LAB-SCALE EXPERIMENTS IN EXHAUSTED ZEOLITE FILTER FOR BIOLOGICAL AMMONIUM REMOVAL

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Summary: *Research was made on a rarely applied form of biological ammonium removal, a rapid filter (with at least 5 m/h flow velocity) dedicated solely for nitrification. A model equipment was operated with raw water of relatively high ammonium content (> 2,5 mg/l), in order to gain information about the limits and capacities of this method. Results have shown that this process can remove the requested amount of ammonium, efficiency is stable enough and the biological growth can be easily controlled by simple backwash methods. Further research needed to observe the effect of operating conditions (hydraulic load, filter geometry, backwash strategy) and water quality (mainly alkalinity, iron and manganese content) on the efficiency of nitrification and nitrogen balance. The aim of the research is to study such a nitrifying rapid filter that can reduce the ammonium load for the subsequent drinking water purification process steps, and provides an alternative of breakpoint chlorination and other expensive technologies.*

Keywords: *Ammonium, nitrifcation, rapid filtration*

1. INTRODUCTION

The maximum admissible ammonium content in drinking water in Hungary has strictly lowered by law from 2,0 mg NH_4^+/dm^3 to 0,5 mg NH_4^+/dm^3 regarding subsurface water from confined aquifers. Nearly on twenty percent of the settlements, ammonium content of supplied drinking water fails to fulfil this new requirement, affecting more than fifteen percent of the population (2250401 capita in 835 settlements [1]). In most cases breakpoint chlorination technology was the applied solution, regardless its disadvantages [2]. There were only a few cases where the already available treatment process allowed application of biological ammonium removal. In these cases only spontaneous nitrification in filters for iron removal had been utilized. Though this provided some

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factory scale experience in this matter already, independent ammonium removal process steps never introduced into drinking water treatment.
Research was made on a rarely applied form of biological ammonium removal, a rapid filter (with at least 5 m/h flow velocity) dedicated solely for nitrification.

2. LABORATORY EQIUPMENT AND HYDRAULIC OPERATING CONDITIONS

The model equipment was a standing plastic pipe (Fig. 1.), partly filled with roughly shaped plastic objects with 1,5-2 cm diameter and its lower part filled with zeolite (trademark: Granofilter, particle size: 2-3 mm). The raw water was introduced at the top of the filter, where it became nearly saturated with oxygen due to the trickling effect on the large surface of the media and to the free fall and splash down below to the headwater of the second filter. Feeding of the filter with raw water was started late February in year 2013. The adsorption capacity of the zeolite media had been already exhausted and ammonium removed from the water only by biological means after two months by the time of the experiments. Filtration velocity was between 4.5 – 7.0 m/h because of the periodic pressure changes in the hydrophore tank. Over the three months of operation the water feed stopped for approximately 36 hour long periods in the weekends.
Only two occasional backwashes needed over the sampling period a month apart: 27th May and 1st of July. It took the headwater a month to reach the overflow pipe due to the increased pressure loss in the filter. 0,9 m increase in the water level occurred during treating approximately 1380 bed volume of water (1380 times the volume of the filter media, in this case 8 m^3 of water in 5,78 dm^3 filter media).

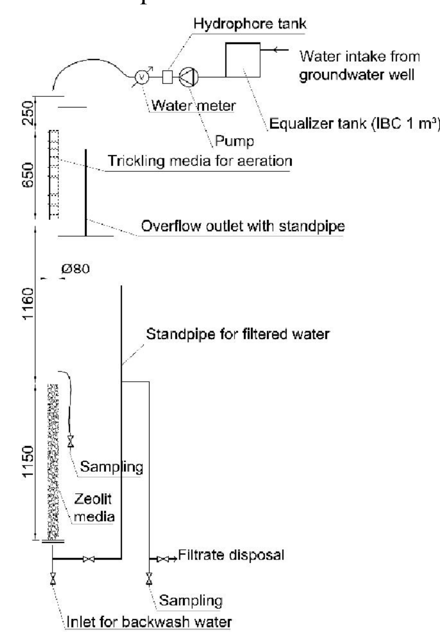

Figure 1. Sketch of model equipment (dimensions in mm)

3. WATER QUALITY

Two different water qualities were studied. In the first period until 25th of June raw water from a groundwater well was introduced to the filter. Tap water was used in the second period from 1st of July and its ammonium content had been set to an average of 5,0 mg NH_4^+-N / dm^3 by adding ammonium-chloride. The characteristics of the two water shown in Table 1.

