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Synthesis of oxidized chlorine compounds by electrodialysis using a strongly basic anion exchange resin

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ABSTRACT

The work investigated processes for treating solutions similar in composition to concentrates obtained from reverse-osmosis desalination of water containing sodium chloride, using the method of electrodialysis. Two-chamber electrolyzers equipped with MA-41 anion membranes were used to electrolyze model solutions. Sodium chloride solutions were placed in the anode chamber, while the cathode chamber was filled with an alkaline solution at a concentration of 200 mg-eq/dm^3. Electrolysis processes were conducted at anodic current densities ranging from 1.67 to 8.33 A/dm^2. It was found that the intensity of chloride oxidation increased with higher anodic current density and higher chloride concentrations in solutions. Alongside the formation of active chlorine, other oxidized chlorine compounds were also formed, as indicated by the discrepancy between the number of oxidized chlorides and the synthesized oxidized chlorine compounds at the initial electrolysis stage. Extended electrolysis periods did not achieve high concentrations of oxidized chlorine compounds in the anolyte due to significant losses via degassing in the form of Cl_2 and ClO_2. A significant increase in the current efficiency of active chlorine compounds was achieved by introducing the strongly basic anion exchange resin AB-17-8 into the anode chamber, which effectively adsorbed hypochlorite anions and other oxidized chlorine anions. The yield of adsorbed ClO^-, ClO_2^- and ClO_3^- anions decreased due to degassing processes involving Cl_2 and ClO_2.

Keywords: membrane, reverse osmosis, concentrate, electrodialysis, active chlorine, anion exchange resin, anodic current density, current efficiency.

INTRODUCTION

The shortage of freshwater resources in Ukraine has recently been offset using artesian, surface, and mine waters with increased mineralization. The utilization of such water for municipal and industrial purposes is possible only after desalination.

To a considerable extent, increased surface water mineralization is caused by anthropogenic factors. Outdated water treatment technologies and wastewater purification methods from the 20th century are incapable of effectively removing dissolved substances from water. The use of modern desalination methods is significantly constrained by the complexity of processing and disposing of concentrates formed during water treatment. Unfortunately, in Ukraine, saline solutions are practically not processed. In most cases, they are discharged into surface water bodies, significantly deteriorating the condition of aquatic ecosystems. The situation is worsened by the fact that a substantial portion of mine water, suitable for use, is discarded into the environment after dilution, or even without dilution or purification, due to concentrate disposal issues [Gomelya et al., 2016].

One of the most challenging and critical issues regarding protecting natural water bodies from mineral contamination involves the purification, processing, and disposal of mine waters, industrial wastewater, and desalination of mineralized artesian waters. Various methods are used for purification and desalination, depending on the composition and level of mineralization of contaminated wastewater and natural waters. These include ion exchange methods [Klimonda et al., 2021; Kyohei 2022; Martins et al., 2020], baromembrane methods such as reverse osmosis and nanofiltration [Li et al., 2021; Torkian et al., 2025; Tokui et al., 2014], electrodialysis [Habib et al., 2018; Bagastyo et al., 2021], freezing methods [Lyashenko et al., 2017; Adeniyi et al., 2014], distillation [Camacho et al., 2013], and evaporation [Wang et al., 2019]. Particularly challenging is the problem of water purification from chlorides, which along with sulfates, are the most common anions in highly mineralized waters. While sulfates can be precipitated chemically, forming easily disposable residues [Shabliy et al., 2011], or processed via electrodialysis to produce sulfuric acid [Li et al., 2024], concentrating and processing chloride solutions is significantly more difficult. The ion exchange method is widely used in water treatment practices, including chloride-anion removal. Strongly basic anion exchange resins are used for chloride removal during water softening, achieving chloride removal efficiency of nearly 90% [Gomelya et al., 2022]. Additionally, membrane technologies are often employed to remove chlorides from water [Naidu et al., 2015; Wenna et al., 2015]. The efficiency of chloride removal using this method can range from 82% to 96% [Tokui et al., 2014], depending on the initial characteristics of the treated water.

It is important to emphasize that chlorides can also be removed from water using sorption methods. The type of sorbent utilized significantly influences the process efficiency [Nigiz et al., 2017].

The most challenging issue in water desalination processes is managing and processing newly formed eluates (regeneration solutions) from ion-exchange technologies and concentrates from membrane-based desalination methods [Gomelya et al., 2020].

