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THE INFLUENCE OF MICROFLOC AGE ON ITS STRENGTH AND SORPTION CAPACITY

In the process of direct filtration, reagents are fed into the system before a filter or just above a filter bed. However, it is not clear which place is best. The results of many investigations prove that a short time of the reaction of water with coagulant before the filter bed should allow only coagulant hydrolysis and the change of electrokinetic potential ζ. Such a time of coagulant dosing just before filtration should unable agglomeration of flocs which are less susceptible to an attachment to filter media.

The results of the research presented in this paper indicate that in the treatment of soft waters collected from mountainous streams, where dissolved organic matter is a prevailing contaminant, the time of the reaction of water with coagulant before the filer bed does not significantly influence the treatment effectiveness. Microflocs generated just after coagulant dosing are not only stable and effective in contaminant sorption, independently of their age and temperature, but also susceptible to further separation during filtration.

1. INTRODUCTION

Treatment of waters collected from mountainous streams, which are mainly contaminated with dissolved organic matter, is based on coagulation. The quality of these waters changes in a wide range depending on season. For these reasons their treatment should be carried out by means of two coagulation methods, i.e., coagulation in filter bed (direct filtration) when contamination is low and conventional treatment ("sweeping coagulation") when contaminant concentration is too high to apply a direct filtration. The effectiveness of "sweeping coagulation" first of all depends on the size, density and strength of flocs [1]–[3]. Generally, the flocs generated during coagulation of coloured water by alum coagulants are regarded to be fragile and unsusceptible to sedimentation. However, under optimal technological and hydraulic conditions it is possible to produce water of proper quality. The necessity to treat the water in direct filtration is of prime importance at low temperature when "sweeping coagulation" is ineffective.

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As is generally known, the above-mentioned treatment technology, which involves two coagulation methods, requires two different points of reagents dosing, depending on the method applied. In a conventional treatment, this point is before the flocculator. In direct filtration, according to MINZ [5], a coagulant should be dosed just before filtration to prevent flocs from agglomeration, otherwise the flocs produced are less susceptible to attachment to filter media. Hence, the time of the reaction of coagulant with source water should be so short as to enable the coagulant hydrolysis only and the change in the electrokinetic potential ζ. According to GANCZARCZYK [4] a 10-minute flocculation in a filter bed is insufficient to meet water quality requirements.

In this work, the influence of microfloc age on its strength and sorption capacity and its susceptibilty to separation during filtration were evaluated. Based on the results obtained we can state whether or not it is possible to treat water during direct filtration and conventional treatment in one technological system (a flocculator, a sedimentation tank, a filter) with one common point of coagulant dosing (before the flocculator) independently of the treatment method.

2. PROCEDURE

2.1. WATER QUALITY

A raw water, supplied to the research systems directly from its intake, was soft, weakly mineralized (its coductivity was ranged from 45 to 90 μS/cm) and slightly

Table

Characteristics of raw water and the water after treatment in pilot-scale plant

Parameter	Series I (without coagulant dosing)		Series II (temperature of 16 °C)			Series III (temperature of 6 °C)		
	Raw water	Filter I effluent	Raw water	Filter I effluent (t_r = 10 min)	Filter II effluent (t_r = 3.5 h)	Raw water	Filter I effluent (t_r = 10 min)	Filter II effluent (t_r = 3.5 h)
Temperature [°C]	17.3–17.7	–	16.1–16.4	–	–	6.2–6.5	–	–
pH [–]	5.9–6.1	–	6.0–6.2	–	–	5.5–5.9	–	–
Apparent colour [mg Pt/dm^3]	28–30	25–26	15–20	0–5	3–8	20	0–2	0–5
Turbidity [NTU]	0–4	0–1	2–3	0–1	0–1	2	0–1	0–1
Alkalinity [mval/dm^3]	0.6	–	0.5	–	–	0.5	–	–
Total hardness [mg $CaCO_3$/dm^3]	55	–	45	–	–	50	–	–
Mn-COD [mg O_2/dm^3]	5.2–7.1	4.6–5.0	3.1–3.3	1.1–1.9	1.5–1.9	2.5–3.1	0.8–1.2	1.0–1.3
Absorbancce UV_{254} *F* (filtered sample) [cm^{-1}]	0.13	0.12	0.08–0.09	0.02–0.04	0.03–0.04	0.09–0.1	0.03–0.04	0.03–0.04
Absorbance UV_{254} *UF* (unfiltered sample) [cm^{-1}]	0.14	0.13	0.09	0.02–0.04	0.03–0.04	0.09–0.11	0.03–0.04	0.03–0.04

