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DRINKING WATER TREATMENT WITH RECOVERED FLOCCULANT FROM ALUMINA FABRICATION PROCESS

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Abstract. This paper presents the application of treated industrial waste from alumina fabrication in the field of drinking water treatment as coagulant-flocculant reagent. Experimental tests emphasised the efficiency of recovered and purified sodium aluminate for surface water treatment. Three different flocculants (sodium aluminate, classic flocculant, polyaluminum chloride – PAC) at four aluminium doses were tested. Turbidity, total organic carbon (TOC), iron, manganese and sodium indicators were monitored. Similar removal efficiencies have been calculated for turbidity (>99%), iron (>99%), manganese (~80%), aluminium (94–98%) and 58 and 47% for TOC in case of recovered sodium aluminate and PAC, respectively. The application of recovered flocculant proved its efficiency for coagulation-flocculation treatment phase, which mean that could be used instead classical flocculants without any secondary pollution effects. Recovered sodium aluminate is a good flocculant for drinking water treatment with many other applications in the field of wastewater treatment.

Keywords: drinking water, sodium aluminate, flocculant, turbidity.

AIMS AND BACKGROUND

Traditional and modern technologies for drinking water treatment (surface water sources) have integrated in the treatment scheme coagulation-flocculation in order to remove inorganic and organic matter, which can be in suspension or in colloidal system[1].

Coagulation term describes destabilisation process of colloidal system, flocculation is referring to the destabilisation by adsorption and formation of large bridges between particles, and agglomerations in order to gravity settle in a short time[2].

Water clarification is not the only effect of coagulation-flocculation. Some dissolved pollutants are adsorbed on the flocks and removed by settling, together with the solid phase[3,4]. Three main categories of coagulants and flocculants can be identified[5]:

– Hydrolysed metallic salts: ferric chloride, ferric sulphate, aluminum sulphate;

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– Pre-hydrolysed metallic salts: aluminum polychloride, ferric polychloride, ferric polysulphate, aluminum ferric polychloride, aluminum polysulphate;

– Synthetic organic polymers: amino methyl polyacrylamide, polyamines, etc.

In the frame of present paper, the application of sodium aluminate in drinking water treatment field is a feasible alternative to classic coagulants. It is a cheaper reagent because is a byproduct from alumina fabrication which was considered to be a waste. This 'waste' can be capitalised as coagulant for drinking and wastewater treatment on the market of environmental technologies.

EXPERIMENTAL

Experimental tests were performed in order to demonstrate the efficiency of recovered sodium aluminate for removal of suspended mater and colloidal system from drinking water source (Arges river) during coagulation-flocculation treatment phase. Sodium aluminate was a conditioned product from alumina fabrication having density 1.468 g/cm^3, Al_2O_3 19.2% and Na_2O 20.65%. Laboratory tests were done with 25 times dilution of the base product and Romanian flocculant – based on starch and acrylamide copolymer with 0.2% active substance. Comparative test with aluminum polyaluminum chloride were done.

River water source had the following main characteristics: COD (Chemical oxygen demand) 5.9 mg O_2/l, TOC (Total organic carbon) 5.5 mg/l, turbidity 585 NTU, fixed residue 95 mg/l, conductivity 0.11 mS/cm, alcalinity 2.2 mval/l, hardness 8.4 ^{0}dH, aluminum 13 mg/l, iron 5.7 mg/l, manganese 0.2 mg/l. Turbidity, aluminum, manganese, iron had value over the Romanian admitted limits for drinking water quality.

The raw water was settled for 60 min before the beginning of coagulation-flocculation tests.

Coagulation-flocculation tests with recovered sodium aluminate. All coagulation-flocculation tests were performed to pH 7 (in order to diminish the amount of dissolved aluminum in the treated water), coagulation time 30 min, flocculation time 5 min, settling 60 min. The main parameters which had to be determined were aluminate and flocculant doses. The drinking water pretreatment flow was proposed at the end of coagulation-flocculation experiments.

Six coagulant (sodium aluminate) doses were tested (15, 10, 7, 5, 3 and 2 mg Al/l sample) and four flocculant doses (5, 3, 2 and 1 ml/l sample). Sulphuric acid was used for pH correction to pH ~ 7.

