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EFFECTIVENESS OF „ENHANCED COAGULATION" IN LOW MINERALIZATION WATER TREATMENT

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COMMUNICATION

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SKUTECZNOŚĆ „GŁĘBOKIEJ KOAGULACJI" W UZDATNIANIU WÓD O NISKIEJ MINERALIZACJI

Celem „głębokiej koagulacji" jest usunięcie z uzdatnianej wody związków organicznych, w tym prekursorów ubocznych produktów dezynfekcji. Wiąże się to ze znacznym obniżeniem barwy i mętności wody często do wartości znacznie niższych od dopuszczalnych dla wody przeznaczonej do spożycia. Na podstawie wyników przeprowadzonych badań stwierdzono, iż zachowanie ściśle ustalonych parametrów technologicznych koagulacji pozwala na skuteczne uzdatnianie wód o niskiej mineralizacji, nawet w okresach bardzo niskich temperatur wody, zapewniając tym samym znaczne obniżenie stężenia związków organicznych w wodzie, w tym prekursorów trihalometanów. Wymaga to jednak zastosowania dwóch różnych metod koagulacji w zależności od temperatury wody. W okresie „wysokich temperatur" proces uzdatniania może być realizowany w oparciu o koagulację objętościową, a w okresie „niskich temperatur" o koagulację powierzchniową. Powyższa technologia może być realizowana w jednym układzie technologicznym.

Summary

During the process of „enhanced coagulation" except for colloids and suspensions removal, the removal of associated organic compounds including DPD (Disinfection By-Products) precursors is crucial. It is often necessary to decrease color and turbidity of treated water to values which are significantly lower than accepted for drinking water. On the basis of presented results of the research it was found out that under strict technological conditions coagulation of low mineralization waters ensures effective treatment, including significant THMs precursors removal, even when water is of low temperature. However, it is necessary to apply two different methods of coagulation (volumetric coagulation and direct filtration) dependently of water temperature with the usage of the same equipment (a flocculation chamber, a vertical sedimentation tank and a pressure rapid filter) including the same point of a coagulant dosing. During the periods of „high temperature" the treatment should be based on volumetric coagulation and during the periods of „low temperature" of water direct filtration should be applied.

INTRODUCTION

Coagulation is a basic treatment process of surface waters. At optimal coagulation parameters the process results not only in a distinct removal of colloids and suspensions but also in organic compounds, associated with them. When the main purpose of treatment in a conventional system is organic matter removal, including DPD (Disinfection By-Products) precursors described as TOC (Total Organic Carbon) the process is called enhanced coagulation. The decrease of TOC concentration is connected with a removal of color and turbidity often to the values which are much lower than acceptable for drinking water. This process is also essential before other technological processes; first of all before sorption on activate carbon. Water which is supplied to active carbon filter must meet high quality requirements basically of color and turbidity. Otherwise filter operation would be very uneconomical. Enhanced coagulation may also be applied before UV disinfection. This method of disinfection requires high operating and capital expenditure. This is why exposed water should be free from suspensions which absorb some ultraviolet radiation causing lowering of disinfection effectiveness [2–9].

The need for water treatment in the process of enhanced coagulation mostly concerns soft waters collected from mountain runoff. In this paper the results of research over treatment of low mineralization water (supplied from water reservoir) are presented. The estimation of treatment effectiveness both in conventional treatment and direct filtration is also performed. On the basis of the investigation results the technology of organic compounds removal from soft water, taking into consideration significant fluctuations of temperature, has been proposed.

SCOPE AND METHODS OF INVESTIGATION

The source water was soft and of low alkalinity. The maximal value of total hardness during the research was 60 mg $CaCO_3/dm^3$. The value of conductivity (45–90 μS/cm) indicates that the water was very low mineralized. Such the low buffer capacity is often the reason of serious problems in keeping proper technological regimes of coagulation, especially during fluctuation of raw water quality.