The problem of treating concentrates and eluates produced during desalination can be largely addressed by employing electrodialysis methods. In electrodialysis of sulfate and chloride salts, it is possible to produce sulfuric or hydrochloric acid and alkali solutions [Zhu et al., 2024; Scarazzato et al., 2017]. The reduction of chlorides, sulfates, and hardness in water enables the evaluation of the potential economic efficiency of electrodialysis processes for desalination. When wastewater contains chlorides, their treatment using electrochemical methods converts chlorides into active chlorine, sodium hypochlorite, or other oxidized chlorine compounds. These compounds are widely used as disinfectants across various industries [Kryzhanovska et al., 2023].

Sodium hypochlorite solutions are commonly used to disinfect drinking water and municipal wastewater, bleach fibers in the textile industry, disinfect and detoxify, purify wastewater from organic contaminants, and serve as effective antiseptic agents [Gomelya et al., 2024]. Sodium hypochlorite (NaOCl) is more active than chlorine, has low toxicity, is safer to handle, and is simpler to apply.

Thus, it can be concluded that producing such a valuable and relevant product from water purification waste through the implementation of waste-free mineralized water treatment processes would be economically advantageous.

The aim of this research was to determine the efficiency of processing sodium chloride solutions similar in composition to membrane water purification concentrates or other wastewater by the electrodialysis method, with the production of sodium hypochlorite and other oxidized chlorine compounds, depending on water characteristics, anodic current density, and electrolysis duration.

To address this scientific objective, the following research tasks must be performed:

- to determine the impact of solution composition and electrolysis conditions on chloride oxidation efficiency, and to assess the relationship between current efficiency of oxidation products, anodic current density, and chloride concentration.
- to investigate the changes in concentrations of oxidized chlorine compounds depending on anodic current density, chloride concentration, electrolysis duration, and the sorption efficiency of oxidized chlorine compounds onto strongly basic anion exchange resin present in the anolyte.

MATERIALS AND METHODS

Electrolysis was carried out using sodium chloride solutions with chloride concentrations ranging from 100 to 1725 mg-eq/dm^3 in a two-chamber electrolyzer. An MA-41 anion-exchange membrane was employed. The cathode was made of alloy steel 12X18H10T, and the anode was a titanium plate coated with ruthenium oxide. The electrode surface areas were $S^a=S^k=12$ cm^2. The current was varied between 0.2 A and 1 A, corresponding to an anodic current density of 1.67 to 8.33 A/dm². Chloride concentration was determined using Mohr's method, hardness and alkalinity were measured according to standard methods, and the concentration of oxidized chlorine compounds was determined using the iodometric method [Nabyvanets et al., 2006].

The cathode chamber was filled with a 0.2 N NaOH solution; the anode chamber was filled with the working sodium chloride solution. At each given current, electrolysis was conducted for 2 to 8 hours, periodically monitoring the alkalinity in the catholyte and the concentrations of chloride and active chlorine in the anolyte. The current efficiency (B, %) was determined by equation 1 as the ratio of the actual amount of substance produced or transferred to the theoretically possible amount according to Faraday's law:

$$B = \frac{q_f}{q_t} \cdot 100 = \frac{m_f}{m_t} \cdot 100 \tag{1}$$

where: q_f – quantity of electricity corresponding to the actual transferred, oxidized, or reduced substance; q_t – theoretically calculated quantity of electricity; m_f – actual amount of transferred (oxidized, reduced) substance, in grams-equivalent (g-eq); m_T – theoretically possible amount of transferred (oxidized, reduced) substance, in grams-equivalent (g-eq).

The actual amount of transferred, oxidized, or reduced substance was calculated according to equation 2, and the theoretically possible amount of transferred, oxidized, or reduced substance (g-eq) was calculated using equation 3.

$$m_f = (C_s - C_r) \cdot V \tag{2}$$

where: C_s – initial concentration of the component in water, mg-eq/dm^3; C_r – residual concentration of the component at a given time in the treated water, mg-eq/dm^3; V – volume of the treated water sample, dm^3.

$$m_t = K_e \cdot I \cdot t \tag{3}$$

where: K_e – electrochemical equivalent (0.03731 g-eq/(A·h)); I – electric current, A; t – time, h.

The efficiency of water purification from chlorides (EEE, %) was calculated using equation 4:

$$E = \frac{(C_s - C_r)}{C_s} \cdot 100 \tag{4}$$

When using a strongly basic anion exchange resin in the two-chamber electrolyzer, the cathode chamber was filled with a 0.2 N NaOH solution, while the anode chamber contained sodium chloride solutions with chloride concentrations of [Cl$^-$] =1690 mg-eq/dm^3, [Cl$^-$] = 850 mg-eq/dm^3, [Cl$^-$] = 88.5 mg-eq/dm^3, along with the anion exchange resin AB-17-8 in Cl$^-$-form. The volume of the ion exchange resin V_i = 50–56 cm^3 with a solution volume V_p = 15–23 cm^3.

