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THE EFFECT OF WATER TEMPERATURE ON THE COURSE OF ALUM COAGULATION OF COLLOIDAL PARTICLES IN WATER

The relation between the temperature of water and the optimum pH range for the process of coagulation has been determined. It has been stated that the optimum pH values increased with the decreasing temperature of water. At lower temperatures the efficiency of coagulation decreases. This is due to the decrease in the capacity of alum to reduce the electrokinetic potential of particles at low temperature.

1. INTRODUCTION

The process of coagulation is generally applied to purification of water and wastewater, in reuse of waters, as well as in a number of industrial processes. It has been assumed that the course of coagulation and of the accompanying flocculation and sedimentation processes depend on the temperature of water. This relationship is of a special importance under climatic conditions of Poland which in most months of the year are characterized by water temperatures below 283 K (10 °C). Summary distribution of water temperatures in Poland is given in Fig. 1.

Camp [1] has stated that low temperature slightly decreases the rate of coagulant hydrolysis and that the very process of flocculation is also slightly inhibited. Thus, it could be inffered that the low tem-

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perature affects solely the sedimentations of flocs after coagulation. The hypothesis suggested by Camp is inconsistent with experiments performed at many water purification plants, where it was found that at seasons of the year characterized by low water temperatures the flocculation

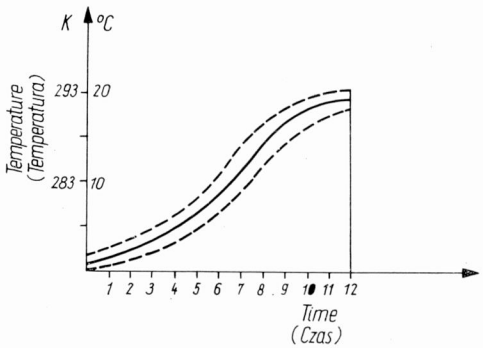

Fig. 1. Cumulative distribution of annual water temperature
Rys. 1. Kumulatywna dystrybucja rocznej temperatury wody

as well as the sedimentation of flocs are remarkably slower. According to Chojnacki [2, 3] the studies of the coagulation process should also cosider the effect exerted by the changes in the chemical composition of water occurring at to low temperatures. Kastalski and Klaczko [4] have found the inhibition of coagulation process at water temperatures ~293 K (20 °C) and pH 7.0. They explain this fact by an increased desorption from the floc surfaces.

Estimating the effect of pH on determination of optimum polymer dose Pressman [7] has found that for waters with low pH values smaller doses of coagulants should be applied.

Mohtadi and Rao [6] have studied the effects of temperature on flocculation of aqueous dispersions and found that in alum coagulation optimum pH depends on the temperature. This relationship appeared to be insignificant in coagulation with a cationic polyelectrolyte.

The effect of anionic and nonionic polyelectrolytes on the intensification of coagulation water impurities is more significant at low temperatures of water [5].

The difficulties connected with proper coagulation of aqueous dispersions at low temperatures and the conflicting information on the effect of low temperatures on the coagulation process have inclined the authors to undertake the research work.

2. RESEARCH METHODS

The water of the Odra river was coagulated at the following temperatures: 274.5 K (1.5 °C), 277.5 K (4.5 °C), 281 K (8 °C) and 295.5 K (22.5 °C). Natural temperature of water (281 K (8 °C)) has been changed into the required one by means of thermostabile bath.

The water impurities have been coagulated with alum in one liter beakers. Rapid (80 rpm) and slow (20 rpm) mixing lasted for 1 minute and 20 minutes, respectively.

The optimum dosage of alum has been determined without correcting pH value, the effect of pH on the efficiency of coagulation performed the with selected dose of coagulant was investigated at each experimental temperature.

The pH of water was adjusted by 0.1 n solution of either hydrochloric acid or sodium hydroxide. After coagulation and a 30 minute sedimentation the colour, turbidity, permanganate value, aluminum content and electrokinetic potential have been determined. The latter value has been determined from the measurement of electrophoretic mobility of particles by a ζ-meter aquipped with Riddick's cell [5, 6].

3. RESULTS

In coagulation of water at 281 K (8 °C) the applied doses of coagulant: $Al_2(SO_4)_3 \cdot 18\,H_2O$ ranged from 30 to 150 mg/dm³. With all applied doses quite distinct flocculation has been observed. Results of the investigations performed under the above conditions are presented in Fig. 2.