alkaline (0.5–0.6 mval/dm^3). It was mainly dissolved organic matter (close values of absorbance UV_{254} in filtered and unfiltered samples) that gave the water colour which varied from 15 to 30 mg Pt/dm^3. The turbidity was very low and its value did not exceed 4 NTU. The research was conducted in various seasons in order to investigate the treatment processes in a wide range of water temperature. The characteristics of the water quality in the series investigated are given in the table.

2.2. EQUIPMENT

In the research, two different technological system were applied: the system of direct filtration (the system I, figure 1) and the conventional system (the system II, figure 2). Both systems operated under optimum hydraulic conditions determined in the earlier research. The reagents at the optimum doses for the direct filtration were fed directly into the water pipe (water flow ensured rapid-mixing processes) and then supplied to both systems.

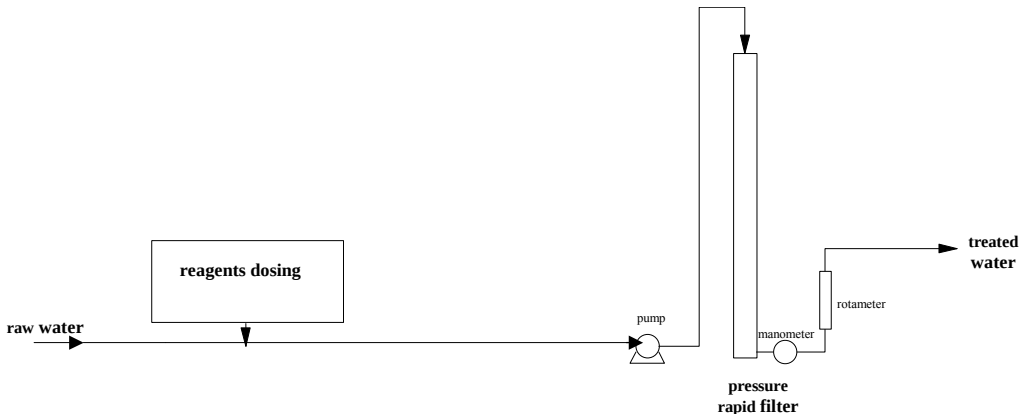

Fig. 1. Schematic diagram of water treatment by direct filtration in pilot-scale plant

The operation of the system I was based on a direct filtration of water through a two-layer pressure rapid filter (the granulation of layers: sand – 0.8–1.2 mm and anthracite – 0.6–2.0 mm). Each layer was 55 cm high. The supporting layer of 0.3 m thickness was made of gravel (grain-size distribution in the range of 2–20 mm). The filtration rate in both systems was 6 m/h. The height of water column above the filter bed reached 1 m. Hence, at a given filtration rate, in this system the time of the reaction of the coagulant with raw water before the filter bed was 10 minutes.