There were two systems of treatment in the pilot scale. These systems operated parallel (Figs 1 and 2). The system I (the system of conventional coagulation) consisted of a rotational flocculation chamber, a vertical sedimentation tank and a pressure rapid filter. The system II (the system of direct filtration) included a pressure rapid filter. The dual media filters were applied in both systems (sand – 0.8–1.2 mm and anthracite – 0.6–2.0 mm). Each layer was 55 cm high. Both systems were supplied with the raw water directly from the water intake.

At the beginning of investigation both systems operated separately until optimum technological and hydraulic parameters were found. The research started in summer time to eliminate negative influence of water temperature on the course of coagulation. Afterwards in order to compare and estimate the effectiveness of treatment by sweep coagulation (system I) and direct filtration (system II) both systems operated parallel by using the same source of water, under previously determined optimum parameters. The series of investigation was stopped when water quality in both systems did not conform to stringent criteria (turbidity

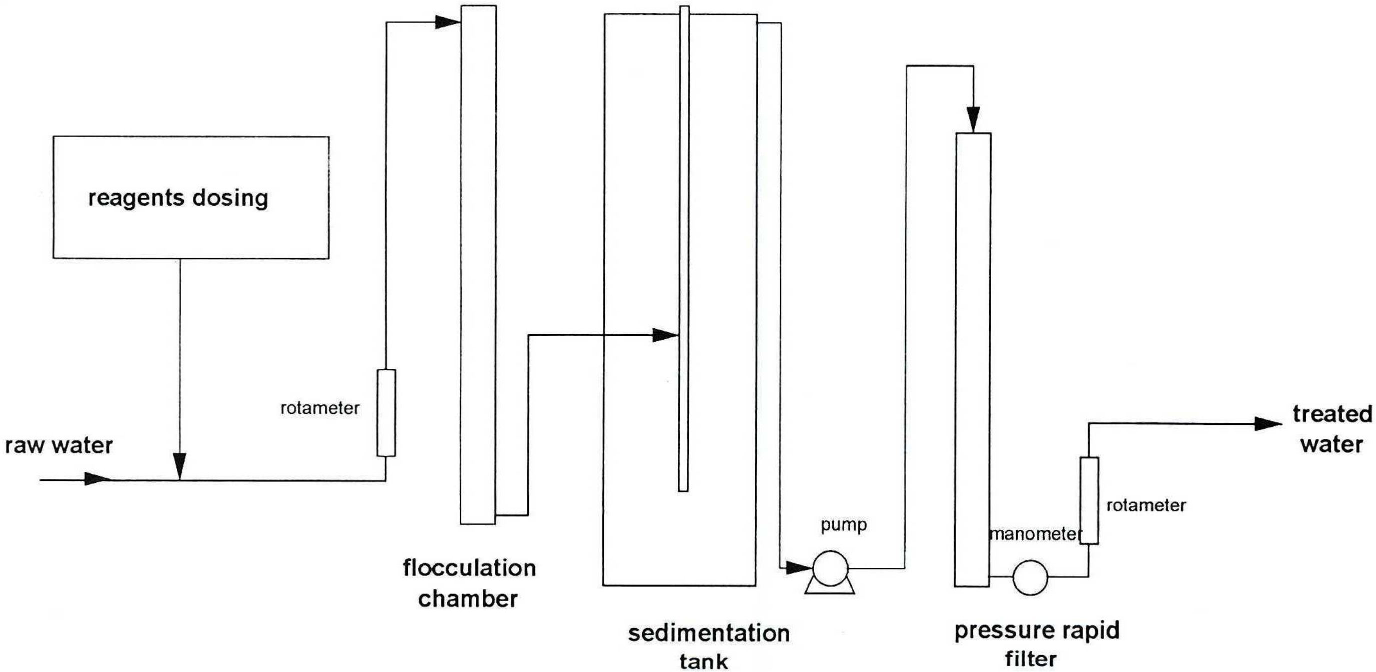

Fig. 1. Schematic diagram of the conventional water treatment in the pilot scale

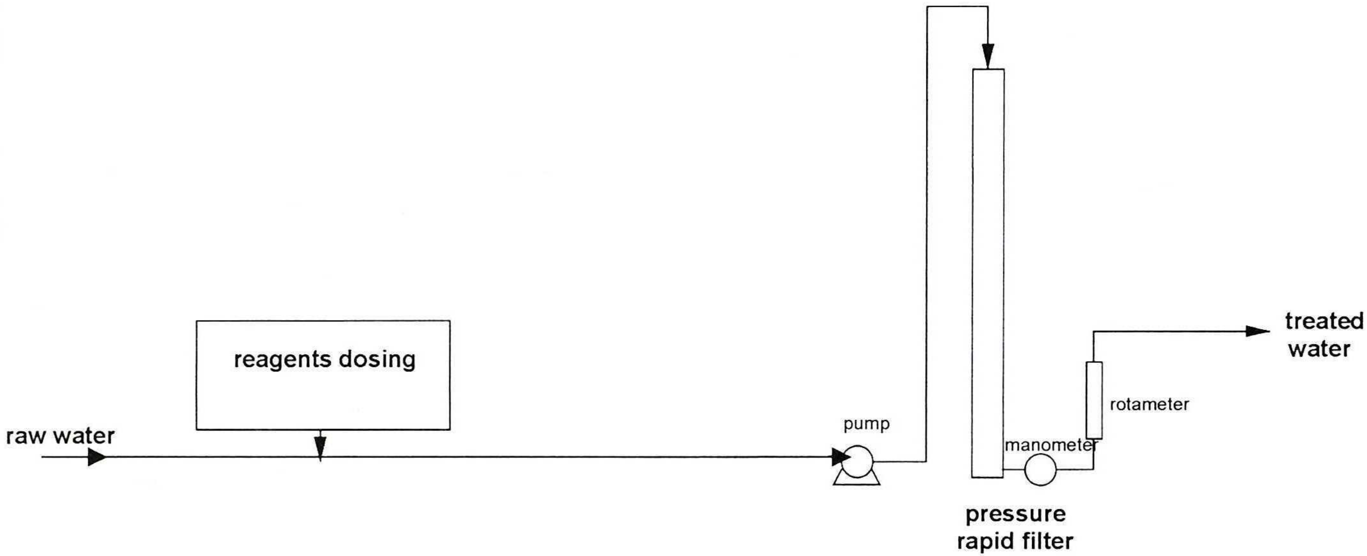

Fig. 2. Schematic diagram of the direct filtration water treatment in the pilot scale

1 NTU, color 5 mg Pt/dm^3). Water quality was estimated on the basis of pH, color in unfiltered samples, turbidity, POD (Permanganate Oxygen Demand) and absorbance UV_{254}.

RESULTS