During electrolysis, at regular time intervals, the chloride concentration, active chlorine [Nabyvanets et al., 2006], and pH were measured in the anode chamber.

The exchange capacity of the anion exchange resin to active chlorine was also determined during electrolysis. For this purpose, a specific volume of resin was placed into a flask and filled with sodium sulfite solution of known concentration with volume (V_p). The flask was sealed tightly and left for 24 hours. The next day, the residual amount of sodium sulfite in the solution was measured using the iodometric method [Nabyvanets et al., 2006].

The ion-exchange capacity (IEC) of the resin was calculated using equation 5:

$$IEC = \frac{(C_s - C_i) \cdot V}{V_i} \tag{5}$$

where: C_s – initial concentration of sodium sulfite solution, mg-eq/dm^3; $C_{i.}$ – final concentration of sodium sulfite solution, mg-eq/dm^3; V – volume of sodium sulfite solution, dm^3; V_i – volume of ion-exchange resin, dm^3.

RESULTS

The use of electrolysis for producing active chlorine, sodium hypochlorite, and other oxidized chlorine compounds from water-treatment waste, specifically concentrates containing sodium chloride, is a promising approach. Currently, the production of active chlorine and sodium hypochlorite from sodium chloride for water disinfection in Ukraine remains quite limited. Moreover, purified salt (sodium chloride) is a product that must be either produced or purchased. In contrast, concentrate waste is not only freely available but its disposal incurs a cost. The main challenge of this approach is that industrial production of sodium hypochlorite typically uses sodium chloride solutions with concentrations of at least 100 g/dm^3.

Real concentrates from reverse-osmosis water desalination, however, contain salts at much lower concentrations – between 5 and 40 g/dm³.

Therefore, it is essential to determine the efficiency of synthesizing oxidized chlorine compounds at sodium chloride concentrations below 100 g/dm³. In this study, model sodium chloride solutions, similar in composition to concentrates obtained by baromembrane water desalination, were used.

Two-chamber electrolyzers equipped with an MA-41 anion-exchange membrane were employed for chloride oxidation. Using this membrane protects the cathode from poisoning by hardness ions. Moreover, this membrane allows hydroxide anions to migrate from the cathode chamber, maintaining a neutral environment in the anion exchange resin and chemically binding active chlorine to form sodium hypochlorite and chlorine dioxide to form sodium chlorite and chlorate. The results for oxidizing sodium chloride solutions at a concentration of 100 mg-eq/dm³ are presented in Figures 1 and 2.

The best results were obtained at an anodic current density (J) of 1.67 A/dm², achieving the highest concentration of oxidized chlorine compounds in the anolyte (Fig. 1) and high current efficiency for oxidized chlorine compounds (Fig. 2).

The decrease in concentration of oxidized chlorine compounds in solutions at higher anodic current densities (4.17 and 8.33 A/dm²) can be explained by their decomposition into Cl_2 and ClO_2 and their subsequent losses through degassing. This also accounts for the observed reduction in the current efficiency of oxidation products (Fig. 2). The degree of chloride removal increases with rising anodic current density and electrolysis duration.

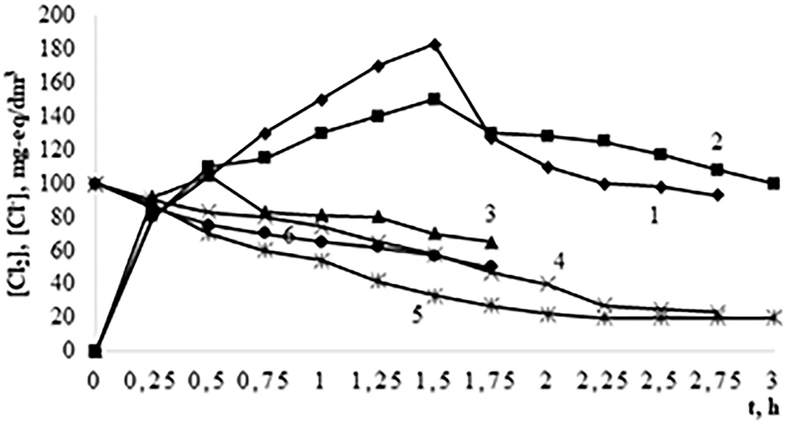

Figure 1. Dependence of oxidized chlorine compounds concentration (1; 2; 3) and chlorides concentration (4; 5; 6) on electrolysis time for sodium chloride solution (100 mg-eq/dm³) in a two-chamber electrolyzer (membrane MA-41) in the anode chamber, with catholyte alkalinity of 200 mg-eq/dm³ at anodic current densities (A/dm²): 1.67 (1; 4), 4.17 (2; 5), and 8.33 (3; 6)