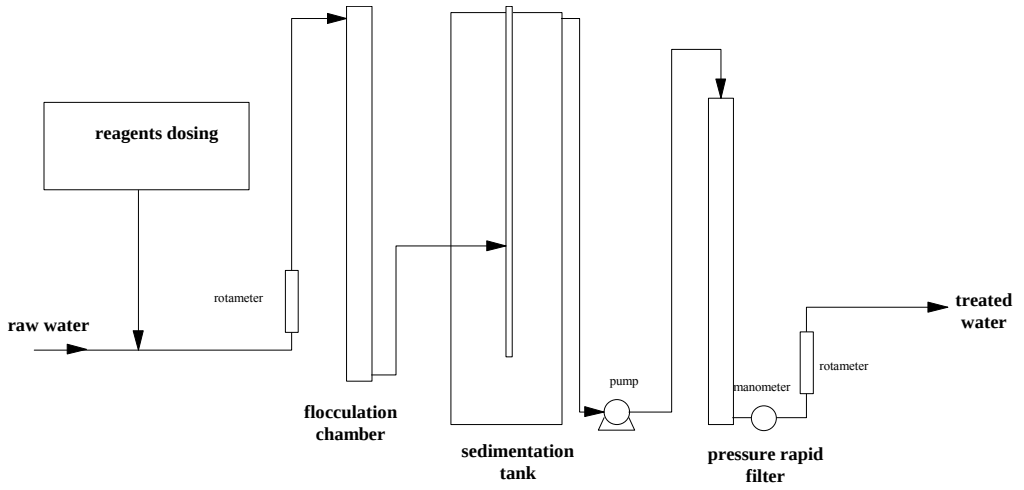

Fig. 2. Schematic diagram of conventional water treatment in pilot-scale plant

In the system II, which was to extend the time of the reaction of coagulant with water before the filter bed, the water was flowing through a rotational flocculation chamber, a vertical sedimentation tank and a pressure rapid filter (of the same characteritics as that in the system I). This system is the same as a typical conventional system, but its task is quite different. Because coagulant doses were much lower than these required for "sweep coagulation", it was impossible to produce the flocs susceptible to sedimentation. Therefore the flocculator and the sedimentation tank could have been treated as the reaction chambers with extended retention time. Taking into consideration the retention time in the flocculator (~ 20 min) and in the sedimentation tank (~3 hours) as well as the height of the water column above the filter bed we could infer that the time of the reaction of water with coagulant before filtration approached 3.5 hours. Therefore in the system II, the reaction time was about 20 times longer than in a typical system of direct filtration, where the coagulant was applied directly before the filter.

In the system I, the first effluent samples were collected after 30-minute filtration. In the system II, the results of treatment were analysed neglecting the first 6 hours of system operation. Such a long time lag was necessary to reach optimum technological parameters of constant values.

2.3. REAGENTS

Aluminium sulphate was used as a coagulant. All its doses were expressed in mg Al/dm^3. The optimum coagulant dose for direct filtration determined in dynamic tests in the pilot plant (the system I) was found to be in the range of 0.8–1.2 mg

Al/dm^3, depending on water temperature. A decrease in water temperature resulted in an increase in the optimum coagulant dose. During the tests which aimed to determine the optimum pH for a direct filtration, the pH of raw water changed in the range of 5.5–6.3. In the dynamic tests, the optimum pH for the direct filtration was found to be in the narrow range of 6.0–6.2. Because of the low pH of raw water it was essential to adjust it to the optimum range by means of sodium carbonate. The optimum pH range was confirmed by the lack of residual aluminium in water (figure 4).

2.4. PROCESS CONTROL

The optimum dose of coagulant for the direct filtration, much lower than this necessary for "sweep coagulation", prevented both systems from visible floc formation. However, that dose resulted in the generation of microflocs being able to adsorb dissolved organic matter. Hence, in order to establish the influence of time (microflocs age) on their strength, the changes in the absorbance UV at 254 nm in filtered samples were analysed. The results obtained were treated as the basis for the analysis of the changes in dissolved organic matter (DOM) concentration during treatment processes in the systems, i.e., at different age of microflocs before filtration.

The effectiveness of treatment was estimated on the basis of filtrate quality: colour, turbidity, Mn-COD (permanganate chemical oxygen demand) and absorbance UV_{254} in filtered (absorbance *F*) and unfiltered (absorbance *UF*) samples.