Table 1. Characteristics of raw water used for biological ammonium removal

Parameter name and unit	Groundwater	Tap water
Nitrite (mg N / l)	0.12-0.51	0.05-0.13
Nitrate (mg N / l)	0.4-2	0.1-1.,4
Ammonium (mg N / l)	0.25-3,0	4.0-6.3 (added manually)
COD_{ps} (mg O_2 / l)	1.5-3.0	0.9-1.5
m-alkalinity (mmol / l)	9.4-10.9	4.2-7.0
Conductivity (µS/cm)	1130-1393	572-664
pH	6.28-6.77	6.51-7.13
Temperature (^oC)	17.3-23.2	23.3-26.8
Dissolved oxygen (mg O_2 / l)	1.4-2.5	1.25-1.90

Total dissolved iron content of the inlet water was less than 0,04 mg Fe / dm^3, total arsenic content was less than 1,5 µg/dm^3. Ammonium content of the groundwater dropped significantly on rainy days. Though the dissolved iron content was negligible, the hydrophore system and the pipeline had significant amount of iron precipitation in them. Some small flocks of oxidised iron reached the zeolite filter media, but they were retained in the top layer, never entering the internal pores.

4. RESULTS

Two different raw water qualities are identifiable on the time series of the measured ammonium contents (Fig. 2.):

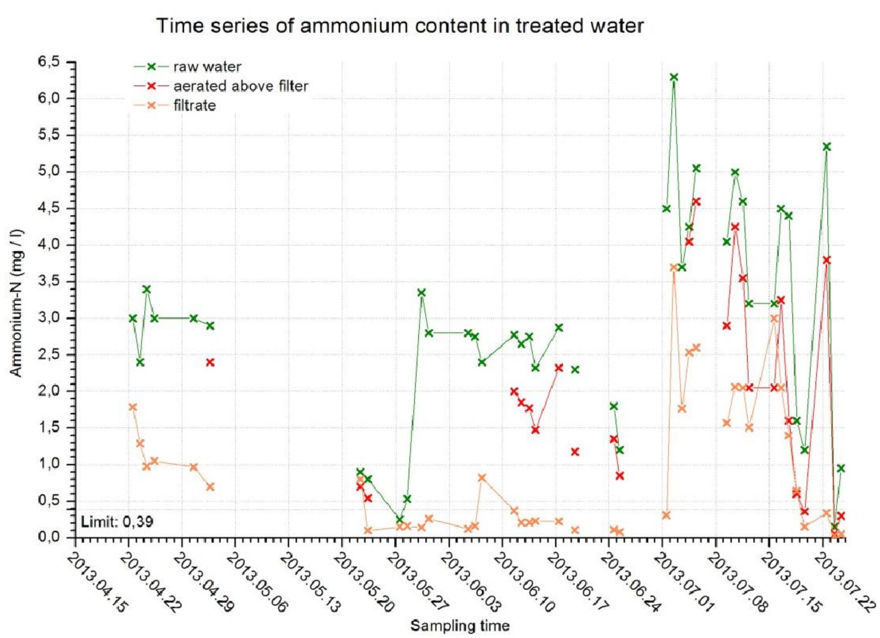

Figure 2. Time series of measured ammonium content

Analytic results of samples from different places show that there is a significant nitrification on the trickling media. Measured nitrite content was also higher in the headwater of the second filter after aeration on trickling media, than in the raw water or in the filtrate. There was not any major setback in the efficiency of nitrification after backwashing the filter. Possible reasons are that the biofilm was not washed out from the pores of the zeolite and the bacteria have been rapidly populated the zeolite filter from the trickling media above. The explanation for the poor results of the last two samples is that the filtrate was recirculated back and the removed ammonium content was replaced in it. This caused nitrate to accumulate in the water up to 15 mg N /dm^3 and more importantly alkalinity to drop below 3 mmol/dm^3. Observed decrease in ammonium content was approximately 1,0 – 2,0 mg NH_4^+-N / dm^3 regarding the whole filter. Nitrogen balance was also investigated separately for the trickling media and zeolite media. It is not yet clear that which one of them was less inhibited or more efficient in nitrification, because of fluctuations in water quality. Nitrification rate for the whole model is estimated to 5 – 10 mg NH_4^+-N / (dm^3 · h), retention time calculated from the bed volume and the flow rate. This suggests that under more steady conditions this method is capable of removing the requested amount of ammonium from the raw water to meet with the drinking water requirements. Similar results of 7 mg NH_4^+-N / (dm^3 · h) were measured under nearly similar conditions in rapid sand filter [3]. To check nitrogen balance of the process, the amount of ammonium loss and the increase of the inorganic nitrogen (nitrite and nitrate) content were calculated. Ammonium loss and increase of the inorganic nitrogen are in acceptable correlation and there is no significant difference between them. Total nitrogen loss also in correlation with the loss of inorganic nitrogen (Fig. 3).