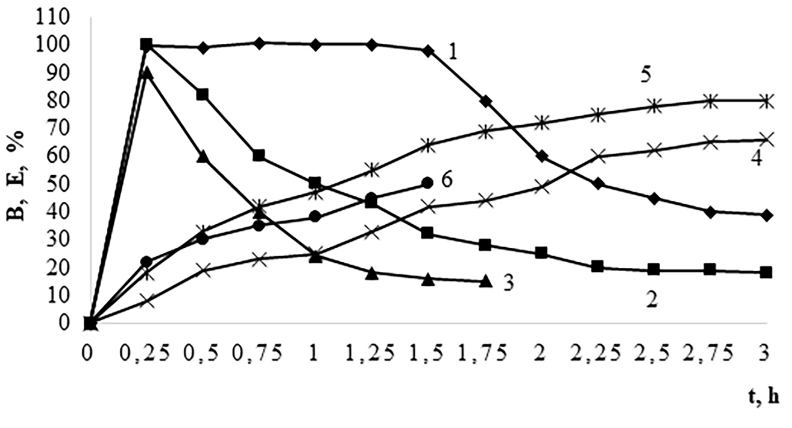

Figure 2. Dependence of current efficiency for oxidized chlorine compounds (1; 2; 3) and efficiency of NaCl solution purification (C(NaCl)=100 mg-eq/dm³) (4; 5; 6) during chloride oxidation in the anode chamber of a two-chamber electrolyzer (membrane MA-41) with catholyte alkalinity of 200 mg-eq/dm³, at anodic current densities (A/dm²): 1.67 (1; 4), 4.17 (2; 5), and 8.33 (3; 6)

It is evident that increasing anodic current density leads to a substantial portion of energy being consumed in side reactions, primarily water electrolysis. At J = 1.67 A/dm², the concentration of oxidized chlorine compounds reached 183 mg-eq/dm³, despite only 42 mg-eq/dm³ of chlorides being oxidized. This notable discrepancy between the amount of chlorides removed and the oxidized chlorine compounds obtained can be explained by the oxidation of chlorides to higher oxidation states, forming free chlorine (Cl_2), sodium hypochlorite (ClO^-), chlorite (ClO_2^-), chlorate (ClO_3^-), and chlorine dioxide (ClO_2). These processes likely occur due to both the generated active chlorine and the hydroxide anions migrating from the cathode chamber through the anion membrane. Typically, the quantity of hydroxide anions generated at the cathode corresponds to the amount of chlorides oxidized at the anode. When excess hydroxide ions accumulate in the anolyte, they are oxidized at the anode, producing oxygen and protons.

An increase in chloride concentration in the solution significantly enhances the current efficiency for synthesizing oxidized chlorine compounds during the initial stage of the process (Fig. 3). The subsequent decrease in current efficiency of active chlorine during further electrolysis is not caused by a reduction in chloride concentration – residual chloride concentrations in the anolyte remain between 300–1100 mg-eq/dm³ – but rather by losses of active chlorine and chlorine dioxide through evaporation.

It should be noted that the current efficiency for active chlorine and other oxidized chlorine compounds, as well as the degree of chloride removal, increase with an increase in the initial chloride concentration at a given current density. At low anodic current densities, the proportion of oxidized chlorides with higher oxidation states increases as the initial chloride concentration decreases. Consequently, at lower anodic current densities and lower chloride concentrations, the current efficiency of oxidized chlorides may exceed the degree of chloride removal. This is due to chlorine being further oxidized to higher oxidation states at the anode instead of direct oxidation of chloride ions. According to Faraday's law, the total amount of oxidized chlorine compounds produced at a given anodic current density over a fixed time will remain constant, irrespective of the initial chloride concentration. However, as chloride concentration increases, the relative proportion of oxidized chlorine compounds with higher oxidation states decreases. Therefore, it is natural to observe a decline in the degree of chloride

