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Purification of Industrial Waste Water by Electrocoagulation

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Abstract: *The article presents purification of industrial wastewater by electrocoagulation is based on electrolysis using metal (steel or aluminum) anodes subjected to electrolytic dissolution under the influence of an electric field. The electrocoagulation method is technologically quite simple and effective - it is used to remove inorganic and organic contaminants from wastewater - heavy metals, chromates, phosphates, finely dispersed impurities, emulsified oils, fats and oils and petroleum products, organic suspensions, etc.*

Keywords: *electrocoagulation, wastewater, coagulation. Electrolysis.*

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Introduction

Modern wastewater treatment by electrocoagulation is used in the textile, machine-building and metallurgical industries, where waste water is characterized by a high content of dyes, salts, heavy metals, insoluble sediments, technical oils and petroleum products. Electrocoagulation can also be used to clarify and discolor water, remove iron, silicon, chromium, surfactants and radioactive substances from it, as well as to purify water from biological contaminants.

Along with electrocoagulation, when an electric field is applied, the following also occurs: electrolysis of water; polarization of colloidal particles; movement of charged particles in an electric field (electrophoresis); redox processes; chemical reactions between Al^{3+} or Fe^{2+} ions formed during the electrolytic dissolution of metal anodes and some ions contained in water (S^{2-}, PO_4^{3-}); interaction of electrolysis products with each other; flotation of solid particles with bubbles of gaseous hydrogen released at the cathode; sorption of ions and molecules of dissolved impurities on the surface of iron and aluminum hydroxides, which have a significant sorption capacity.

There are electrostatic, electrochemical and galvanic coagulation. Electrostatic coagulation proceeds due to the polarization of colloidal particles under the influence of an external electric field and sticking together of the resulting dipoles. In this case, it is possible to use both a constant field and a pulsating and alternating one. Electrostatic coagulation requires very high electric field strengths, around 10–30 kV/m, so this method is little used in wastewater treatment. A variety of electrostatic can be considered electro contact coagulation, which occurs when water is filtered in an electric field.

In this case, partial polarization of hydrated ions and colloidal particles under the action of an electric field is possible, followed by coagulation of the dipoles. However, the electric field strengths necessary for the coagulation of colloidal particles are very high, and this method is used mainly for the purification of demineralized waters.

Electrochemical coagulation proceeds due to the electrolysis of water and changes in the pH value and redox potential in the volume of water near the electrodes. Electrolysis is carried out with insoluble electrodes at an electrical voltage on the electrodes exceeding the water decomposition potential.

The process of electrocoagulation is influenced by the material of the electrodes, the distance between them, the speed of the wastewater between the electrodes, its temperature and salt composition, voltage, strength and density of the electric current. With an increase in the concentration of suspended solids over 100 mg/l, the efficiency of electrocoagulation decreases. With a decrease in the distance between the electrodes, the energy consumption for anodic dissolution of the metal decreases. The theoretical energy consumption for dissolving 1 g of iron is 2.9 Wh, and 1 g of aluminum is 2 Wh.

The degree of use of the metal of the electrodes is 50–90% and depends on the design of the coagulators, the anode material and the composition of the treated water.

Electrocoagulation is recommended to be carried out in a neutral or slightly alkaline medium containing at least 20% chloride salts (of the total salt content) and not more than 75% bicarbonates and sulfates, causing passivation of the electrodes, at an electric current density of not more than 10 A/m2, the distance between the electrodes should not exceed 20 mm, and the speed of water movement is not less than 0.5 m/s.

If there are large amounts of Ca2+ and Mg2+ cations in the water and it is impossible to add chlorides to it, stainless steel should be used as a cathode material and the polarity of the electrodes should not be changed. The duration of electrical water treatment is determined by the properties of contaminants and on average can vary within one to five minutes. Given the small distance between the electrodes and the possibility of clogging the electrode space, it is advisable to subject the wastewater to mechanical sorption from coarsely dispersed contaminants before electrocoagulation.

