Active Polymers for Water Treatment

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Most of the Romanian treatment stations use surface waters to obtain potable water. Suspensions elimination is achieved though coagulation with aluminium sulphate or with aluminium polyhydroxychloride. These chemical reagents contaminate the potable water with aluminium ions, which may lead to different diseases of the organism. This paper focuses on a comparative assay of different coagulation agents or coagulation/ flocculation agents based on laboratory studies or purification stations. In the same time we propose a new ionic polymer as flocculation agent.

Keywords: coagulation/flocculation, polyelectrolytes, potable water

The potable water delivered to population needs to be treated with coagulation-flocculation reagents in order to ensure its standard quality [1]. The crude water from the surface areas contains many organic and mineral impurities and the treated water is contaminated with metallic or chlorine ions from the purification reagents.

The potable water treatment stations from Romania use aluminium sulphate or aluminium polyhydroxychloride in the coagulation process [2-4]. Therefore, the potable water delivered to population contains aluminium ions. Their concentration increases with the amount of purification reagent. The contamination of the human organism with aluminium ions through potable water may lead to serious diseases [5-6] such as: osteomalacy, encephalopathy, Alzheimer or Parkinson disease, anaemia, heart attack etc.

The increase of the purity degree of potable water within the European standards [7] and the decrease of the content of aluminium ions could be achieved by the use of macromolecular polyelectrolytes such as: hydrolysed polyacrylamide (PAH) or polyacrylamide modified by Mannich reaction (PAM).

This paper reports the experimental laboratory results and industrial tests for the obtaining of potable water at European standards with the help of polyelectrolytes and classical coagulation systems.

Experimental part

Materials and methods

Polyacrylamide (PAA) was obtained by inverse suspension polymerisation of acrylamide and has a molecular weight of $M_v=3.6\cdot10^6$ g/mole. The molecular weight was determined by viscometric means in 1N aqueous solution of $NaNO_3$ with Sakurada equation:

$$[\eta] = k \cdot \bar{M}_v^{a} \qquad (1)$$

where:

$k=134\cdot10^{-3}$ mL/g;

$a=0.57$ [8]

The basic hydrolysis was performed with NaOH in methanol-water suspension [9]. This product (PAH=20% hydrolysis degree) was used in laboratory tests. The industrial tests (Tulcea and Braila) were done with PAH (21% hydrolysis degree, and $M=3\cdot10^6$ g/mole, A321).

Polyacrylamide PAM was obtained by Mannich reaction with PAA, CH_2O, $(CH_3)_2NH$ (DMA). The final pH of PAM solutions adjusted at 4.5 with 0.1 N HCl solution [8].

Clay suspensions (3%, composition $Al_2O_3\cdot2SiO_2\cdot2H_2O$) were used in laboratory to test the efficiency of PAH and PAM polymers. The chemical composition of PAH and PAM was established by elemental analysis. The sedimentation rate (variation in time of the volume of clear phase) and the total sedimentation time were measured both for PAH and PAM used in flocculation process. The turbidity was determined by turbidimetric method jar-test and the aluminium ions content by spectrophotometric method. $Al_2(SO_4)_3\cdot H_2O$ and aluminium polyhydroxychloride, PAX were used as coagulation agents.

Results and discussions

Table 1 shows the transformation degrees of PAA by Mannich reaction determined by elemental analysis.

Table 1

REACTION CONDITIONS FOR PAM SYNTHESIS AND THE COMPOSITION OF THE FINAL POLYMER

Sample	$\frac{[CH_2O]=[DMA]}{-CONH_2}, \frac{mole}{mole} x100$	$\frac{Transf.Groups[-CONH_2]}{TotalGroups[-CONH_2]}, \frac{mole}{mole} x100$
P1	10	7
P2	20	15
P3	30	25
P4	40	35
P5	50	43

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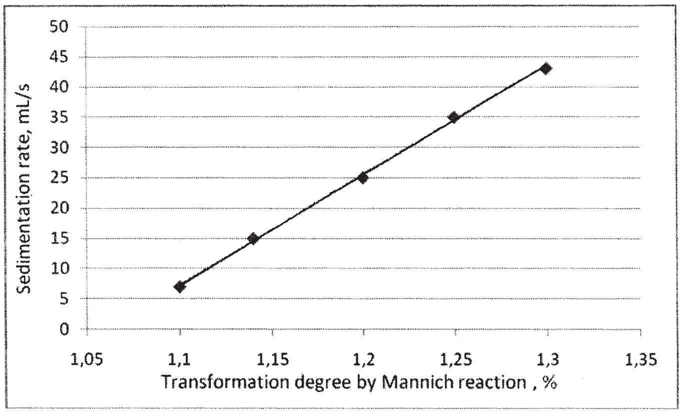

