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Intensification of Technical Water Clarification by a Magnetic Water Conditioner

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The purpose of this research is to examine the impact of magnetic water conditioners (MWC) on clarification of open water reservoirs. In typical desalting technologies of power and industrial enterprises clarification and elimination of carbonaceous hardness is the first operation to be performed in the clarifier. The influence of MWC treated water on coagulation characteristics of coagulant iron sulphate solution was investigated. It has been presumed, that clarification rate of $FeSO_4$ with MWC is greater 1.8 – 3.3 times; magnetic activation by conditioners decreases electro kinetic potential of dispersive particles; using MWC technical water may be clarified with $FeSO_4$ in alkaline solution at 20 °C without waters heating to 33 °C.

Keywords: magnetic water treatment, coagulation, clarification, magnetic field, colloid.

INTRODUCTION

Recently the amount of information on intensification of technological processes, during which materials are activated by different physical methods, i.e. magnetic, acoustic, electric etc. has been continuously growing. Using strong magnetic field (60 – 2000 T), it is possible to accelerate distinctly the precipitation of Cd, Hg, Pb, Cr, Ni, Zn ions and other ions, which are found in drains, by flocculants [1]; the exposure of colloidal particles in electrolyte solutions to a magnetic field reduces their rapid coagulation rate [2]; electromagnetic field may be used to modify crystallization process of materials in solutions in such a way, that it would be possible to avoid deposit layer on surfaces of heat exchangers, water communications, and other equipment [3]; it is possible to reduce precipitation of organic colloids in veins of live organisms (including humans) [4]; the magnetic field effect on the water flow accelerates heterogeneous ions changes processes at ion exchanger resins [5].

The purpose of this work was to determine the influence of CEPI-CO MWC on clarification of technical water in the Chemistry Department of JSC "Kaunas energija". In typical desalting technologies of power and industrial enterprises, clarification with coagulants and elimination of carbonaceous hardness is the first operation to be performed in a device called clarifier. Temporal hardness is eliminated by lime solution and therefore in a clarifier the level of pH ~ 10 is maintained. At this level of pH, granules of micelles of negative silicate and aluminized origin are prevailing in water $\{mH_2SiO_3{\cdot}nSiO_3^{2-}{\cdot}(n-x)Ca^{2+}\}^{2x-}$, $\{mAl(OH)_3{\cdot}nAlO_2^{-}{\cdot}(0.5n-x)Ca^{2+}\}^{2x-}$. In order to neutralize their electro kinetic potential, coagulant with a positive micelle granule is added $\{mMe(OH)_3{\cdot}nMeO_2^{-}{\cdot}(0.5n-x)SO_4^{2-}\}^{2x+}$. The coagulant mentioned is produced of ferrous (2) sulphate, which in water is hydrolyzed and oxidized by oxygen dissolved in water.

INVESTIGATION METHODS

The composition of raw water depends on seasons and power plants regiment. The highest turbidity of water had been in autumn and wintertime. The lowest turbidity of water had been in spring and summer time, when power plants used water is retuned and mixed with clarified water. The composition of raw Nemunas water during 2000 – 2001 periods is shown in the Table 1.

For water of high turbidity research model Nemunas, water with added counted amount of clay suspension was used. The composition of clays fraction is shown in the Table 2.

Magnetic activation impact on water clarification with iron sulphate was analyzed by a device, elementary diagram of which is presented in Fig. 1. In CEPI device model water and water of the Nemunas used in Kaunas Power Plant was conditioned by the following ways: passing clarified water through one R1/2''DP MWC; through two R1/2''DP MWC; providing circulation of clarified water through MWC as far as volume of container (2) flows through a conditioner once or twice.

