



## REMOVAL OF IRON ORGANIC FORMS FROM UNDERGROUND WATER WITH APPLICATION OF REAGENTS AND ELECTRIC FIELD

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### ABSTRACT

Experimental data on removal of iron organic forms from underground water with application of coagulation, aeration and imposition of electric field are presented. Conditions of mixing of coagulating agent with processed water in electro-hydrodynamic device (EHDD) are shown to influence the subsequent water purification by filtering through sand bed. Magnitudes of specific electrical energy consumed for maximum saving of coagulating agent are defined. Water electric treatment in region of the Camp criterion magnitudes  $(2,8-3,4) \cdot 10^4$  at specific electrical energy consumption of  $(6,7-8,0) \cdot 10^{-2} \text{ A} \cdot \text{h/m}^3$  in electro-hydrodynamic device (EHDD) allows by 27-33% decrease in polyaluminium chloride (PACl) consumption as compared with reagent treatment without application of electric field at the same degree of organic iron removal.

**Keywords:** underground water, organic iron complexes, coagulation, aeration, electro-hydrodynamic device, filtering.

### INTRODUCTION

Concentrations of dissolved and undissolved iron in underground water may reach high magnitudes. Content neither of iron compounds in tap water used by people may nor exceed 0, 3 mg/l while in the case of some industries (food industry, textile, chemical, medicine, pulp and paper industries, heat-and-power engineering) residual concentrations of iron in purified water may no be higher than 0, 1-0, 2 mg/l.

One of the most critical problems at water deferrization consists in removal of organic forms of iron from water that form at availability of higher water oxidizability (up to 15 mgO<sub>2</sub>/l and higher) in water. Organic forms of iron are removed from water by aeration [1-4], coagulation, liming [5-10], processing with strong oxidizers [11-13] and filtering through grainy bed [2, 3, 5, 14]. To accelerate coagulation of impurities, processed water is subjected to electric field effects [15-16].

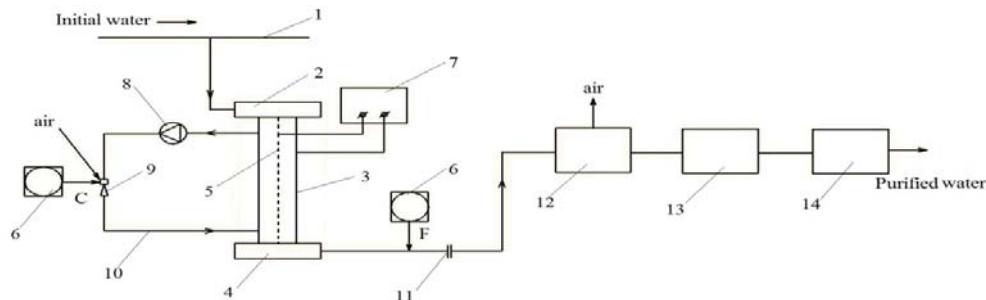
This research aims at analyzing the combined application of reagent treatment and electric processing of aerated underground waters in electro-hydrodynamic device (EHDD) for determination of removal degree of organic ion compounds there from.

### MATERIALS AND METHODS

Experiments were made with underground water extracted from one of wells in the territory of the town of Kuznetsk of Penza Region. EHDD was placed as technological element into water purification works of heat-and-power enterprise.

Underground water composition was relatively permanent in seasons and features the following properties: pH 6, 8-7, 0; turbidity 0, 1-0, 15 mg/l, hardness 1, 7-1, 9 mmol/l, chlorides 2-3 mg/l, sulphates 14-18 mg/l, iron 5,0-5,3 mg/l, oxidizability 10-11, 2 mgO<sub>2</sub>/l.

Scheme for reagent deferrization of underground water with application of EHDD is shown on Figure-1.