With the 50 mg/dm³ dosage of the coagulant the colour and turbidity of water were lowered to permissible limits and electrokinetic ζ potential amounted to about -20 mV, about 33 % lower than the potential of colloids in raw water. Hence, the above dosage has been assumed as the optimum one.

The best results of permanganate value removal (47 %) have been obtained with 80 mg/dm³ aluminum sulphate. At this dosage the colloids potential was lowered to -12 mV (Fig. 2).

Optimum pH for coagulation performed at the given temperature has been examined using a constant dosage of coagulant 50 mg/dm³ $Al_2(SO_4)_3 \cdot 18\,H_2O$. For each temperature optimum pH for coagulation process has been obtained, as shown in Figs. 3 and 4.

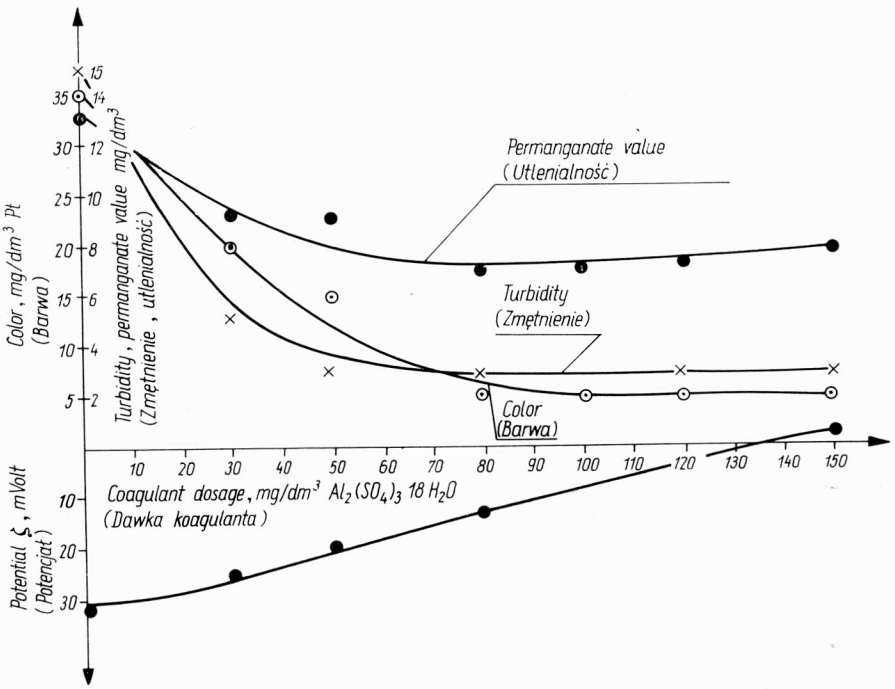

Fig. 2. Effect of alum dosage on the coagulation effect
Rys. 2. Wpływ dawki siarczanu glinowego na efekt koagulacji

For the water at 281 K (8 °C) and pH 5.85 the reduction of permanganete value reached 51 %, whereas with pH value beyond the optimum range the reduction was considerably lower. With the above parameters of pH and temperature the electrokinetic potential was also the lowest (−7 mV) and the flocs had the largest size.

Similar effects of coagulation have been found for the water temperatures and pH values ranging from 274.5 K to 295.5 K and from 6.3 to 5.2, respectively (Fig. 3).

It follows from Fig. 3 that for a given temperature, at optimum pH range during coagulation, only trace quantities of aluminum are left in water.

The increase in the concentration of aluminum in coagulated water was observed at temperature 295.5 K, pH < 5.0, and at temperature range 274.5 K – 284 K (1.5–8 °C) at pH < 6.0 (Fig. 3).

The relationship between the optimum pH of coagulation and the temperature of water is shown in Fig. 4. The values of electrokinetic