After magnetic activation water was supplied to the reaction chamber (4), and for 2 minutes was stirred slowly together with the quantity of measured lime milk and coagulant. A measure of coagulant is determined as follows:

$$n = (H_1 - \check{S}_1) - (H_2 - \check{S}_2)\text{, mE dm}^{-3}, \tag{1}$$

where H_1, $\check{S}_1$ is the total hardness and alkalinity of raw water, mE dm^{-3}; H_2, $\check{S}_2$ is the total hardness and alkalinity of clarified water, mE dm^{-3}.

From the reaction chamber water was supplied to clarification columns, where change of turbidity in terms of time was analyzed in the depths of 10, 30, and 40 cm. Water turbidity was measured by a photoelectric colorimeter KFK using a 540 nm light filter.

The electro kinetic potential of colloidal particles was determined from the measurements of electrophoresis speed. The motion of dispersions phases in electric field was fixed by "U" form electrophoresis device when liquids line get move on 0.5 cm. The gradient of external electric

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Table 1. The composition of raw technical water

Water composition	Value
T. hardness, $mE\cdot dm^{-3}$	3.4 – 6.0
Alkalinity, $mg\cdot dm^{-3}$	2.5 – 5.5
Ca^{2+}, $mg\cdot dm^{-3}$	35 – 70
Mg^{2+}, $mg\cdot dm^{-3}$	11 – 23
Fe^{3+}, $mg\cdot dm^{-3}$	0.43 – 0.75
SiO_2, $mg\cdot dm^{-3}$	7.5 – 14.7
SO_4^{2-}, $mg\cdot dm^{-3}$	20 – 75
Oxidation, $mgO_2\cdot dm^{-3}$	4.3 – 10.2
Dissolved oxygen, mg $O_2\cdot dm^{-3}$	7.6 – 14.0
Suspended solids, $mg\cdot dm^{-3}$	5.0 – 23.0
PH	8.0 – 8.7

Table 2. Chemical composition of natural clay

Component	%
SiO_2	44.8
Al_2O_3	16.0
CaO	13.0
MgO	5.1
Fe_2O_3	6.1
Calcine	15.0

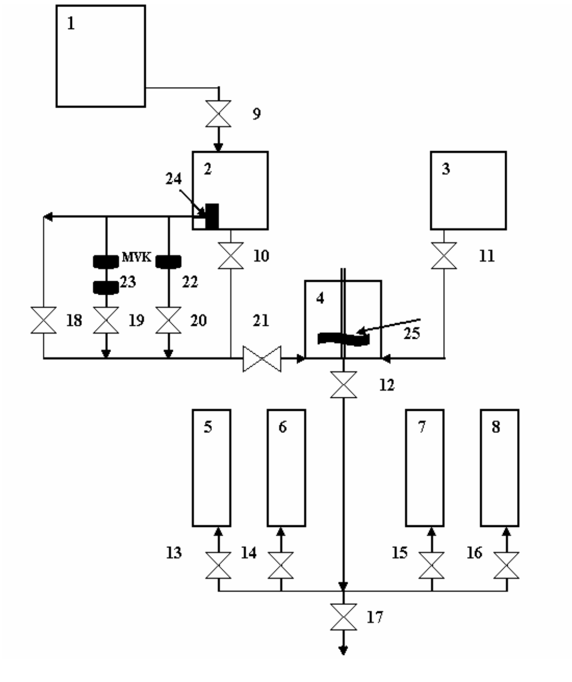

Fig. 1. Elementary diagram of the clarification with $FeSO_4$ in alkaline solution device: 1, 2 – containers of model water (50 l and 10 l); 3 – container of lime milk; 4 – reaction chamber; 5 – 8 – clarification columns; 9 – 21 – control valves; 22 – 23 – MWC R1/2’’DP; 24 – peristaltic pump; 25 – mechanic mixer

field $E = 120$ V/m. The electro kinetic potential is calculated:

$$\varsigma = \frac{u_e \eta}{\varepsilon \varepsilon_0 E} . \tag{2}$$

There ς is the electro kinetic potential of dispersions particles, mV, η is the dispersion viscosity, $N\cdot s/m^2$, u_e is the electrophoresis speed, m/s, ε is the dielectric permittivity, F/m, ε_0 is the dielectric constant ($8.85\cdot 10^{-12}$ F/m), E is the external electric field, mV/m.