3. RESULTS AND DISCUSSION

In order to establish the mechanism of contaminant removal in direct filtration, at the beginning of the study a raw water without any reagents was filtered (the series I). The results indicate that organic contaminants responsible for water colour have not been separated during filtration (the table 1, figure 3). The presence of organic matter in a dissolved or colloidal form was confirmed by the close values of colour and absorbance UV_{254} in filtered and unfiltered samples. Filtration allowed only turbidity to be removed from the maximum of 4 NTU in the raw water to the maximum of 1 NTU in the filtrate. An insignificant decrease in Mn-COD was also observed. This could be due to the fact that only contaminants causing turbidity (suspensions) and negligible amount of organic matter associated with them were separated in the filter bed.

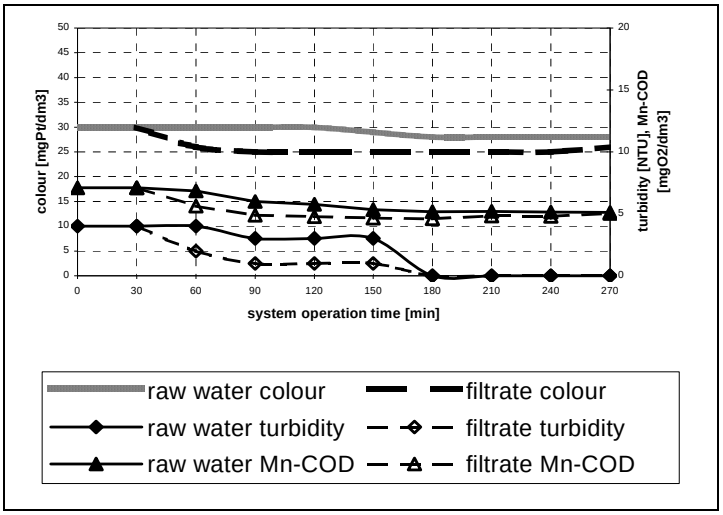

Fig. 3. Contaminant removal during filtration without coagulant

The aim of the present investigations was to establish the influence of the micro-floc age on its strength and sorption abilities. In order to find a possible influence of water temperature on the processes of interest, the investigations were carried out in two series: at 16 °C – the series II and at 6 °C – the series III.

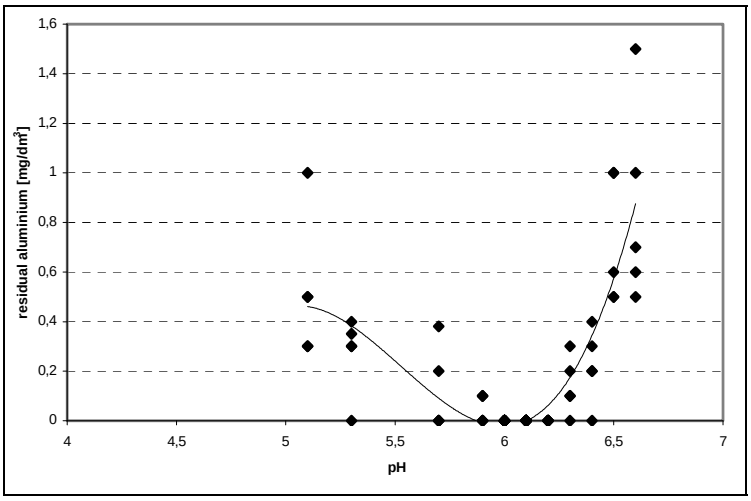

Fig. 4. pH versus residual aluminium concentration in water treated in direct filtration

During investigations in the system II, conducted in such a way as to rule out the possibility of contaminants removal in the sedimentation tank, the samples were also

collected and analysed directly in the outflow from a sedimentation tank. On the basis of the water quality it was concluded that the sedimentation tank had no important impact on contaminant removal. The raw water turbidity was not susceptible to "rapid" sedimentation. To sum up, it could be assumed that the flocculator and the sedimentation tank were only the tanks for the reactions of the prolonged retention time.