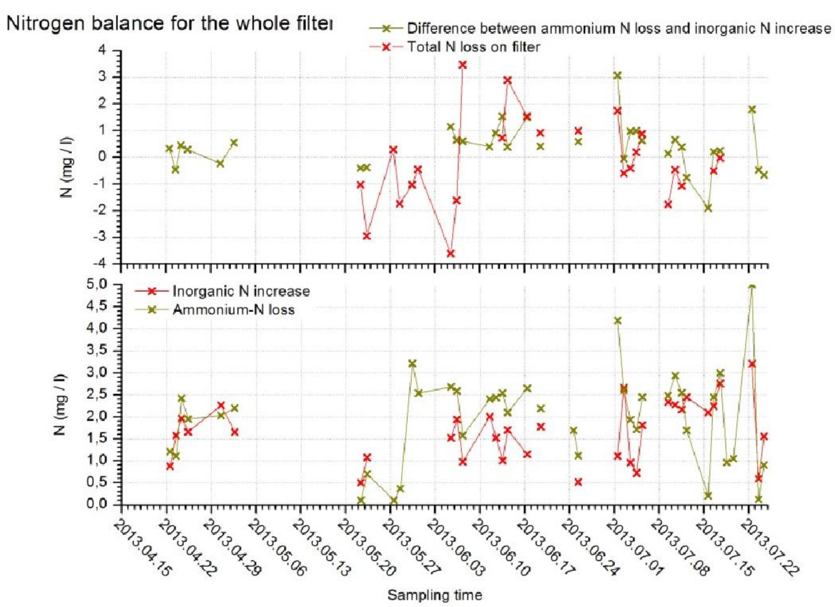

Figure 3. Time series of nitrogen balance

The differences in nitrogen balance are mainly due to the assimilation of nitrogen into the biomass. Inorganic nitrogen forms were measured by photometric methods and total nitrogen measured by TOC equipment. There are nearly error rates of 10% in the latter method, which make hard to carefully study the total nitrogen balance.
Even in this experiment with rather fluctuating conditions there were only nitrite peaks in the filtrate when sudden changes occurred. The measured nitrite content is shown in Fig. 4.:

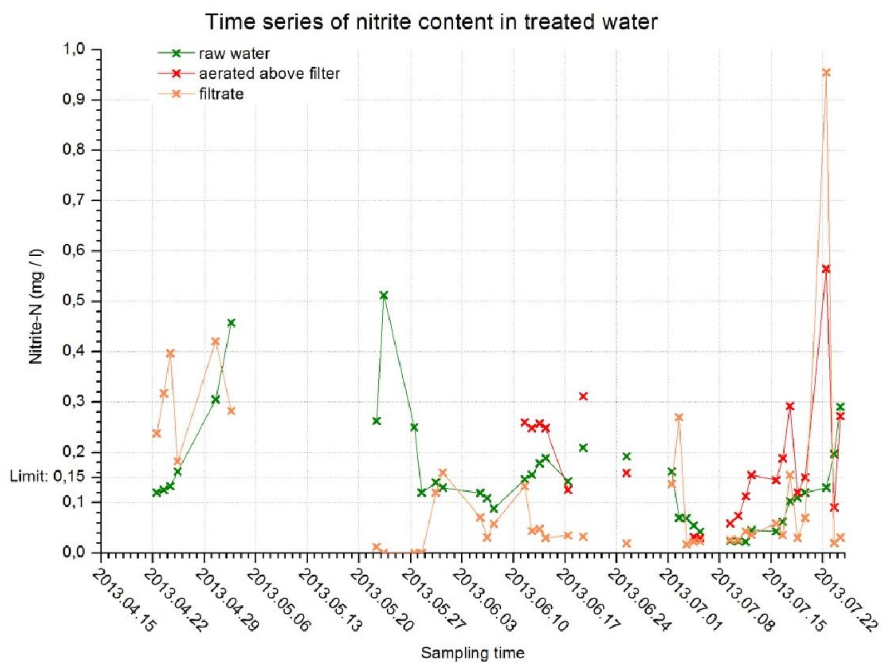

Figure 4. Time series of measured nitrite content

Since usually there is negligible amount of organic nitrogen in our subsurface water reservoirs, the easy photometric measurement of the inorganic nitrogen forms is satisfactory to operate biological ammonium removal processes for now. Results revealed that subsequent studies needed on total nitrogen balance, and to find correlations between the organic nitrogen forms and the operating conditions of biological ammonium removal processes.

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