The relative viscosity of dispersions was counted from the measurements of term when the same volume of dispersions and demineralized waters was effused from a viscosimeter capillary through the same time

$$\frac{\eta_1}{\eta_2} = \frac{\tau_1 \rho_1}{\tau_2 \rho_2} . \tag{3}$$

There η_1 and η_2 are the dispersions systems and waters viscosity, $N\cdot s/m^2$, τ_1 and τ_2 is the effusion term, s, ρ_1 and ρ_2 are the liquid densities, kg/m^3.

RESULTS AND DISCUSSIONS

In power plants the clarifying water is to be warmed to 33 °C because in the clarifier maintained temperature is 30 °C. The clarification with $FeSO_4$ is not satisfactory at lower temperature.

Kinetic curves (see Fig. 2 – 3) demonstrate that coagulation of natural colloids and other materials suspended in water is faster in water impacted by a magnetic conditioner. When iron sulphate was used as coagulant clarification rate with MWC is greater 1.8 – 3.3 times. In the beginning of the process, i.e. in water of high turbidity influence of different coagulation methods on coagulation processes may be seen the most obviously (see Table 3). Water conditioned by two MWC devices or water, which circulated twice as long, coagulates a little bit faster, whereas magnetic conditioning practically makes no effect on water of low turbidity (see Table 4).

Magnetic activation application for clarification of technical water is valuable in terms of both technological process intensification and economical benefit. Currently water clarified in all power plants is to be heated to 33 °C, whereas using MWC water may be clarified at 20 °C temperature. In power plants used water is retuned to clarified water, and by adding milk of lime clarification proceeds especially hardly. Technological process may be accelerated the by adding flocculants. With MWC and micro amount of AF352 flocculants, clarification rate with MWC is greater 2.2 – 4.5 times and water is clarified in 5 minutes at 20 °C temperature (see Table 5).

In accordance to modern theory of stability, the coagulation of colloidal systems depends not only on electro kinetic potential but also on colloidal particles hydration, which block up mechanical agglomeration of colloidal particles. The author claims that coagulation capability of electrolytes depends on decreasing of the repulsive forces between colloidal particles or zeta potential and on the dehydration of diffusive layer. The magnetic water treatment reduces the magnitude of the zeta potential of colloidal particles approximately 23 – 29 % (Table 6). This shows that magnetic exposure reduces thickness of diffusive layer.

Some of opposite charged ions penetrate to the adsorbed layer and micelle hydration rate has a decrease.

The dramatic improvement using the magnetic conditioning taught by this invention is due to effect of the magnetic field on ionic interactions of the solute which modifies the hydration of the ions, creating favorable conditions for the formation of new ionic associates which enhance the formation of colloids.

The idea is proposed that magnetic conditioning also changes the internal energy of the system which further influences intermolecular interactions. In the magnetic field charged particles motion are more intensive because they are under influence of Lorentz force. Particles with opposite charges rotate in different directions and move at corresponding frequency by helical trajectory around the magnetic field lines.

The magnetic field influences the surface forces of the colloids causing the magnetic dipoles to align, thus creating forces which further enhance the growth of the colloidal particles.

$$F = K \cdot Q \cdot v \cdot B \cdot \sin\alpha , \tag{4}$$

there F is the Lorentz force, v is the particle speed, Q is the charge of particle, B is the magnetic induction, α is the angle between fluid flow and particles motion directions and K is the proportion coefficient.