Coagulation-flocculation tests with polyaluminum chloride (*PAC*). Polyaluminum chloride is a good coagulant/flocculant and this way was selected for comparative tests.

Four doses of PAC were tested (10; 7; 5; 3 mg Al/l sample) and three flocculant doses (3; 2; 1 ml/l sample). Sodium hydroxide was used for pH correction to pH ~ 7. The rest of work conditions were similar with those of the sodium aluminate tests.

RESULTS AND DISCUSSION

Coagulation-flocculation tests with recovered sodium aluminate. The efficiencies of coagulation-flocculation were high for 15, 10, 7 and 5 mg Al/l doses corresponding to COD 71%, TOC 49%, turbidity 99%, aluminum 98%, iron 99% and manganese 80%. In order to optimise the process two lower sodium aluminate doses have been taken into consideration 2–3 mg Al/l. For the same dose of coagulant (3 mg Al/l) the effect of flocculant dose was studied. Table 1 shows the characterisation data for the treated water (with lower aluminate doses) compared with Romanian admitted limits for drinking water quality.

Table 1. Coagulation-flocculation with recovered sodium aluminate

Reagent doses/Indicators	Samples						Admitted limits
	initial	A1	A2	A3	A4	A5	
Sodium aluminate doses (mg Al/l)	–	5	3	3	3	2	–
Flocculant (0.2% active substance) dose (ml/l)	–	5	2	3	1	3	–
COD (mg O_2/l)	5.9	3.3	3.9	3.1	3.3	3.1	5
TOC (mg/l)	5.5	3.7	2.3	2.6	4.3	2.5	–
Turbidity (NTU)	585	4.5	4.3	2	2	3	<5
Conductivity (mS/cm)	0.11	0.27	0.34	0.35	0.36	0.35	2.5
Alcalinity (mval/l)	2.2	1.6	1.7	1.8	1.9	1.7	–
Hardness (^{0}dH)	8.4	5.8	6.3	6.5	6.8	6.7	>5
Aluminum (mg/l)	13	0.3	0.19	0.34	0.38	0.18	0.2
Iron (mg/l)	5.7	0.03	0.04	0.03	0.03	0.03	0.2
Manganese (mg/l)	0.2	0.04	0.032	0.035	0.033	0.037	0.05
Sodium (mg/l)	31.3	32.3	127.9	85.1	95.7	61.9	200

The best results were obtained in the case of A2 sample (3 mg Al/l, 2 ml flocculant/l). Treated water is in the frame of admitted limits and the efficiencies were 34% for COD, 42% for TOC, > 99% for turbidity, 98% for aluminum. Similar efficiencies were in case of A5.

A pretreatment flow was proposed taking into account these data (Fig. 1). Operating conditions are mentioned being feasible for this type of surface water. It is possible that for surface waters with higher values of the characterisation indicators the residual aluminum concentrations might be over admitted limit because of increase of coagulant dose.

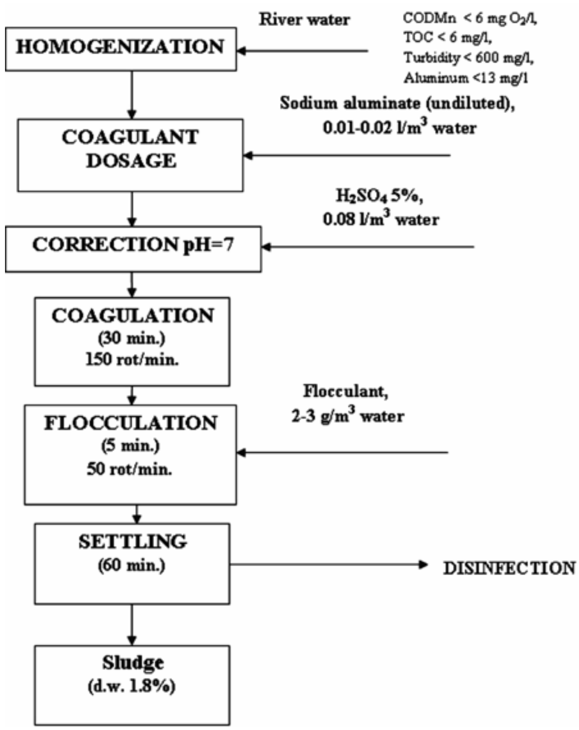

Fig. 1. Pretreatment flow for drinking water treatment

Coagulation-flocculation tests with polyaluminum chloride (*PAC*). The experimental results in case of PAC application confirm its efficiency for diminishing of turbidity, organic load (COD, TOC) iron and manganese (Table 2) except aluminum (3–4 times higher than admitted limit).

