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Influence des caractéristiques des matières organiques naturelles sur le traitement et la qualité des eaux potables

Influence of natural organic matter characteristics on drinking water treatment and quality

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EFFECTS OF DECLINING AND CONSTANT RATE DIRECT FILTRATION ON TREATMENT OF SOFT HUMIC WATERS

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Introduction

Treatment of soft humic waters is still not fully understood. Troubles with high residual aluminium and COD were in some cases solved in full scale practice by measures, which are partially in contradiction with general theory. First example might be that in cold water season, it was proved to be beneficial if coagulant dosing point was moved just ahead of rapid filters, instead of the standard place at the beginning of flocculation. At treatment plant, where our pilot-plant was operated, even well designed 15-20 minutes flocculation with gradients above 100 s^{-1}, suggested for such type of waters by Odegaard et al. [1], performed generally worse than operation without flocculation. With flocculation, filter runs were shorter, both residual aluminium and COD were higher.

Not any change of coagulant type (e.g. use of polyaluminiumchlorides) and other chemical conditions was found to be the reason for the peculiar behaviour of full scale filters. Full scale operation of hardening with lime and carbon dioxide also did not bring any convincing effect in coagulation/filtration performance. But on the other hand, in both cases, aggregates, which were produced under optimised chemical conditions and by 'proper' flocculation, were proved by several other separation methods (e.g. small laboratory filters, centrifugation, sedimentation) to be 'better' than aggregates formed without flocculation. Similar peculiarities were found at several other treatment plants treating soft humic waters. In full scale, filter runs with good treated water quality were too short and early breakthrough of residual coagulant and COD was the main problem.

It was hypothesised that in treatment of soft humic waters, pre-treatment must match much better the needs of direct filtration, or vice versa, filtration has to be closely adopted to the character of produced aggregates. One of the overlooked possibilities to optimise the treatment train is the use of declining rate control of filters. There are two methods for controlling filter rates: constant rate filtration and variable declining rate filtration. Constant rate filtration is the most common method. In variable declining rate filtration, filtration rate declines as headloss builds up during the filtering process. The use of declining rate control of filters has been discussed in the literature for many years. Recent results were published in [2]. Some authors even showed no water quality advantage of either control system. The rate of headloss development was the same of the constant and declining rate operations [3].

Interactions between pre-treatment, two flow rate control systems (constant rate and declining rate filtration) and type and number of layers of filter media were studied at our direct filtration pilot-plant. In this paper, we will focus on the influence of the two flow control methods on the performance of a direct filtration pilot plant.

Materials and methods

Source of the raw water was a headwater reservoir. The Fláje reservoir is located in North Bohemia near Litvínov. Basic characteristics of raw waters used for the experiments and some pilot-plant operating conditions are given in Table I.

Table I
Experimental conditions of pilot-plant operation.

Parameter/Results in	Fig. 1 and 2	Fig. 3	Fig. 4
COD [mg/l]	4.1	5.3	4.8
alkalinity [mmol/l]	0.15	0.15	0.16
pH	6.30	6.35	6.40
conductivity [µS/cm]	98	107	109
Al [mg/l]	0.12	0.14	0.16
colour [°Pt, mg/l]	30	35	34
abs.387 nm [5 cm]	0.116	0.136	0.132
turbidity [NTU]	0.5	0.4	0.6
alum dosis [mg/l]	*15*	*18*	*16*
filter aid	-	*non-ionic, 0.012 mg/l*	-
filter media and media depth	*sand, 1.0-1.7 mm 100 cm*	*sand, 1.0-1.7 mm 80 cm*	*anthracite 2-4 mm 65 cm + sand, 0.65-1.0 mm 65 cm*

Single media (sand) and dual media (anthracite/sand) filters were investigated. $Al_2(SO_4)_3 .18\ H_2O$ - alum - was used as coagulant. To carry our experiments with 'real' suspension, water from full scale flocculation tank with theoretical residence time 20 minutes, which was equipped with adjustable baffles was used for the investigations presented in this paper. Previous experiments have shown that under conditions of our experiments it is nearly impossible to produce the same character and size distribution of aggregates in pilot-plant and full scale even keeping all the similarity criteria.

Results

Results of pilot plant experiments are presented in Figs. 1-4. Fig. 1 a,b presents results of the constant rate filter, and in Fig. 2 a,b performance of the declining rate filter treating the same water under the same pre-treatment conditions. Comparing both figures shows clearly the major difference between constant and declining rate operation.