The Lorentz force on the moving electrical charges also tends to align the electric dipoles. This alignment of previously randomly oriented dipoles enhances the grouping of existing ionic associates which enhances the formation of colloids. Coagulation enhancement is thus influenced by the magnitude of the magnetic field, the gradient of the magnetic field, the orientation of the magnetic field with respect to the direction of the fluid flow and the velocity of the fluid flow in the region of the magnetic field. In a preferred embodiment it is also a purpose of the magnetic conditioning means to create local turbulent mixing to reduce the equivalent mean free path of magnetically modified ionic species to enhance the

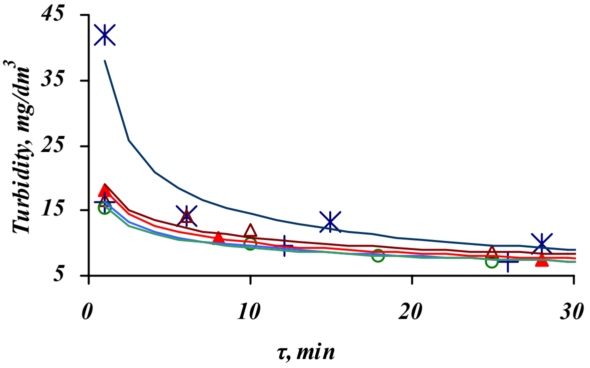

Fig. 2. Kinetic curves of clarification of water with iron sulphate, performance of which is specified in Table 3: ж – water not activated magnetically; Δ – with 1 MWC; ▲ – with 2 MWC; + – after 5 min of circulation through MWC; o – after 10 min of circulation through MWC

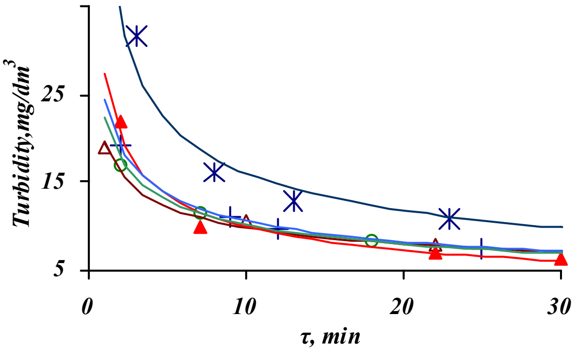

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Table 3. Impact of Magnetic Waters Conditioner (MWC) on clarification of model water by ferrous sulphate (II)*

Water performance	Water of Nemunas + + 5 g/dm^3 of clay suspension	Clarified water				
		Excluding MWC	With 1 MWC	With 2 MWC	With 5 min of circulation	With 10 min of circulation
1. B, hardness, mE dm^{-3}	5.8	2.0	2.0	2.0	2.0	2.0
2. pH	8.0	10.2	10.2	10.2	10.2	10.2
3. Alkalinity, mE dm^{-3}	5.4	0.75	0.75	0.75	0.75	0.75
4. Electric conductivity, µS/cm						
a) in non-clarified water	1273	1247	1273	1283	1263	1270
b) in clarified water		705	710	708	707	710
5. Turbidity, mg/dm^3	31.72	10	10	10	10	10
6. Clarification duration up to 10 mg/dm^3, min						
a) in the depth of 10 cm		27	10	9	11	8
b) in the depth of 20 cm		32	15	12	17	16
c) in the depth of 30 cm		32	15	12	17	16

*Note. $FeSO_4$, $7H_2O$ conc. = 0.197 mM dm^{-3}, temperature 20 °C

Table 4. Impact of MWC on clarification of the Nemunas water by ferrous sulphate (II)*

Water performance	Water of Nemunas	Clarified water				
		Excluding MWC	With 1 MWC	With 2 MWC	With 5 min of circulation	With 10 min of circulation
1. *B*, hardness, mE/dm^3	7.0	2.0	2.0	2.0	2.0	2.0
2. pH	7.2	9.8	9.6	9.6	9.5	9.5
3. Alkalinity, mE/dm^3	6.0	1.0	1.0	1.0	1.0	1.0
4. Electric conductivity, μS/cm						
a) in non-clarified water	1350	1350	1381	1383	1380	1385
b) in clarified water		848	871	870	873	870
5. Turbidity, mg/dm^3	14.98	10	10	10	10	10
6. Clarification duration up to 10 mg/dm^3, min						
a) in the depth of 10 cm		32	11	11	11	11
b) in the depth of 20 cm		34	12	12	12	12
c) in the depth of 30 cm		37	13	13	13	13