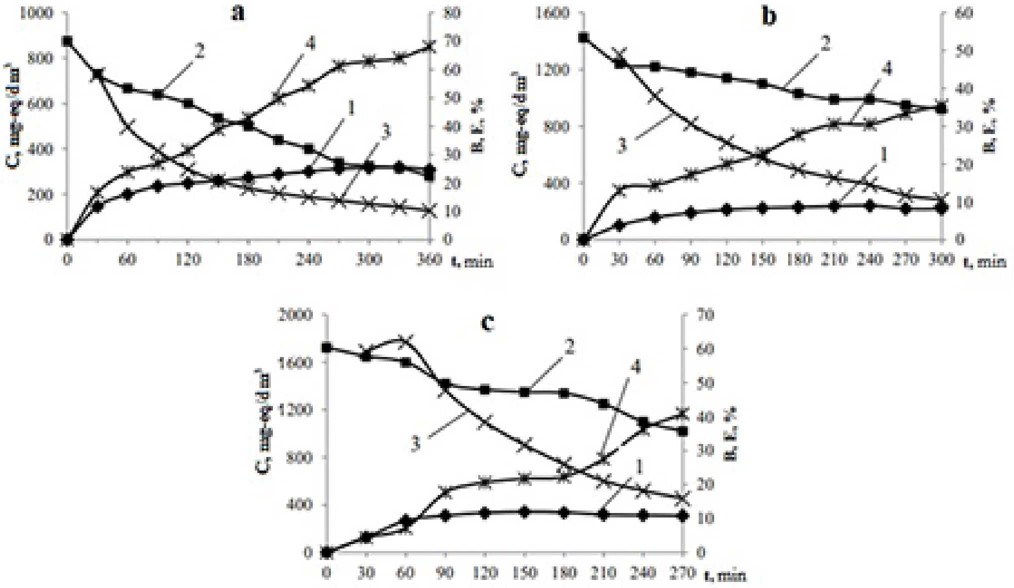

Figure 3. Dependence of active chlorine concentration (1) and chloride concentration (2), current efficiency of active chlorine (3), and efficiency of chloride removal from water (4) in the anode chamber of a two-chamber electrolyzer with an MA-41 anion-exchange membrane, on electrolysis time at catholyte alkalinity of 200 mg-eq/dm³ and anodic current density of 4.17 A/dm², for different chloride concentrations in the anode chamber. Chloride concentration, mg-eq/dm³: 875 (a), 1425 (b), 1725 (c) pH: $pH_{поч}$.=7,01, $pH_{кінц}$= 9.02 (a); $pH_{поч}$.= 7.10, $pH_{кінц}$= 11.20 (b); $pH_{поч}$.= 7.00, $pH_{кінц}$= 11.71 (c)

removal at lower anodic current densities as the initial chloride concentration decreases.

As evident from the presented results of sodium chloride solution electrolysis, the concentration of active chlorine in the anode chamber of the two-chamber electrolyzer is rather limited, regardless of the electrolysis duration. It was possible to increase it only up to about 3%. This limitation is due to losses of active chlorine caused by degassing processes that convert oxidized chlorine compounds into Cl_2 or ClO_2. The likelihood of such reactions is confirmed by the observed increase in the pH of the anolyte during prolonged electrolysis (Fig. 3), which results from reactions 6 and 7.

$$NaCl + NaClO + H_2O = Cl_2 + 2NaOH \qquad (6)$$

$$NaClO + 2NaClO_2 + \\ + H_2O = 2ClO_2 + NaCl + NaOH \qquad (7)$$

To capture oxidized chlorine compounds in the anolyte, the strongly basic anion exchange resin AB-17-8 in the Cl^--form was used, capable of effectively sorbing hypochlorite, chlorite, and chlorate anions. A specific feature of the two-chamber electrolyzer's operation is its ability to maintain the anolyte pH due to the diffusion of hydroxide ions from the cathode chamber through the anion membrane, where hydroxide anions are formed during hydrogen reduction. This is confirmed by the relatively stable pH values observed in the anolyte during hypochlorite anion sorption.

As shown in Figure 4, the chloride concentration in the anolyte decreased from 2690 mg-eq/dm^3 to 875 mg-eq/dm^3 during 10 hours of electrolysis at a current density of 4.17 A/dm^2, despite a relatively low concentration of active chlorine. The active chlorine concentration reached 30 mg-eq/dm^3 after just 0.5 hours of electrolysis, gradually increasing up to 86.7 mg-eq/dm^3. The exchange capacity of the anion resin for active chlorine was determined by taking samples of resin (1 cm^3) and measuring their active chlorine capacity. The sampled resin was replaced with fresh resin in the Cl^--form.