On the basis of jar tests the optimum dosage of coagulant for sweep coagulation was determined. The optimum dose for aluminium sulphate was found to be 4.8 mg Al/dm^3. It is noteworthy that during the above mentioned tests water temperature was about 15°C (temperature of water is crucial for sweep coagulation). Taking into consideration the fact that the raw water quality during research changed, the optimum dosage could not be precisely pinpointed. Therefore, if necessary, the optimum coagulant dosage was adjusted to the optimum one obtained in jar tests just before the beginning of each series. The optimum pH was 6.0–6.5. The optimum coagulant dosage for direct filtration was determined in dynamic tests in the pilot plant. The optimum dose was found to be 0.8 mg Al/dm^3. The coagulant was dosed to the pipe which supplied the source water to the systems. At that moment a rapid-mixing started. The optimum pH for the direct filtration was in the narrow range 6.0–6.2. The filtration rate in both systems was 6 m/h. The optimum flocculation time was determined to be 18 min., ascending velocity in the clarification zone of the sedimentation tank 0.22 mm/s. Research over treatment of the soft water in sweep coagulation and direct coagulation proceeded in different seasons. This way effectiveness of both treatment methods for the raw water of variable quality, especially of various temperatures, was determined. The water was collected directly from a gravitational pipe which supplied the water treatment plant. The results of treatment in the system I were analyzed neglecting the first 6 hour system operation. Such a long time lag was necessary so that to reach the stable optimum technological parameters. In the system II the first effluent samples were collected after 30-minute filtration.