**Figure-1.** Scheme of organic iron reagent removal from underground water.

- 1- pressure line; 2- intake chamber; 3 - EHDD case; 4 - discharge chamber; 5- central core; 6- proportioning pumps;
- 7- constant current source; 8- recycling pump; 9 -ejector; 10 - recycling line; 11- choke; 12- air separator;
- 13- contact filter; 14- clarification filter; C- coagulant, F- flocculant



Water from pressure line 1 of artesian well was forced at excess pressure of  $2 \cdot 10^5$  Pa into EHDD intake chamber 2 that doubled as the mixer. Pipes tangentially connected to intake chamber 2 and to discharge chamber 4 developed the internal downburst vortex of water-air mix at the EHDD case central section 3. Simultaneously, tangential bleed from case 3 and tangential feed of water-air mix by recycling pump 8 back into case 3 at EHDD periphery, developed the external rising whirl, its direction was opposite the aforesaid internal downburst vortex. Such configuration of motion allowed better mixing of coagulating agent with water and increased the dispersion of air bubbles over the entire volume of case 3.

Overall dimensions of EHDD were as follows:

- diameters of intake and discharge chambers - 500 mm
- case diameter - 350 mm
- central core diameter - 38 mm
- total height - 1800 mm
- EHDD material - stainless steel.

Air concentration in EHDD was maintained by recycling in the range of  $\varphi=0,07-0,08$ .

Unit with EHDD allowed feed of reagent at two points:

- coagulating agent solution (C) was fed in air pipe of ejector 9 in EHDD recycling line 10;
- flocculating agent solution (F) was fed into water-air discharge pipe from EHDD upstream of choke 11.

Reagents were dispensed from service tanks by two peristaltic pumps 6.

Polyaluminium chlolate (PACl) was used as the coagulating agent while polyacrylamide (PAM) was used as the flocculating agent.

Underground water was processed in EHDD at voltage of 48 V across electrodes and at central core cathode polarization, specific electrical energy consumption varying from  $q=2, 4 \cdot 10^{-2}$  to  $q=8,0 \cdot 10^{-2}$  A·h/m<sup>3</sup>. Cathode current density varied from 4, 8 to 16,0 A/m<sup>2</sup>. Downstream of EHDD, water was fed to air separator 12 and, further, to contact and clarification filters 13, 14 respectively. Quartz sand, grain size making 0, 8-1,2 mm and depth equal to 1,0 m, was filled in clarification filter. Filtering rate was kept equal to  $v_f=5-5,5$  m/h. Contact filter 13 used coarse-grained bed to form in water the strength aggregates of coagulated impurities, said bed being composed of crushed granite with grain size of 10 to 30 mm and depth of 1,5 m. Filtering rate at contact filter made 20-25 m/h.

The common view of EHDD in water purification works is shown on Figure-2.



**Figure-2.** EHDD unit.

Conditions of underground water mixing with reagents in EHDD were evaluated by the Camp criterion

$$K = \sqrt{\frac{\Delta p \cdot t}{\mu}} , \quad (1)$$

where

- $\Delta p$  - are pressure losses in EHDD, Pa;  
 $t$  - time of water-air mix stay in EHDD, s;  
 $\mu$  - dynamic coefficient of water-air mix viscosity, Pa·s.

Magnitude  $\mu$  was defined with due allowance for air saturation of the mix  $\varphi$

$$\mu = v_w \cdot (1 + 4,5\varphi) \cdot \rho_w , \quad (2)$$

where  $V_w$  and  $\rho_w$  is water kinematic viscosity coefficient, m<sup>2</sup>/s, and water density, kg/m<sup>3</sup>, respectively.

During the tests pressure loss  $\Delta p$  in EHDD varied from 0,  $2 \cdot 10^5$  Pa to  $0,7 \cdot 10^5$  Pa while time of water processing in EHDD varied from 30 to 35 s. Under such mixing conditions, minimum Camp criterion magnitude make  $K_{min}=22000$ , while maximum magnitude  $K_{max}$  equaled 45000

Water purification effect after filtering was defined by the formula

$$E = \frac{C_0 - C}{C_0} \cdot 100\% , \quad (3)$$

where  $C_0$  and  $C$  - iron concentrations in initial and purified waters, respectively, mg/l.