As illustrated in Figure 4, the anion resin's exchange capacity for active chlorine, sorbed as ClO^- or ClO_2^-, increased over time. After 10 hours of electrolysis, 174.8 mg-equiv of active chlorine had been sorbed. The dynamic exchange capacity of the resin for active chlorine reached up to 3500 mg-eq/dm^3. Such high resin capacity values are due to the fact that 1 mg-equiv of hypochlorite, determined iodometrically, corresponds to 2 mg-equiv of active chlorine, and 1 mg-equiv of chlorite corresponds to 4 mg-equiv of active chlorine. The current efficiency for oxidized chlorine compounds remained at a relatively high level (60–98%), decreasing over time as chloride concentrations in the solution declined.

Figure 5 shows the results obtained using a sodium chloride solution with a chloride concentration of 850 mg-eq/dm^3 and AB-17-8 anion exchange resin in chloride form in the anode chamber at a current density of 4.17 A/dm^2. The figure demonstrates that in this case as well, the current efficiency for hypochlorite anions sorbed onto the resin remained quite high. At the beginning of the experiment, the current efficiency for hypochlorite reached 98–100% and gradually decreased to 58% after 10 hours of electrolysis.

As in the previous experiment, the active chlorine content in the solution did not exceed 80 mg-eq/dm^3. The anion exchanger capacity for active chlorine exceeded 3000 mg-eq/dm^3, which is related to the fact that active chlorine was mainly sorbed in the form of hypochlorite anions, 1

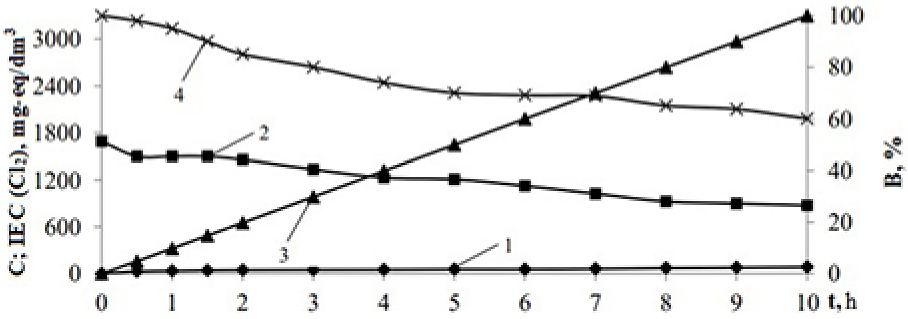

Figure 4. Dependence of active chlorine concentration (1), chloride concentration (2), ion-exchange capacity of the anion exchange resin AB-17-8 for active chlorine (3), and current efficiency for active chlorine (4) in the anode chamber of a two-chamber electrolyzer (membrane MA-41) on electrolysis time. Conditions: initial chloride concentration 1690.1 mg-eq/dm^3, anion resin volume 56 cm^3 in the anode chamber, catholyte alkalinity 200 mg-eq/dm^3 (I = 0.5 A, S^a=S^k=12 cm^2, j=4.17 A/dm^2)

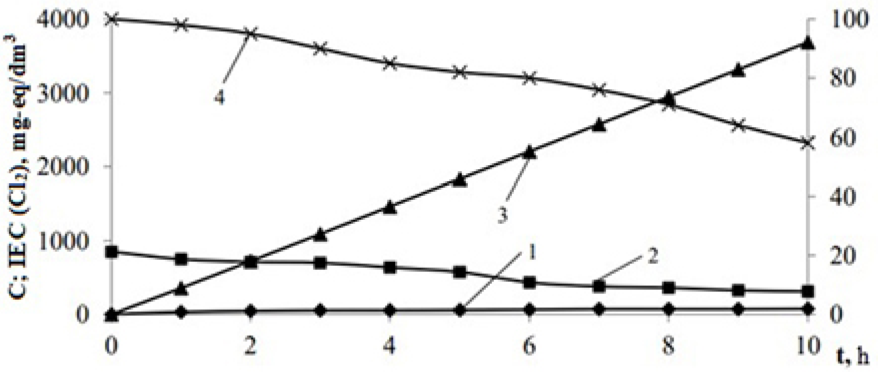

Figure 5. Dependence of active chlorine concentration (1), chloride concentration (2), ion-exchange capacity of AB-17-8 anion resin for active chlorine (3), and current efficiency of active chlorine (4) in the anode chamber of a two-chamber electrolyzer (membrane MA-41) on electrolysis time (10 h). Conditions: chloride concentration 850 mg-eq/dm^3, resin volume 50 cm^3 in the anode chamber, catholyte alkalinity 200 mg-eq/dm^3 (I = 0.5 A, S^a=S^k= 12 cm^2, j = 4.17 A/dm^2)

mmol of which corresponds to 2 mg-eq of active chlorine. The residual chloride concentration decreased to 420 mg-eq/dm^3. This slow reduction in chloride concentration in the solution is due to their desorption from the anion exchanger during exchange with hypochlorite anions.