The main limiting stage of electrocoagulation is the formation of metal cations - the result of the electrochemical dissolution of metal anodes in accordance with the equation:

$$M \rightarrow Mn^{+} + ne^{-}, \qquad (1)$$

where M is the metal symbol; n is its valency. The following reaction takes place on aluminum anodes:

$$Al \rightarrow Al^{3+} + 3^{e-}, \qquad (2)$$

and on steel anodes the following reaction takes place:

$$Fe \rightarrow Fe^{2+} + 2e^{-}, \qquad (3)$$

at the same time, part of the iron cations is oxidized under the action of oxygen dissolved in water at the anode to ferric iron (III):

$$Fe^{2+} \rightarrow Fe^{3+} + e^{-}. \qquad (4)$$

The second stage of coagulation is reduced to the chemical hydration of the resulting metal cations, the formation of insoluble metal hydroxides, their precipitation (crystallization) with the subsequent formation of flakes capable of flocculating coarse water impurities. The corresponding chemical reactions occur in the interelectrode space and include several stages:

$$Al^{3+} + 3\ OH \rightarrow Al(OH)^{3+}, \qquad (5)$$

$$Fe^{3+} + 3\ OH \rightarrow Fe(OH)^{3+}, \qquad (6)$$

$$Fe^{2+} + 2\ OH \rightarrow Fe(OH)^{2+}, \qquad (7)$$

$$Fe(OH)_2 + O_2 + H_2O \rightarrow Fe(OH)_3. \qquad (8)$$

As a result of the intake of the required amount of iron or aluminum cations into the water due to the above reactions, the same situation arises as in the treatment of water with coagulants: iron or aluminum salts. However, unlike the use of salt coagulants during electrocoagulation, water is not enriched with sulfates or chlorides, the content of which in purified water is limited both when it is discharged into water bodies and when it is reused in industrial water supply systems.

The coagulation process in electro coagulators proceeds much more intensively than in reagent coagulation, which is explained by the positive effect of electrophoresis on the mutual enlargement of the nuclei of metal hydroxide particles and the mixing of water by hydrogen bubbles released on the cathodes. Favorable conditions for electrocoagulation make it possible to reduce the doses of metal required for purification by 10–20% or more compared to the doses for reagent coagulation.

Electrocoagulation is carried out in special electrical devices that generate metal cations (most often aluminum and iron) - electro coagulators. The main element of the electro coagulator is an electrode chamber with a replaceable set of steel or aluminum (duralumin) electrodes of alternating polarity, in the gaps between which (5–20 mm wide) the treated water flows at a speed of at least 0.5 m/s. As in electrolyzes, in electro coagulators, electrodes can be located horizontally or vertically with a gap of 10–16 mm, which depends on the conditions of placement and installation, as well as on the flow rate of the treated water.

Operational works include: averaging over the costs and quality of water entering the electro coagulator; adjustment of water quality (cleaning from coarse impurities, adjustment of pH and salt composition); maintaining the design mode of water recirculation in the electro coagulator circuit, if this is provided for by the processing scheme; control of values and maintenance at the required level of electrical parameters - current strength, voltage; observance of the mode of polarity reversal of electrodes for DE passivation and the method of uniform dissolution of all electrodes; cleaning the interelectrode space from deposits and foam; removal of foam formed during electrolysis; timely replacement of electrodes;

Monitoring the state of the gas environment and ensuring the efficient operation of the ventilation system; proper maintenance of facilities for subsequent water treatment (settlers, flotation tanks, filters).

Conclusion

The main advantages of the electrocoagulation method in comparison with the reagent ones are the compactness of the installation, the relative simplicity of its operation and a sharp reduction in the cost of chemical reagents. Along with electrocoagulation, bactericidal water treatment also takes place.

The disadvantages are the consumption of metal (aluminum and iron) and electricity. Theoretically, 3 and 12 Wh are consumed to dissolve 1 g of iron and 1 g of aluminum, respectively. The actual power consumption turns out to be higher due to the costs of heating water, polarizing electrodes, overcoming the electrical resistance of oxide films formed on the surface of dissolved anodes, etc.

Electrocoagulation requires a significant amount of electricity and sheet metal, so it can be recommended for local treatment schemes for small amounts of wastewater (50–80 m3/h). Electrocoagulation is effective for removing finely dispersed impurities, emulsions, oils and petroleum products, organic suspensions, etc. from wastewater. It is recommended to apply this method for the treatment of wastewater with a neutral or slightly alkaline reaction (pH = 6–9).

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