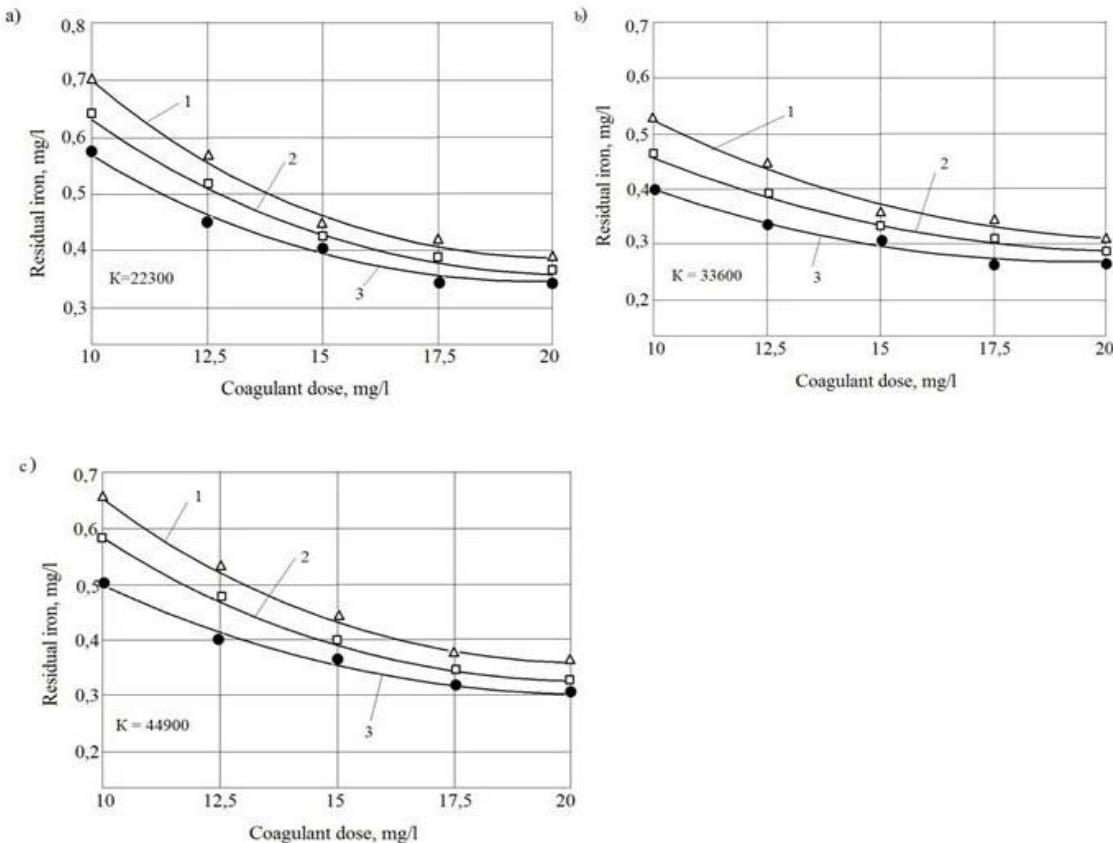
Iron concentrations in initial and purified waters were defined by salicyl-sulphonic method.



## RESULTS AND DISCUSSIONS

Results of experiments with iron removal from underground water at its processing in EHDD with  $\text{PACl}$