During electrolysis over a period of 20 hours (Fig. 6), the chloride content was reduced to 18.5 mg-eq/dm^3 without a significant increase in the anion exchanger capacity for active chlorine. This is because with prolonged electrolysis, the capacity of the anion exchanger for hypochlorite anions was exhausted, and the electrolysis process proceeded with considerable losses of gaseous chlorine.

When using a sodium chloride solution with a concentration of 88.5 mg-eq/dm^3 (Fig. 7), under the same electrolysis conditions over 10 hours, the chloride concentration was reduced to 20 mg-eq/dm^3 while maintaining a high ion-exchange capacity of the anion resin for active chlorine.

As in previous experiments, along with the chloride ions from the solution, chlorides desorbed from the anion-exchange resin during hypochlorite-anion sorption were also oxidized at the anode. Overall, chloride concentration in the solution decreased from 88 mg-eq/dm^3 to 20 mg-eq/dm^3. The active chlorine concentration in the solution remained at the level of 20–50 mg-eq/dm^3, while the resin's active chlorine exchange capacity exceeded 2500 mg-eq/dm^3. It should be noted that as the chloride concentration decreased during the last three hours, there was a slowdown

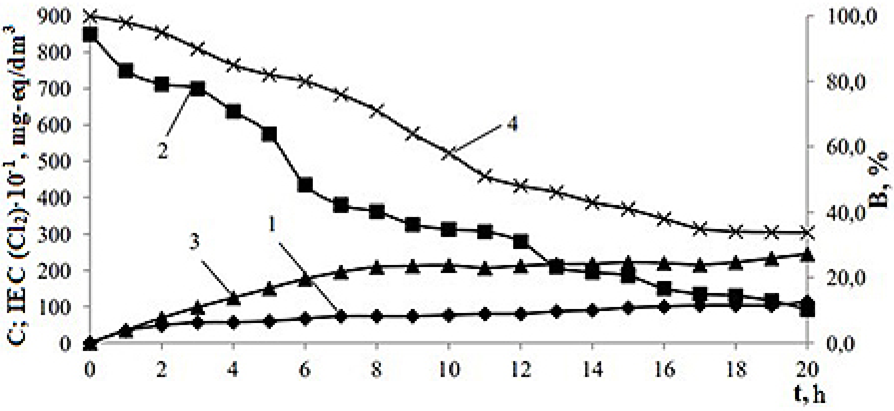

Figure 6. Dependence of active chlorine concentration (1), chloride concentration (2), ion-exchange capacity of AB-17-8 anion resin for active chlorine (3), and current efficiency of active chlorine (4) in the anode chamber of a two-chamber electrolyzer (membrane MA-41) on electrolysis time (20 h). Conditions: chloride concentration 850 mg-eq/dm^3, resin volume 50 cm^3 in the anode chamber, catholyte alkalinity 200 mg-eq/dm^3 (I = 0.5 A, S^a = S^k= 12 cm^2, j = 4.17 A/dm^2)

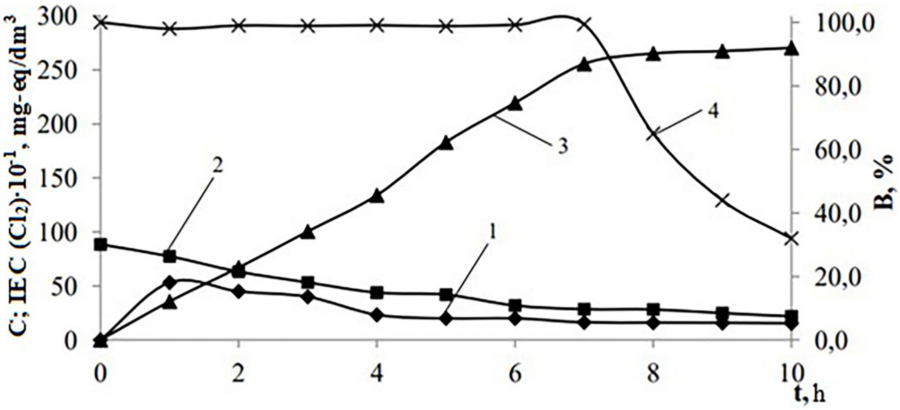

Figure 7. Dependence of active chlorine concentration (1), chloride concentration (2), ion-exchange capacity of AB-17-8 anion resin for active chlorine (3), and current efficiency of active chlorine (4) in the anode chamber of a two-chamber electrolyzer (membrane MA-41) on electrolysis time. Conditions: chloride concentration 88.5 mg-eq/dm^3, resin volume 53 cm^3 in the anode chamber, catholyte alkalinity 200 mg-eq/dm^3 ($I = 0.5$ A, $S^a = S^k = 12$ cm^2, $j = 4.17$ A/dm^2)

in the growth rate of the resin's active chlorine exchange capacity, with current efficiency declining from 95–98% down to 35–64%.