*Note. $FeSO_4$, $7H_2O$ conc. = 0.17 mM dm^{-3}, temperature 20 °C

Table 5. Impact of MWC on clarification of the Nemunas water with $FeSO_4$ in alkaline solution and AF352 flocculants*

Water performance	Water of Nemunas	Clarified water				
		Excluding MWC	With 1 MWC	With 2 MWC	With flocculant AF352	
					With 1 MWC	With 2 MWC
1. B, hardness, mE dm^{-3}	4.2	1.7	1.7	1.7	1.7	1.7
2. pH	8.1	10.2	10.2	10.2	10.2	10.2
3. Alkalinity, mE dm^{-3}	2.5	0.05	0.05	0.05	0.05	0.05
4. Turbidity, mg/dm^3	19.320	4.440	4.130	4.440	3.200	3.200
5. Clarification duration up to 10 mg/dm^3 in the depth of 2 cm, min		9	4	4	2	2

*Note. $FeSO_4 \cdot 7H_2O$ conc. = 0.17 mM·dm^{-3}; the flocculants doze was 0.2 mg/l; temperature 20 °C

Table 6. The Magnetic Waters Conditioner enfluence on electrokinetical potential of colloidal systems in clarified water

Collloid	Electrokinetical potential of colloidal particules, mV				Decreasing of electrokinetical potential, %
	Excluding MWC	With 1 MWC	With 2 MWC	10 min of circulation with MWC	
1. Model Nemunas water of high turbidity (Characteristics in Table 3)	–32	–23	–23	–23	~ 29
2. Coagulant ($FeSO_4$) C = 0.01 %, pH = 8.9, with alkaline $Ca(OH)_2$	55	42	44	43	~ 23

creation of new associates. In the presence of the means for introducing such turbulent mixing, the parallel flow creates a combination of magnetic and hydrodynamic conditions which favor the electrochemical interaction which initiates nucleation of the colloid.

This hypothesis confirms measurements of electric conductivity. Water conductivity depends on ion concentration and their mobility. Impact of magnetic field on water leads to increased electrical conductivity both before coagulation and in clarified water (see Table 1 and Table 2). Negligible increasing of electric conductivity proves the hypothesis that MWC reduce hydration of electrolytes and enlarge mobility of particles which exist in water. Thus decreasing electro kinetic potential of dispersive particles and accelerating coagulation. As it was given in the experimental results clarification rate with MWC is greater 1.8 – 3.3 times. Visually observing the formation of flakes it is seen that considerably larger and branchy flakes are forming in water impacted by MWC. Besides, the hypothesis is also proved by earlier research of MWC impact on water desalting by cation exchangers and anion exchangers [5].

CONCLUSIONS

1. The magnetic field acting on the water flow increase viscosity and electric conductivity and decreases electrokinetic potential of waters dispersion systems. Experimental facts confirm hypothesis that magnetic activation decreases the hydration degree of ions and colloidal particles in addition accelerate coagulation and ions diffusion to deeper layer of ions exchangers granules.
2. The coagulation of natural colloids and other materials suspended in water is faster in water is impacted by a magnetic field of permanent magnet. When iron sulphate was used as coagulant, clarification rate with MWC was greater 1.8 – 3.3 times.
3. Adding flocculants may accelerate the clarification process of low turbidity water with coagulants. With iron sulphate and micro amount of flocculants, clarification rate with MWC is greater 2.2 – 4.5 times.
4. The magnetic effect on the water flow can be used to decrease clarification temperature from 33 °C to 20 °C, when clarification under way with $FeSO_4$ alkaline solution.

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