Fig. 1. Sedimentation rate (mL/s) versus PAA transformation degree by Mannich reaction (%)

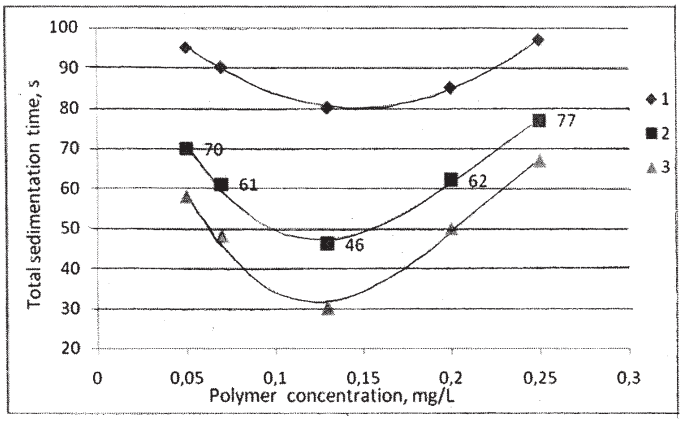

Fig. 2. Total sedimentation time versus polymer concentration (flocculation agent): 1-PAH; 2-PAM; 3-PAH+aluminium sulphate (40 mg/L)

The sedimentation rate (clear phase volume in time) for PAM with different transformation degrees is shown in figure 1. A clay suspension was used and the polymer concentration was 0.12 mg/L.

We can notice from figure 1 an increase of the sedimentation rate with the PAM transformation degree, thus showing the efficiency of PAM as flocculation agent in complex systems of water purification.

Figure 2 shows the variation of the total sedimentation time of the clay suspension versus the polymer concentration for PAH, PAM and PAH+aluminium sulphate.

The results from figure 2 show an optimum concentration of polymer where the sedimentation rate is maximum (minimum of the total time) and PAM is more efficient than PAH (for clay suspensions), but less efficient than PAH+aluminium sulphate. This behaviour could be explained by the coagulation effect of aluminium sulphate followed by the polymer which acts as a flocculation agent for higher destabilized particles.

The difference in sedimentation rate between PAM and PAA+aluminium sulphate is not so high to use an additional reagent as aluminium sulphate. The use of aluminium sulphate in relative high concentration (40 mg/L) may lead to the contamination of the potable water delivered to population.

In the industrial installations for the obtaining of potable water aluminium sulphate or aluminium polyhydroxychloride are still used as coagulation agents. The increase of the efficiency of water purification process could be achieved by the use of a mixed system flocculation agent-ionic polymer. Such a mixed system is composed of aluminium sulphate or PAX and PAH (A321 sort) and it is used in Braila and Tulcea stations for potable water.

The comparison between the activity of aluminium sulphate and the system aluminium sulphate-A321 is presented in tables 2 and 3.

The data from tables 2 and 3 show an optimum concentration of aluminium sulphate for similar turbidity of crude water and that is why the system of PAH (A321) with aluminium sulphate is more efficient than aluminium sulphate.

The use of aluminium polyhydroxychloride (PAX) instead of aluminium sulphate within the obtaining of potable water

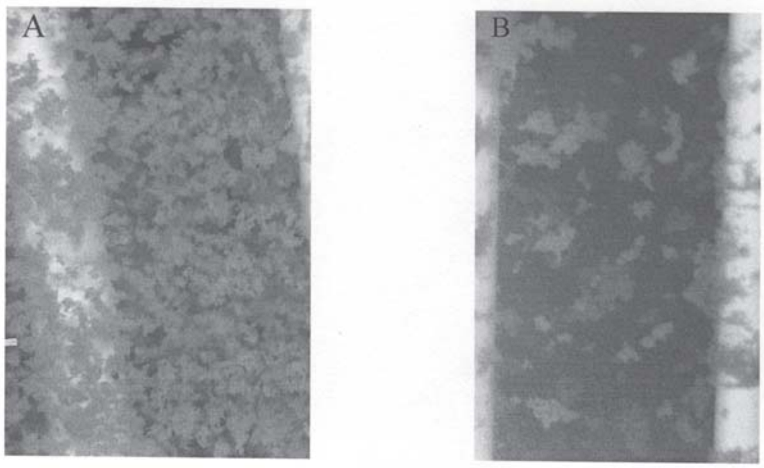

Fig. 3. Flocculation process with aluminium polyhydroxychloride (A) and aluminium sulphate (B)