Overall, this process for treating concentrates containing chlorides is quite satisfactory. However, the chloride-purified solution still contains residual active chlorine. Moreover, solutions frequently exhibit increased pH, necessitating further treatment steps.

A significant advantage of this method is the conversion of the anion-exchange resin from chloride form into chlorite form. Such resin could potentially be used for water disinfection since oxidized chlorine compounds are desorbed when water is filtered through it, including typical surface waters with hardness and alkalinity up to 4–5 mg-eq/dm^3 and chloride and sulfate content up to 100–150 mg/dm^3. However, the main challenge of this approach is the complexity involved in using resins in chlorite or hypochlorite form due to the necessity of transporting the resin to the site of application and returning the spent resin afterward.

Therefore, subsequent studies focused on processes for desorbing oxidized chlorine compounds from the resin using alkaline (NaOH) and soda (Na_2CO_3) solutions. The results are shown in Figure 8. As illustrated in Figure 8, ClO^- and ClO_2^- anions were effectively desorbed from the resin by both alkaline and soda solutions. Using 5 volumes of alkaline solution per 1 volume of resin, the resin regeneration reached 97%. Under the same conditions, using soda solution resulted in desorption efficiency of oxidized chlorine compounds reaching 84%.

The total active chlorine concentration reached 4% when using NaOH and 3.3% when

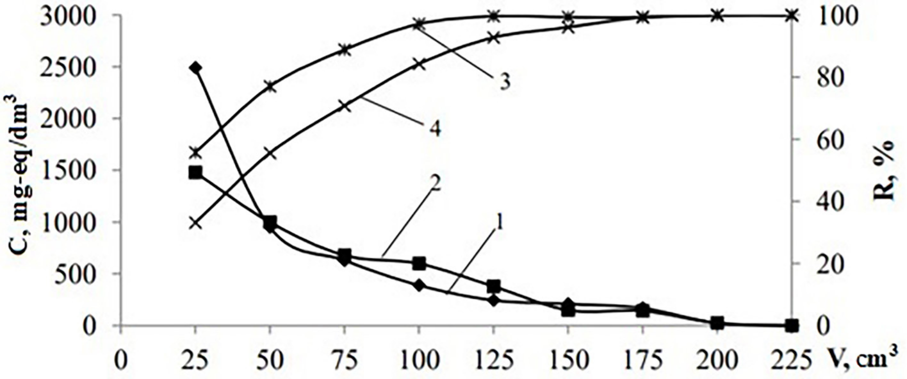

Figure 8. Dependence of active chlorine concentration (1, 2) and desorption efficiency (R) of active chlorine (3, 4) on volumes of regeneration solutions passed through the AB-17-8 anion-exchange resin in chlorite–hypochlorite form. Regeneration solutions: 5 % NaOH solution (1; 3), 15 % Na_2CO_3 solution (2; 4)

using soda (Na_2CO_3). When regeneration was conducted at a solution-to-resin ratio of 2.5:1, active chlorine concentration in the alkaline solution reached 6.1%, and in the soda solution reached 4.4%. Such solutions are suitable for water disinfection.

Thus, by processing chloride-containing solutions, sodium hypochlorite solutions suitable for water disinfection and removal of manganese and iron compounds can be produced.

CONCLUSIONS

It has been established that during the electrolysis of model solutions resembling reverse osmosis desalination concentrates in two-chamber electrolyzers equipped with an MA-41 anion membrane, active chlorine is produced alongside other oxidized chlorine compounds with higher oxidation states. This was confirmed by the significantly higher quantity of active chlorine compounds in the anolyte compared to the amount of oxidized chlorides.

It was shown that the intensity of chloride oxidation increases with rising anodic current density and chloride concentration in the anolyte.

The limit of achievable active chlorine concentrations in the anolyte was determined, considering losses due to degassing of Cl_2 and ClO_2. It was demonstrated that using the highly efficient AB-17-8 anion exchange resin, which sorbs hypochlorite anions, allows increasing the current efficiency of active chlorine compounds to 60–100%, due to the reduced losses from chlorine and chlorine dioxide degassing.

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