Declining rate filter performed in all aspects significantly better than the constant rate filter. The rate of headloss development was much slower. Also the quality of filtered water and filter run time was much better in case of declining rate filter. These results are surprising, and up to now we did not formulate hypothesis for explanation of such differences caused by both systems. One possible way of future research to explain above mentioned findings could be based on hypothesis that aggregates after flocculation stick firmly to the sand surfaces but, probably, they are not so effectively removed after sand grains are covered by the first layer of aggregates.

Fig. 1b
CONSTANT RATE FILTRATION - sand

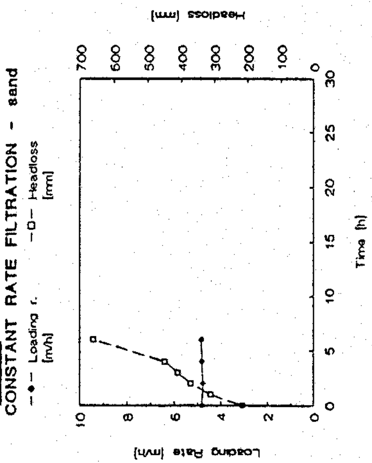


Fig. 2b
DECLINING RATE FILTRATION - sand

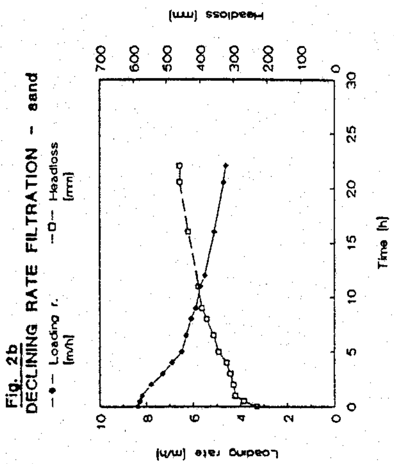


FIG. 1a
CONSTANT RATE FILTRATION - sand

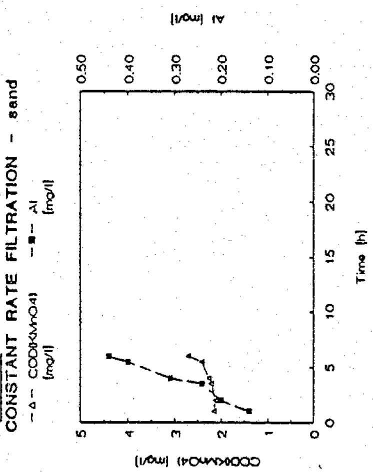
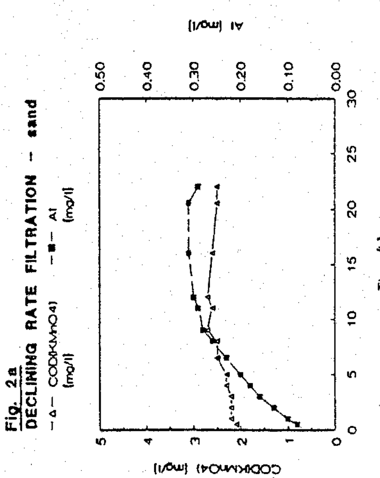