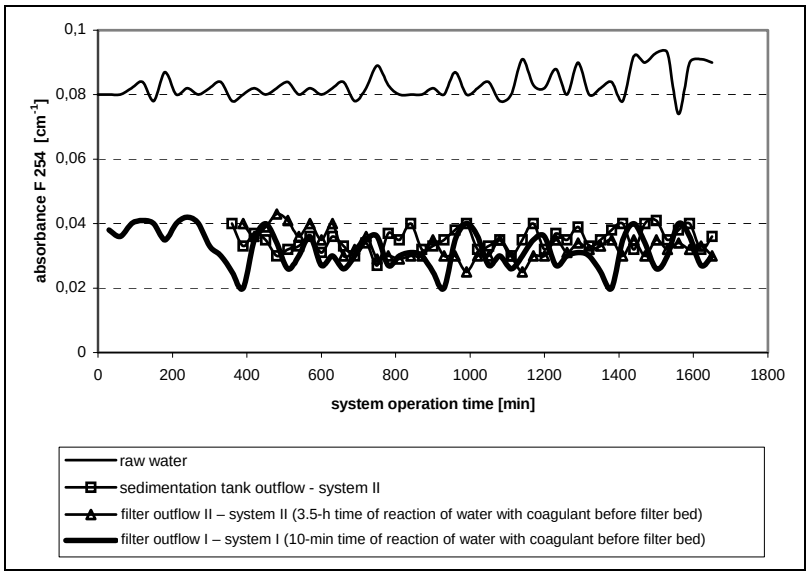

Fig. 5. The time of reaction of coagulant with water before filter bed versus DOM (dissolved organic matter) removal at high temperature (series II)

In the series II, when the temperature of raw water was high (about 16 ºC) and the dose of a coagulant low, the microflocs, which generated just after the coagulant addition, adsorbed dissolved organic matter, being the predominant water contaminant (figure 5). This process was observed in both systems where a decrease in the absorbance *F* was measured. In the system II, the values of the absorbance *F* decreased from 0.08–0.09 cm^{-1} in raw water to about 0.03–0.04 cm^{-1} in the water from flocculator and in the outflow from sedimentation tank. The same values of absorbance measured in both outflows indicate that in this series, the time of water flow in the sedimentation tank did not change the microflocs strength. The microflocs generated in the flocculator were stable and their strength did not change with their age. After filtration no changes of absorbance were recorded. It was concluded that during filtration only dissolved organic substances adsorbed by microflocs were retained in the bed. The similar changes in DOM (dissolved organic matter) were found during water treatment in the system I, where the coagulant was dosed just before the filter (figure 5). The filtrate absorbance *F* ranged from 0.02 to 0.04 cm^{-1}.

A proper course of the treatment processes in both systems was confirmed by a good quality of filtrates. The influence of a long time of the reaction of the coagulant with water before the filter bed on the filtrate quality was negligible (table 1). The colour of the filtrate sampled from the system II ranged from 3 to 8 mg Pt/dm^3 and the turbidity did not exceed 1 NTU. At the same time the colour of the filtrate I varied from 0 to 5 mg Pt/dm^3 and the maximum turbidity reached 1 NTU. After 27.5-hour worktime of both systems the treatment was stopped. The results obtained were reliable enough to allow the analysis of the processes.