Table 2. Coagulation-flocculation with PAC

PAC dose/indicators	Samples							Admitted limits
	initial	P1	P2	P3	P4	P5	P6	
PAC doses (mg Al/l)	–	3	5	7	10	3	3	–
COD (mg O_2/l)	5.9	<1	2	2.4	2.5	1.5	1.8	5
TOC (mg/l)	5.5	2.4	4.5	4.5	4.8	2.9	3.6	–
Turbidity (NTU)	585	1.2	2.1	2.3	1.5	3.9	3.7	<5
Conductivity (mS/cm)	0.11	0.782	0.980	1.547	2.09	0.690	0.632	2.5
Alcalinity (mval/l)	2.2	1.2	1.5	1.5	–	–	–	–
Hardness (^{0}dH)	8.4	–	–	–	–	6.3	6.5	>5
Aluminum (mg/l)	13	0.63	1.14	2.28	2.72	0.72	0.81	0.2
Iron (mg/l)	5.7			<0.01				0.2
Manganese (mg/l)	0.2	0.041	0.047	0.043	0.039	0.040	0.040	0.05
Sodium (mg/l)	32.3	34.6	36.9	37.1	36.2	35.4	36.8	200

Sample P5 was tested at the same conditions with sample A2 (coagulation with sodium aluminate) obviously excepting pH correction which was done with NaOH in case of PAC tests. The efficiencies of inorganic and organic load diminishing using sodium aluminate and PAC in the same working conditions are emphasised in Table 3.

Table 3. Comparative efficiencies of sodium aluminate and PAC application

Indicator	Sodium aluminate		PAC	
	residual value	efficiency (%)	residual value	efficiency (%)
TOC (mg/l)	2.3	58	2.9	47
Turbidity (NTU)	4.3	>99	3.9	>99
Conductivity (mS/cm)	0.34	–	0.69	–
Hardness (^{0}dH)	6.3	–	6.3	–
Aluminum (mg/l)	0.2	98	0.72	94
Iron (mg/l)	0.04	>99	<0.01	>99
Manganese (mg/l)	0.032	84	0.04	80
Sodium (mg/l)	128	–	35.4	–

Comparative analysis of coagulation-flocculation tests emphasised similar treatment efficiencies for sodium aluminate and polyaluminum chloride but in case of PAC application the aluminum residual content was 3–4 times over admitted limit for drinking water.

CONCLUSIONS

The aim of this paper was to prove that sodium aluminate which is a byproduct of alumina fabrication can be used in coagulation-flocculation phase of drinking water treatment plant. The purification method of sodium aluminate is a process owned by Romanian alumina factory able to transform the 'waste' into efficient coagulant. River water with high level of turbidity (~600 NTU) was chosen for experimental test in order to verify the coagulant efficiency in case of river water source after rainy weather (CODMn 5.9 mg O_2/l, TOC 5.5 mg/l, turbidity 585 NTU, fixed residue 95 mg/l, conductivity 0.11 mS/cm, alcalinity 2.2 mval/l, hardness 8.4 ^{0}dH, aluminum 13 mg/l, iron 5.7 mg/l, manganese 0.2 mg/l).

Different dose of sodium aluminate was tested (15, 10, 7, 5, 3 and 2 mg Al/l sample) and parallel tests were performed with polyaluminum chloride (PAC) in similar work conditions in order to compare the removal efficiencies of organic and inorganic load.

Comparative analysis emphasised that both products are efficient, but in the specific testing conditions recovered sodium aluminate proved to be better because secondary pollution (aluminum residual concentration over admitted limit) was not identified.

Based on experimental test, pretreatment flow scheme was elaborated based on laboratory level tests.

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