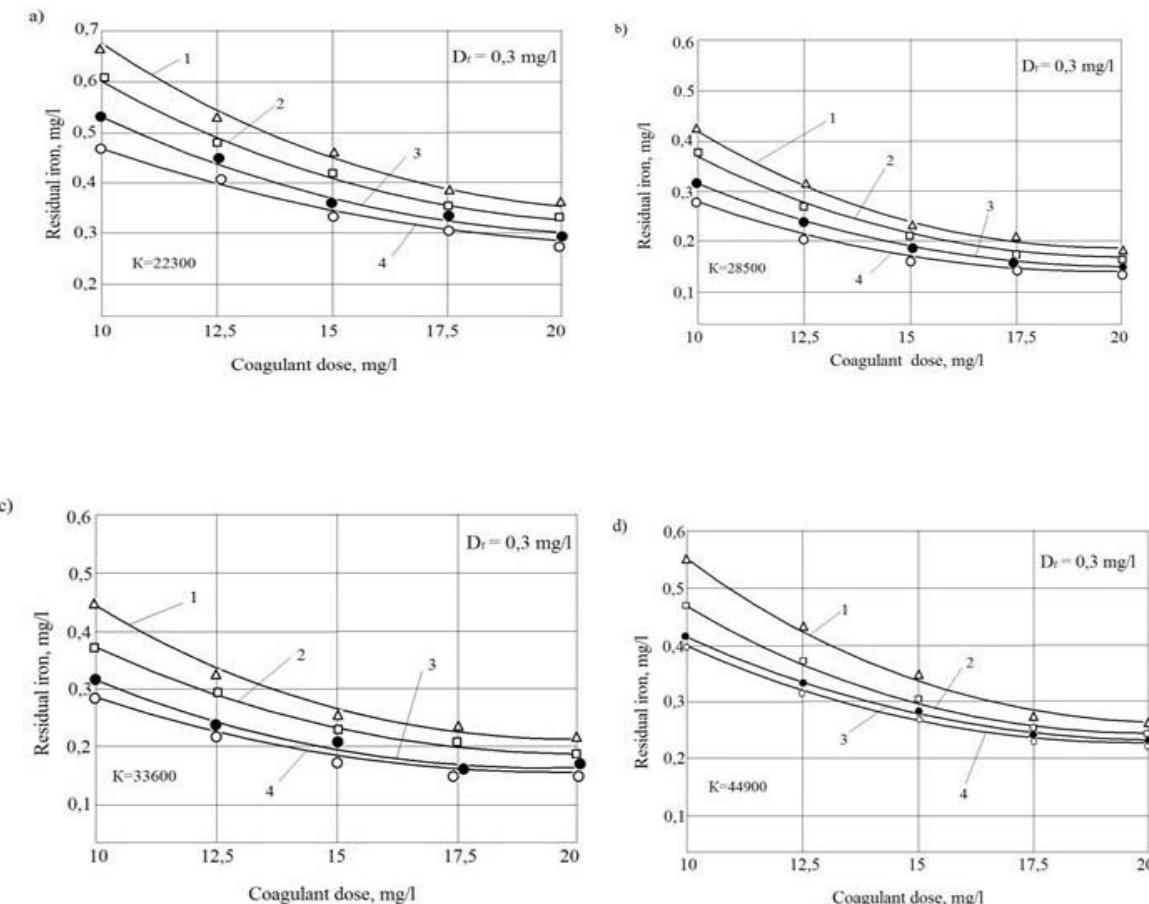
and  $\text{PAM}$  reagents and at subsequent filtering are shown in Figures -3, 4.



**Figure-3.** Residual iron content in water from doses of  $\text{PACl}$  ( $D_c$ ) and  $\text{PAM}$  ( $D_f$ ) at various Camp criterion magnitudes without application of electric field:  
1 -  $D_f = 0, 1 \text{ mg/l}$ ; 2 -  $D_f = 0,2 \text{ mg/l}$ ; 3 -  $D_f = 0,3 \text{ mg/l}$

Analysis of graphs displayed that the efficiency of organic iron components from water without professing in electric field at constant dose of coagulating agent  $D_c = \text{const}$  (see Figure-3) directly depended on flocculating agent  $D_f$  dose. Note here that maximum purification effect varied from 93% to 94, 6%. At  $D_c = 20 \text{ mg/l}$ , increase in flocculating agent  $D_f$  dose from 0,1 mg/l to 0,3 mg/l improved the purification effect  $\Delta E$  on a par by 0,7 % over the entire range of Camp criterion magnitudes. As of effects of mixing conditions on purification degree, the most optimum range of Camp criterion magnitudes is  $K = (3,3-2,4) \cdot 10^4$ . In this range of Camp criterion

magnitudes residual content of iron in purified water corresponding to standard requirements for population ( $\text{Fe} \leq 0,3 \text{ mg/l}$ ), was observed at  $D_c$  of 15 mg/l to 17, 5 mg/l and  $D_f$  of 0,2 mg/l to 0,3 mg/l (see figure- 3, b). Decrease in oxidizability to thresholds set from drinking water (less than 5 mgO<sub>2</sub>/l) occurred also at  $D_c \geq 15 \text{ mg/l}$ ,  $D_f \geq 0, 2 \text{ mg/l}$  and magnitudes  $K = (3, 3-3,4) \cdot 10^4$ . Increase in Camp criterion to  $(4, 0-4, 1) \cdot 10^4$  and higher caused deterioration of purification quality (see figure-3, c) probably because of destruction of weak aggregative structures of coagulating agent with organic iron.