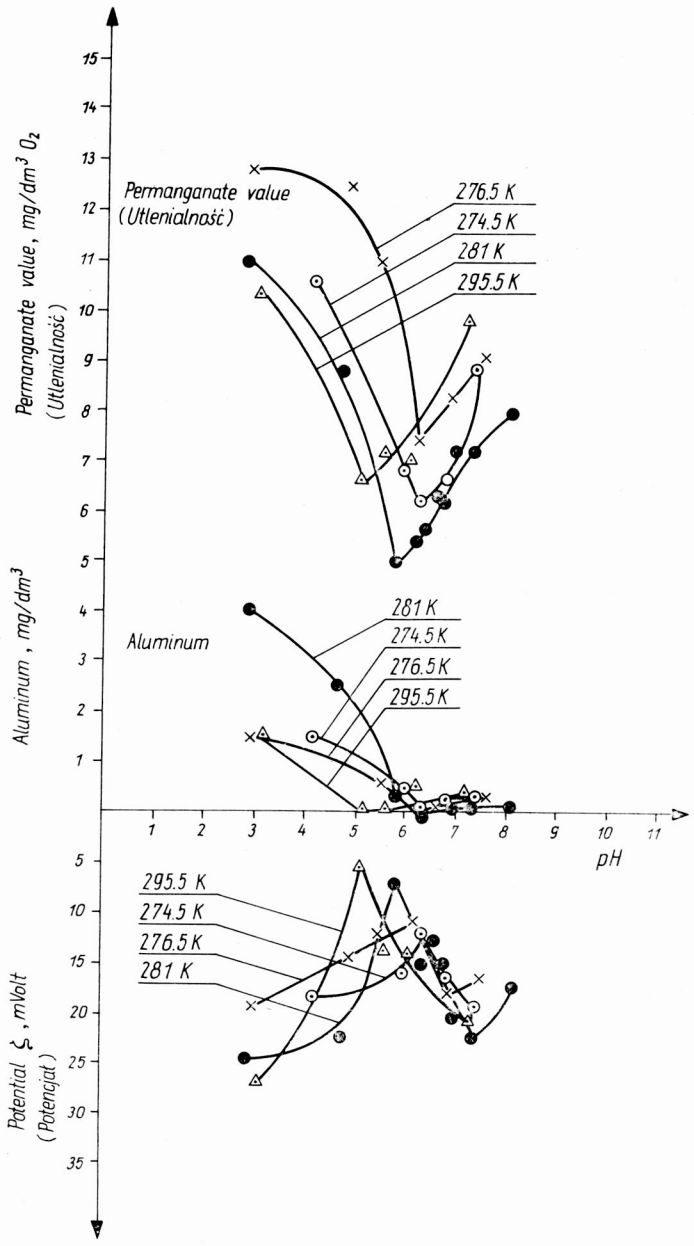

Fig. 3. Effect of pH on alum coagulation of the water
Rys. 3. Wpływ pH na koagulację wody siarczanem glinu

potentials at optimum pH for the given temperature of coagulated water are also presented. Hence, it may be inferred that the optimum pH of coagulation decreases with the increasing temperature. A constant dosage of the coagulant applied at low temperature brings about a smaller decrease in the absolute values of electrokinetic potential. Thus, it follows that

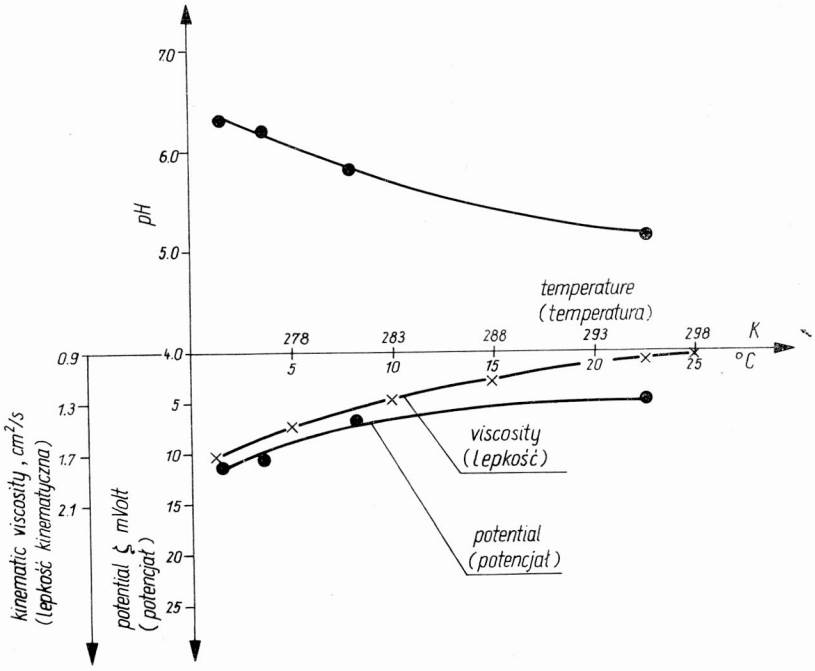

Fig. 4. Effect of temperature on optimum pH, ζ potential and viscosity of coagulated water

Rys. 4. Wpływ temperatury na optymalne pH, potencjał ζ i lepkość koagulowanej wody

low temperatures promote the stability of colloids, which might be due to the increasing viscosity of water at low temperatures (Fig. 4). Low temperature (< 283 K) diminishes distinctly the efficiency of coagulation.

