacterial counts (Grundfos BACMON)
Grab samples • Grain size, surface area and particle shape using Camsizer®64, Retch Technology GmbH	Grab samples • Iron, manganese and ammonium using Hach DR3900 spectrophotometer • Nitrite	Grab samples • Heterotrophic plate counts • DNA isolation (PowerBiofilm, MoBio Laboratories Inc.) • qPCR (Eubacteria and relevant bacterial groups)

RESULTS and DISCUSSION

Physical

Retention time distribution
Tracer tests showed a median retention time in Filter 1 of 29 min. This compares to 12 min. contact with the filter media (green line).





Flow and pressure drop for a filter run during start-up (Day 15-19) showed that values returned to initial values following a backwash event. Note that the goal of backwashing during start-up is to avoid pressure build-up, not to ensure clean finished water.

Colour changes in filter media. Over time, the colour of the filter media changed in the four depths that were sampled.

day 22 day 35 day 39 day 43 day 67

Parameter	Filter 1	Filter 2		Both filters
Description	calcium carbonate	manganese oxide	quartz sand	support material
Particle density (kgL^{-1})	2.41	3.32	2.51	-
Porosity (%)	40	44	45	-
Grain size (mm, 10-90% fractile)	2.3-4.1	1.6-3.2	0.5-0.8	3-5/1.6-2.5
Layer thickness (mm)	2290	200	2090	310

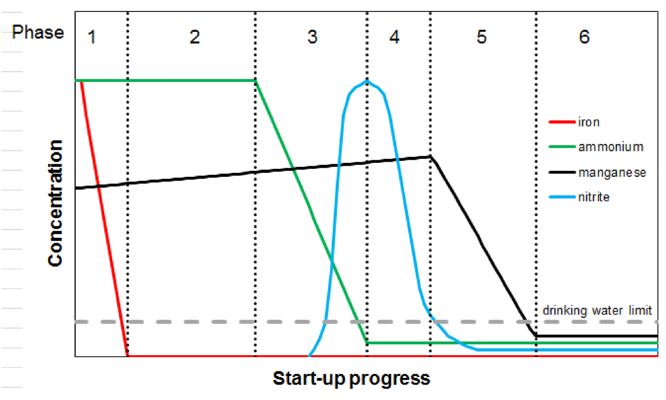
Filter media properties. Precipitation of iron oxides (red color) and manganese oxides (black color) were seen on filter media samples collected over time from four depths of each filter (Breda *et al.*, 2016).

RESULTS and DISCUSSION

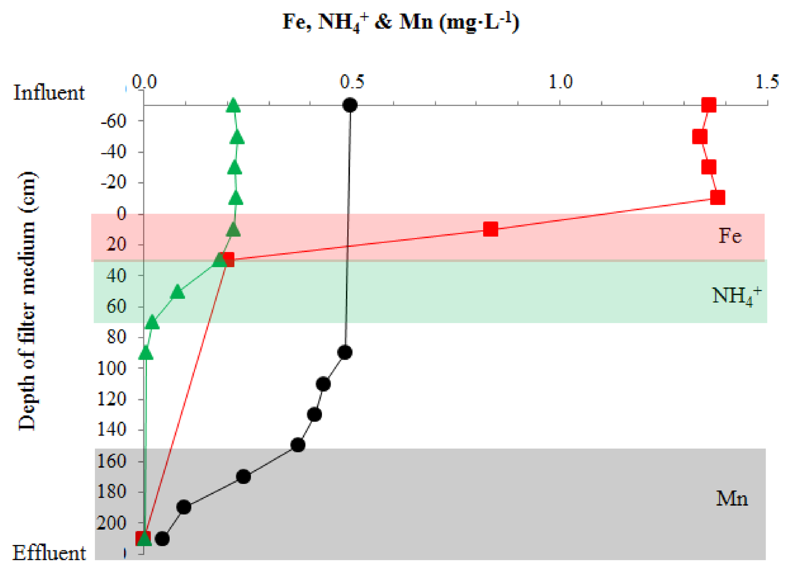
Chemical

Separate **phases** for removal of individual compounds during start-up were observed in this study.

Iron concentrations achieved compliance almost immediately, complete ammonium removal required about 6 weeks while complete manganese removal required about 10 weeks.



(Modified from Frischherz et al., 1985)