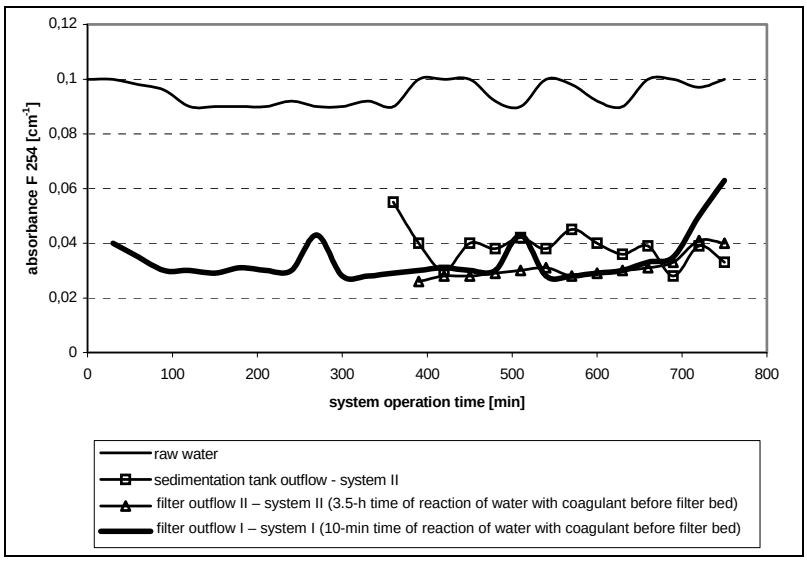

Fig. 6. The time of reaction of coagulant with water before filter bed versus DOM (dissolved organic matter) removal at low temperature (series III)

In the series III (the temperature of raw water about 6 ºC), coagulation of contaminants proceeded in a way similar to this in the series II (figure 6). The changes of the absorbance *F* indicated that sorption of DOM by microflocs took place. Contrary to the flocs generated during "sweep coagulation" (in that research coagulant dose was 4 mg Al/dm^3) when the flocs rupture observed with their ageing caused desorption of dissolved organic matter, microflocs generated after coagulant dosing were stable in spite of low temperature of water [6].

In the series III, the age microflocs had no crucial impact on the treatment effectiveness either (the table). The maximal value of turbidity in both filtrates was 1 NTU. In the system of extended reaction time, the intensity of colour was only slightly higher compared to this in the filtrate I. 8.5-hour passing the water through the filter II resulted in the colour range of 0–5 mg Pt/dm^3, while in the effluent I the colour ranged from 0 to 2 mg Pt/dm^3 after 11-hour filtration. After 12.5-hour work-

time of the systems, the quality of filtrates deteriorated and the treatment processes were stopped.

In a direct filtration, the microflocs generated just after adding an optimum coagulant dose to the raw water were stable independently of temperature. However, a low temperature of water was responsible for a distinct shortening of the filtration cycle.

4. CONCLUSIONS

A long time of the reaction of raw water with the coagulant before the treatment in the filter bed did not deteriorate significantly a direct filtration effectiveness. It is supposed that in the case of soft, slightly mineralized waters, the properties of microflocs generated at the coagulant dose at its optimum for direct filtration ensure their stability, even under low temperature conditions. That is why we can apply one technological system (the flocculator, the sedimentation tank, the filter) for both conventional treatment [6] and direct filtration, with one point of reagents dosing, i.e., before the flocculator. Such a procedure allowing only reagent doses to be changed, depending on coagulation method, ensures a required effectiveness, independently of raw water quality, at each temperature.

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WPŁYW WIEKU MIKROKŁACZKA NA JEGO TRWAŁOŚĆ I ZDOLNOŚCI SORPCYJNE

Podczas koagulacji wód w złożu filtracyjnym reagenty są dozowane bezpośrednio przed filtrem lub tuż nad powierzchnią złoża. Dotychczasowo nie stwierdzono jednoznacznie, jakie dozowanie jest lepsze. Prowadzone badania wskazują, iż krótki czas reakcji koagulantu z wodą ma jedynie zapewnić hydrolizę oraz zmianę potencjału elektrokinetycznego ζ koagulantu, nie powinny natomiast wytworzyć się kłaczki. Przedstawione wyniki badań świadczą jednak, że w przypadku uzdatniania miękkich wód górskich, których podstawowym zanieczyszczeniem są rozpuszczone związki organiczne, czas reakcji koagulantu z surową wodą przed złożem filtracyjnym nie ma istotnego wpływu na skuteczność uzdatniania wody. Powstające mikrokłaczki są trwałe niezależnie od wieku i temperatury, skutecznie sorbują zanieczyszczenia i są podatne na dalszą separację w procesie filtracji.