Best effects of coagulation have been obtained by applying a constant dosage of aluminum sulphate at temperature 295.5 K (22.5 °C), where the electrokinetic potential was reduced to -5 mV.

CONCLUSIONS

Coagulation of colloidal dispersion responsible for colour in the Odra river water and permanganate value depends distincly on temperature and pH of water. For temperatures ranging within 274.5 K (1.5 °C) and 295.5 (22.5 °C) the optimum pH for coagulation ranged from 6.3 to 5.2.

Coagulation process conducted beyond the range of optimum pH values for the given temperature resulted in lower permanganate value removals which could not be improved by increasing doses of coagulant.

The application of pH optimum for the given temperature of water, promoted formation of the largest flocs and complete precipitation of the aluminum.

At low temperature of water the aluminum sulphate ability to reduce absolute values of electrokinetic potential was distinctly lower.

Negative effects of low temperatures on coagulation with aluminum sulphate can be remarkably compensated for by proper adjustment of pH value to its optimum. In coagulation tests both the temperature of water and its optimum pH should be considered jointly.

Measurement of the electrokinetic potential of coagulated particles facilitates accurate determination of the course of the coagulation process.

WPŁYW TEMPERATURY WODY NA PRZEBIEG KOAGULACJI KOLOIDALNYCH ZANIECZYSZCZEŃ WODY PRZY UŻYCIU SIARCZANU GLINOWEGO

Badania dotyczyły wpływu temperatury na optymalny przedział pH w procesie koagulacji wody z rzeki Odry.

W zakresie temperatur od 274,5 K do 295,5 K optymalny odczyn wody wynosił odpowiednio od 6,3 do 5,2 pH. Przy optymalnym, dla danej temperatury wody, odczynie uzyskano największe kłaczki oraz najniższe stężenie pozostałego rozpuszczonego glinu. Niewielki wzrost pH nie wpływał na wzrost stężenia tego metalu.

W temperaturach poniżej optymalnego zakresu koagulant w mniejszym stopniu obniżał potencjał elektrokinetyczny koagulowanych cząstek.

Pomiary potencjału elektrokinetycznego cząstek pozwoliły ustalić optymalne warunki przebiegu procesu koagulacji.

EINFLUß DER WASSERTEMPERATUR AUF DEN VERLAUF DER KOAGULATION KOLLOIDALER WASSERVERUNREINIGUNGEN UNTER ANWENDUNG VON ALUMINIUMSULFAT

Der Untersuchungen betreffen den Einfluß der Temperatur auf den optimalen pH-Intervall im Koagulationsprozeß des Oderwassers.

Im Temperaturbereich von 274,5 K bis 295,5 K betrug die optimale Reaktion

des Wassers 6,3 bis 5,2 pH. Bei der für die angebene Wassertemperatur optimalen Reaktion wurden die größten Flocken und die niedrigste Konzentration des remanenten gelösten Aluminiums erzielt.

Bei Temperaturen unterhalb des optimalen Bereichs erniedrigte der Koagulant in geringerem Grade das elektrokinetische Potential der koagulierten Teilchen.

Die Messungen des elektrokinetischen Potentials der Teilchen ermöglichten es, die eigentlichen Bedingungen für den Verlauf des Koagulationsprozesses zu bestimmen.

ВЛИЯНИЕ ТЕМПЕРАТУРЫ ВОДЫ НА ХОД КОАГУЛЯЦИИ КОЛЛОИДНЫХ ЗАГРЯЗНЕНИЙ ВОДЫ ПРИ УПОТРЕБЛЕНИИ СУЛЬФАТА АЛЮМИНИЯ

Исследования касались влияния температуры на оптимальный интервал pH в процессе коагуляции воды из реки Одры. В температурном интервале от 274,5 до 295,5 K оптимальная реакция воды составляла соответственно от 6,3 до 5,2 pH. При реакции, оптимальной для данной температуры воды, образовались самые большие хлопья и самые низкие концентрации оставшегося не растворенного алюминия. Незначительный рость pH не влиял, при этом, и на рост концентрации этого металла.

При температурах ниже оптимального интервала коагулятор в менее значительной степени понижал электрокинетический потенциал коагулируемых молекул.

Измерения электрокинетического потенциала молекул позволили определить соответствующие условия для процесса коагуляции.

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