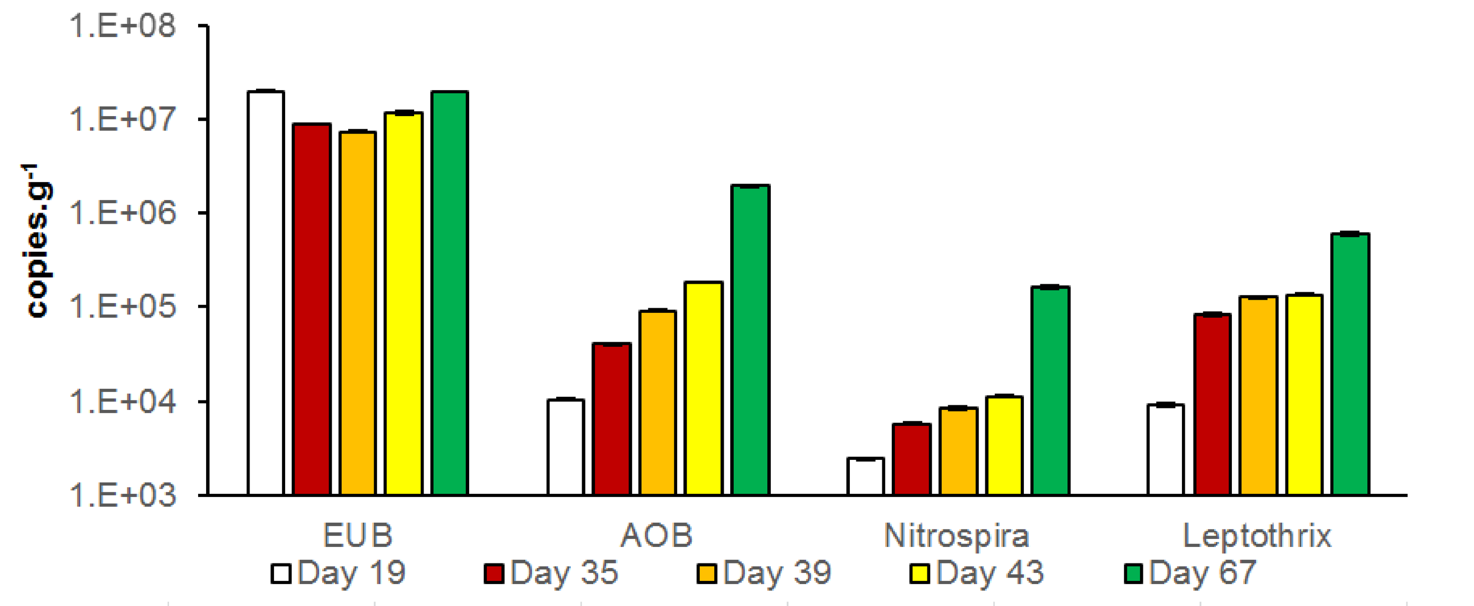
Clear **stratification** with depth was observed in water samples collected from Filter 1:

- Iron was removed at the top of the filter (top 30 cm).
- Ammonium was removed immediately below the iron strata (30-70 cm).
- Manganese was mainly removed close to the bottom of the filter (130-210 cm).

The central portion of Filter 1 appeared to be less active.

Biological

The bacterial community on samples of filter medium was investigated at various times during the start-up period using qPCR methods. Total bacteria (Eubacteria) as well as ammonium oxidizing bacteria (AOB), Nitrospira and Leptotrix were quantified.



Numbers of specific bacterial groups increased over time, while EUB remained nearly constant. The highest number of EUB was found in the top layer of the filter. At the end of the start-up period, EUBs outnumbered the sum of the other bacterial groups by about 10:1.

CONCLUSIONS

- Using inherent inoculation, full-scale start-up was complete after a period of approximately 10 weeks.
- The change from virgin filter media to fully functioning mature filter media is a complex mix of physical, chemical and microbiological processes. Holistic monitoring of these processes using water, filter media and backwash water samples provided a more clear understanding of the start-up period.
- Total bacteria (Eubacteria) were most abundant in the top 40 cm of Filter 1. Selected bacterial groups (AOB, Nitrospira, Leptotrix) represented only a small percentage of the total bacteria.
- Results from this work have important implications for optimizing the start-up process such as when and where to inoculate and what to inoculate with.

References: Frischherz, H, Zibuschka, F, Jung, H, Zerobin, **W,** 1985. Biological elimination of iron and manganese. Water Supply 3, 125, **Søborg, DA**, Breda, IL, Ramsay, L, 2015 Effect of oxygen deprivation on treatment processes in a full-scale drinking water biofilter, WST: Water Supply 15.4, 825-833. **Breda IL**, Ramsay, L, Søborg, DA**,** 2016. The role of backwash in start-up of full-scale drinking water biofilters. J. Water Supply: Research and Technology – AQUA 65(3), 234-243. **de Vet, WWJM**, Rietveld, LC, van Loosdrecht, MCM, 2009. Influence of iron on nitrification in full-scale drinking water trickling filters. Journal of Water Supply: Research and Technology – AQUA 58(4), 247. **Cai, Y**, Li, D, Liang, Y, Luo, Y, Zhang, J., 2015. Effective start-up biofiltration method for Fe, Mn, and ammonia removal and bacterial community analysis. Bioresource Technology 176, 149-155. **Stembal, T**, Markic, M., Briski, F, Sipos, L, 2004. Rapid start-up of biofilters for removal of ammonium, iron and manganese from ground water. Journal of Water Supply: Research and Technology – AQUA 53(7), 509-518. **Zeng, H**, Li, D, Zhang, J, 2010. Rapid start-up of biofilter for removal of iron and manganese from groundwater. Advanced Materials Research 113-116, 1316-1319.

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