**Figure-4.** Residual iron content in water from doses of PACl (Dc) at various camp criterion magnitudes with application of electric field.

$$1 - q = 2,4 \cdot 10^{-2} \text{ A} \cdot \text{h/m}^3; 2 - q = 4,3 \cdot 10^{-2} \text{ A} \cdot \text{h/m}^3; 3 - q = 6,7 \cdot 10^{-2} \text{ A} \cdot \text{h/m}^3; 4 - q = 8,0 \cdot 10^{-2} \text{ A} \cdot \text{h/m}^3$$

Experimental data on removal of organic iron from underground water with application of electric field at mixing in EHDD (Figure-4) were obtained at fixed dose of flocculating agent Df = 0,3 mg/l. Analysis of obtained graphs showed that application of even weak electric field with  $q=2,4 \cdot 10^{-2}$  A·h/m<sup>3</sup> at voltage 12 V allows to increase the purification efficiency over the entire range of magnitudes of coagulating agents dosage and Camp criterion. Increase in voltage at EHDD electrodes to 48 V and in specific power consumption to  $q=8,0 \cdot 10^{-2}$  A·h/m<sup>3</sup> at Dc=18-20 mg/l, increases the purification effect on a par by  $\Delta E=2,1-2,3$  % compared with experiments without electric field application. Maximum effect of removal of organic iron from water was observed in the range of Camp criterion magnitudes  $K=(2,8-2,9)10^4$  at varying  $q$  from  $6,7 \cdot 10^{-2}$  to  $8,0 \cdot 10^{-2}$  A·h/m<sup>3</sup> (see Figure-4, b). Under such conditions of processing for coagulating agent dose Dc=20 mg/l, residual iron content was in the range of 0, 13-0, 14 mg/l. At increase in Camp criterion to  $K=(3,3-3,4)10^4$  iron removal effects was lower, its residual concentrations lied in the range of 0,15-0,19 mg/l at  $q=(4,3-8,0) \cdot 10^{-2}$  A·h/m<sup>3</sup> (see figure- 4, c). Increase in K to over 4,  $1 \cdot 10^4$  like in water processing without application

of electric field resulted in worse purification effect (see Figure-4, d).

Decrease in residual concentration of iron in purified water to standard magnitudes set for drinking water ( $Fe \leq 0,3$  mg/l) in experiments with electric pretreatment was observed at  $K=(2,8-3,4)10^4$ ,  $q=(6,7-8,0) \cdot 10^{-2}$  A·h/m<sup>3</sup> and as coagulating agent dose of Dc=10-11 mg/l. Hence, electric treatment of aerated water at its mixing with coagulating agent PACl in EHDD allows decreasing the coagulating agent dose by 27-33 % as compared with mixing without application of electric field with the same effect of organic iron removal after filtering. Besides, effects of electric field at reagent treatment of water decreased the magnitude of oxidizability to standard magnitudes (less than 5 mgO<sub>2</sub>/l) at Dc=11 mg/l,  $q=8,0 \cdot 10^{-2}$  A·h/m<sup>3</sup> and  $K=(2,8-3,4)10^4$ .

## CONCLUSIONS

a) It was experimentally disclosed that electric treatment of aerated underground water at mixing with PACl and flocculating agent PAM increase the water purification degree from the organic iron compounds by



filtering at (less, than 0,2 mg/l) at invariable amounts of reagents.

b) Optimal conditions of aerated water mixing with coagulating agent in EHDD at removal of organic iron complexes has the area of optimum magnitudes by Camp criterion within  $(3,3-3,4)10^4$  without application of electric field. For electric treatment of water in EHDD area of Camp criterion optimum magnitudes increases to  $(2,8-3,4)10^4$ .

c) Electric treatment of water in said area of Camp criterion magnitudes  $K=(2,8-3,4)10^4$  at  $q= (6,7-8,0)\cdot 10^{-2}$  A·h/m<sup>3</sup> in EHDD allows by 27-33% decrease in consumption of PACl as compared with reagent processing without application of electric field at the same level of organic iron removal.

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