Fig. 2a
DECLINING RATE FILTRATION - sand



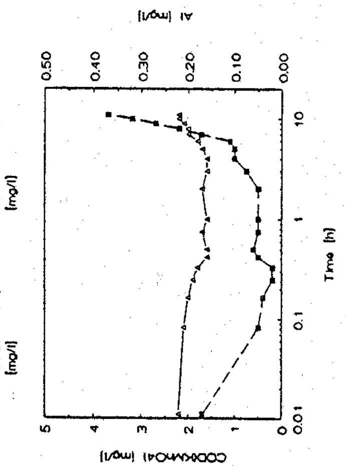


Fig. 3a DECLINING RATE FILTRATION - sand

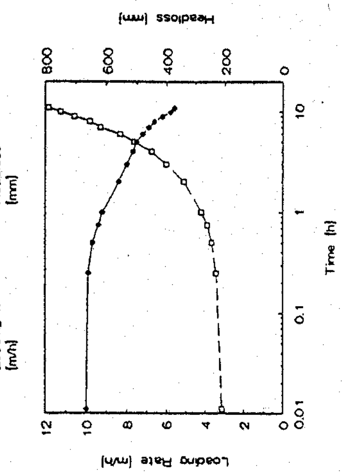


Fig. 3b DECLINING RATE FILTRATION - sand

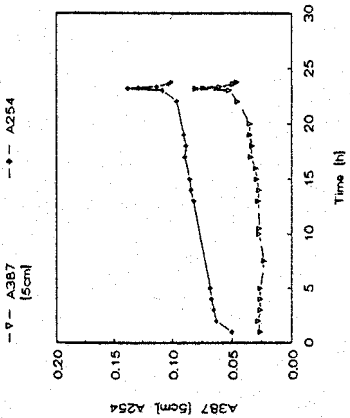


Fig. 4a DECLINING RATE - anthracite/sand

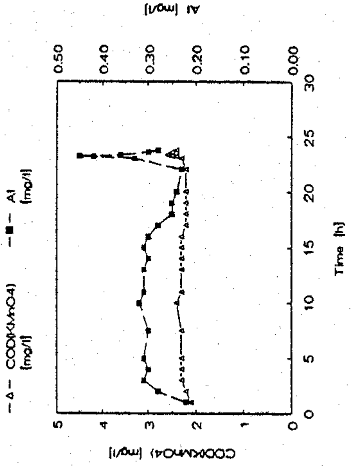


Fig. 4b DECLINING RATE - anthracite/sand

On the other hand, in experiments without any time of flocculation (and without the high G mixing, also called contact filtration), aggregates were 'young' and sticky, operation was relatively stable, but efficiency of removal of both, coagulant and COD, was lower during the whole filter run than at the beginning of the filter run with good flocculation. This hypothesis was based also on observation that no filter ripening phase occurred in our experiments.

Fig. 3a,b shows experiment focused on answering two questions. First, what is the water quality during the ripening period, and second, what is the influence of high initial loading rate? Experiment was made with the use of very low dose of non-ionic filter aid (0.012 mg/l), dosed after proper flocculation to the inflow of rapid sand filter, and, at the same time, with reduced depth of filter bed to only 80 cm of sand. Even as low doses as 0.005 mg/l of non-ionic filter aid did dramatically change the separation effect of direct filtration. This was also verified in full scale.

In Fig. 3 a, we can see 'negative ripening' instead of filter quality deterioration in initial stage of the filter run. The poor water quality at the very beginning of the filter run is caused by the quality of the water used for filter backwash. After starting the filter run, this water is flushed out of the filter bed and quality of the filtrate is improving. Concentration of Al starts rising as late as after 7 hours of operation. These results support the idea that in this particular case, attachment of aggregates of humic substances to sand surfaces does not cause any need for filter to waste period, and that high initial loading rates, which are associated with declining rate operation, would not cause any deterioration of filtered water quality.

One possible reason of filtered water quality deterioration, which was many times observed in full scale operation, is the sensitivity of filter performance to changes of flow, which might be caused by e.g. flow controllers. Fig. 4 a,b shows the response of a filter to single change of operating level above the filter bed, which was intentionally made at the end of the filter run. Operating level was decreased from 75 cm to 65 cm and than back in 10 minutes' time. So, the change of water level was equal to 2 cm/minute. The disastrous results of this fluctuation are quite obvious. From this could be concluded that in some cases not only chemical factors influence the removal efficiency of natural organic matter and that filtration of aggregates which are formed in coagulation/flocculation processes is still source of surprises and research needs.

Conclusions

1) Declining rate filtration showed advantages over constant rate filtration in treatment of soft humic waters coagulated with aluminium sulphate.
2) Non-ionic filter aid in doses as low as 0.01 mg/l did substantially improved the direct filtration performance.
3) Filter ripening period was not observed, even at initial flow rate up to 10 m/h.
4) Operating level fluctuations as slow as 2 cm/minute caused substantial deterioration of filtered water quality.

Literature

1. Odegaard H,. Brattebo, H, Eikebrokk, B. and Thorsen, T.: Removal of humic substances from water. Report, The Norwegian Institute of Technology. Trondheim 1986, p.25.
2. Cornwell D.A. et al.: Full-Scale Evaluation of Declining and Constant Rate Filtration. AWWARF, Denver 1991.
3. Cleasby J.L. and Hilmoe D.J.: Effective Filtration Methods for Small Water Supplies. EPA 600/52-84-088. Cincinnati, OH 1984.