	Units	Sample 1	Sample 2	Sample 3
Turbidity of crude water	NTU	307	307	307
Dose $Al_2(SO_4)_3$	mg/L	20	25	30
Dose polymer A321	mg/L	-	-	-
Turbidity of water after coagulation/filtration	NTU	6.15	2.88	4.48

Table 2
TURBIDITY OF CRUDE WATER AND WATER AFTER COAGULATION WITH ALUMINIUM SULPHATE

	Units	Sample 1	Sample 2	Sample 3
Turbidity of crude water	NTU	292	292	292
Dose $Al_2(SO4)_3$	mg/L	20	25	30
Dose polymer A321	mg/L	0.12	0.12	0.12
Turbidity of water after coagulation/flocculation-filtration	NTU	1.5	1.36	1.61

Table 3
TURBIDITY OF CRUDE WATER AND OF WATER AFTER COAGULATION-FLOCCULATION PROCESS WITH MIXED SYSTEM ALUMINIUM SULPHATE-A321

		Jan.	Feb.	Mar.	Apr.	Mai	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Turbidity of crude water NTU	2006	16	12	28	15	12	10	18	20	13	15	9	8
	2008	12	8.5	8	8.8	9.1	9.8	10.8	12	14	8,1	9	8
Turbidity of potable water NTU	2006	1	1	1	0.7	0.7	0.7	0.7	0.8	0.7	0.5	0.6	0.7
	2008	0.74	0.64	0.51	0.53	0.53	0.52	0.48	0.49	0.56	0.48	0.50	0.49
Aluminium in potable water mg/L	2006	0.14	0.14	0.14	0.13	0.10	0.14	0.15	0.15	0.14	0.13	0.13	0.13
	2008	0.09	0.09	0.12	0.08	0.14	0.12	0.14	0.10	0.14	0.12	0.12	0.12

Table 4
EVOLUTION OF WATER PARAMETERS IN YEARS 2006 AND 2008 USING ALUMINIUM SULPHATE AND RESPECTIVELY PAX AS COAGULATION AGENTS IN TULCEA STATION

Turbidity of crude water (NTU)	Reagents for purification / cost Kg/h / lei/h				Turbidity for potable water, NTU			
	AS	PAX	AS+PAA	PAX+PAH	AS	PAX	AS+PAA	PAX+PAH
10-20	19.8 12.1	11.1 11.6	18.2+0.2 12.7	9.3+0.2 11.5	5.7	4.0	4.6	3.2
20-30	33.8 20.6	11.6 12.2	20+0.2 13.4	6.6+0.2 10.4	6.6	4.2	5.6	2.6

Table 5
COMPARISON BETWEEN DIFFERENT SYSTEMS FOR WATER PURIFICATION IN BRAILA AND TULCEA STATIONS

process has some advantages: higher efficiency in flocculation process (fig. 3), low turbidity of the potable water, low content of aluminium, sulphate and chlorine ions, reduction of specific consumption (so of the price) of coagulation agent, easier dosage and injection of PAX used as solution at normal temperature etc. All these explanations rely on the experimental data recorded in the potable water stations from Braila and Tulcea, which are presented in tables 4 and 5. The experimental results show a reduction of the concentration of aluminium ions in potable water. Also, the reduction of the concentration of sulphate ions in the potable water from 80-120 mg/L (2006) to 40-70 mg/L and of chlorine ions from 1.1-1.2 mg/L in 2006 to 0.8-0.9 mg/L in 2008 due to PAX as coagulation agent was noticed. Using these results from Tulcea and Braila stations we can compare the efficiency of the following systems: aluminium sulphate, PAX, aluminium sulphate+PAH and PAX+PAH (table 5). The best results (low cost and low turbidity for potable water) were obtained with the system PAX+PAH.

Conclusions

The presence of the aluminium ions in the potable water from the purification process seriously affects the health of the population.

The use of aluminium polyhydroxychloride instead of aluminium sulphate brings both economical advantages by the use of low coagulation agent amounts and improvement of the quality of potable water by the reduction of the concentration of aluminium ions.

The use of polymers (PAH, PAM) in the water purification process by coagulation-flocculation instead of flocculation agents alone reduces the turbidity of potable water and the content of aluminium, chlorine and sulphate ions. The best results were obtained with the system PAX/PAH.

PAM has not been industrially used up to now for water purification, so it is a serious candidate in this domain.

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