The treatment effectiveness was analyzed on the example of three chosen series. The prevailing parameter taken into account while choosing the series to present was the temperature (Tab. 1). During the first series, when temperature of water was 16°C, treated water in both systems met the strict requirements. It was confirmed by significant decrease of THMPF (Tab. 1). In spite of the turbidity variation in the influent, the turbidity in the filters outflow did not exceed 0.7 NTU. The color was totally removed. Such a high effectiveness was observed for about 21 hours, when the decision was made to break investigation in that series.

In the second series, when the source water temperature was about 6°C the treatment in system I failed. The increase of turbidity in the filter outflow confirms the improper course of the process. Short periods when good quality of effluent was obtained should be neglected. The results of the treatment in direct filtration were quite opposite. After 30-minute filtration for about 13 hours the treated water met the established requirements. The noticeable decrease in THMPF was also noted (Tab. 1).

When the source water temperature was about 2°C (series 3) the course of the process of coagulation in the system I was very similar to the series 2. The increase of turbidity from 2 NTU in the raw water to 4.5 NTU in the filter outflow indicates the failure of treatment. The trials to improve the results by higher dosages of coagulant were unavailing. On the other hand, high effectiveness of direct filtration was noted (Tab. 1). At 1.2 mg Al/dm^3 the turbidity

Table 1. Characteristics of raw water and after treatment in the pilot scale

Parameter		Series I			Series II			Series III		
		raw water	treated water in the system I	treated water in the system II	raw water	treated water in the system I	treated water in the system II	raw water	treated water in the system I	treated water in the system II
Temperature	°C	16.0–6.5	–	–	6.2–6.5	–	–	2.5–2.9	–	–
pH	–	5.6–6.1	–	–	5.5–5.9	–	–	6.2–6.3	–	–
Color	mg Pt/dm^3	20–25	0	0	20	0–10	0–2	8	2–5	0–5
Turbidity	NTU	4–10	0–0.7	0–0.7	1	0–1.5	0	2	4.5	0
Alkalinity (Z_m)	mval/dm^3	0.4	–	–	0.5	–	–	0.5	–	–
Total hardness	mg $CaCO_3$/dm^3	55	–	–	50	–	–	60	–	–
POD	mg O_2/dm^3	3.0–3.7	1.2–1.6	1.2–2.2	2.7–2.9	0.7–1.7	0.8–1.1	2.4–3.1	1.2–1.4	0.7–1.1
Absorbance UV_{254} S (filtered sample)	cm^{-1}	0.08	0.03–0.04	0.02–0.04	0.09	0.02–0.05	0.03	0.04	–	–
Absorbance UV_{254} NS (unfiltered sample)	cm^{-1}	0.09	0.03–0.05	0.03–0.04	0.09–0.11	0.02–0.06	0.03	0.04	–	–
TOC	mg C/dm^3	4.5	–	–	2.4	–	–	1.5	–	–
THMPF	μg/dm^3	120 (in a chosen sample)	52	49	320 (in a chosen sample)	–	147	56.7 (in a chosen sample)	–	20

was totally removed, the maximal value of color did not exceed 5 mg Pt/dm^3. Such water quality was hold for 11 hours. After that time the deterioration of effluent quality started. It is noteworthy that at lower water temperature the shorter direct filtration run was observed, despite better raw water quality. It indicates that the prevailing agent which influences the length of filtration run is not only contamination concentration but water temperature.

CONCLUSIONS

The results obtained in the research confirmed that direct filtration is an effective method of treatment independently of water temperature. However, it is impossible to apply this method as the only one, because it may be used only for the low-contaminated water. The mountainous water does not meet this requirement. It is periodically contaminated with high turbidity and color, especially after heavy rainfalls and during the spring periods of snow melting. In connection with it the treatment process should be realized in two coagulation methods: in the direct filtration when the source water reveals low turbidity and low color and in the conventional treatment in the periods when water quality significantly deteriorates. This solution is possible to apply using the same equipment. Under strict technological conditions it also ensures effective organic contaminants removal including THMs precursors.

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