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The investigation of on-site generation of disinfectant by electrochemical methods

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ABSTRACT

In the on-site disinfectant generation, chlorine is produced when a sodium chloride solution is passed through an electrolytic cell and electricity is added. It is safer than conventional chlorination systems, provides higher quality disinfection, and energy savings, therefore, the on-site disinfectant generation process has been started to be preferred in treatment plants. In the study, a continuous flow electrochemical reactor and as the anode material IrO_2/RuO_2 coated titanium, and as cathode material, pure titanium sieve plates have been used. For electrical energy supply, a direct current power has been used. In the study, the initial pH value was 7 and the current intensity has been chosen as 20 A. The variable parameters have been examined in the study and the examined ranges of these parameters are as follows; flow rate 40,50,100 ml/min, and salt solution concentration (1, 2, 3, 4, and 5M). It has been observed that the pH value of the investigated solution has not been having significant effects on the disinfectant concentration. The increase in the flow rate has been affected the disinfectant production as negative. It has been concluded that high concentrations of disinfectant can be produced electrochemically under optimum conditions.

Introduction

One of the most important requirements of the water purification process is water disinfection processes [1]. The main goal of the disinfection process is to remove pathogenic microorganisms that can be transported with water, encountered in drinking water systems and at the outlet of treated water [2]. Chlorine and its compounds, which are chemical disinfectants, are the most widely used disinfectants among water and wastewater disinfection applications [3-5]. This is due to the high disinfectant efficiency of chlorine, and the easy availability of chlorine is that it can be applied with simple techniques and at a low cost. However, considering the transportation and storage hazards of chlorine and its compounds, it would be most appropriate to produce disinfectants on-site to minimize transportation and storage from a safety perspective. On-site disinfectant production will minimize the hazards mentioned and increase human and environmental safety [6-7].

The study covers the generation of disinfectant on-site by electrooxidation using a concentrated brine concentration and the development of this process. In this context, the disinfection process, which has become one of the most important processes in water and wastewater treatment, both for the decrease of water-borne diseases and for ensuring the high efficiency required in treatment; an on-site disinfectant generation with electrooxidation will be brought to the fore by improving its use with more reliable, easier operating parameters and more efficient use. This process, which works under optimum conditions, is also aimed to reduce operating and storage costs in water and wastewater treatment, and to bring a more reliable and sustainable process into use.

Material and Method

In the study, a continuous flow electrochemical reactor with dimensions of 20*10*10 cm made of plexiglass material has been used. IrO_2/RuO_2 coated titanium with the size of 18*8 cm has been used as the anode material, and the same size pure titanium sieve plates have been used as the cathode material. 6 anode and 6 cathode electrodes have been used. 5 mm has been left between the electrodes. For electrical energy supply, a direct current power supply with 40 V 120 A power has been used. The study has been carried out at a current intensity of 20 A and initial pH 7. The variable parameters have been examined in the study and the examined ranges of these parameters are as follows; flow rate 40,50,100 ml/min, and salt solution concentration (1, 2, 3, 4, and 5M). A portable ion-selective device has been used to determine the active and total chlorine amounts.

Effect of Flow Rate and Salt Concentration on Disinfectant Generation

The effects of salt concentration and flow rate on disinfectant production have been investigated using 1, 2, 3, 4, and 5 M NaCl with variable parameters of 1, 2, 3, 4, and 5 M NaCl at the initial value at flow rates of 40, 50 and 100 ml/min. The reaction times were determined as 30 min for 40 ml/min, 24 min for 50 ml/min, and 12 min for 100 ml/min, considering the complete cycle of the reactor. These experiments have been carried out at pH 7 and a constant current of 20 A. The solution concentration has been adjusted by adding the molar equivalent of NaCl to distilled water by mass. The salt concentration required for each trial has been prepared and used just before the trials. The pH, temperature, and energy consumption values obtained in each trial are given in the "Table 1.".

Table 1. Output pH values at the end of the reaction times for different salt concentrations

Salt Concentrations	1 M	2 M	3 M	4 M	5 M
40 ml/min	11,12	11,3	11,06	11,33	8,35
50 ml/min	11,06	11,25	11,39	11,05	11,15
100 ml/min	11,68	10,78	9,53	11,28	10,75

The outlet pH has shown a similar trend for all salt concentrations studied. The output pH value indicates that the hypochlorite ion (OCl^-) is higher than the hypochlorous acid. The disinfectant effectiveness of hypochlorous acid is much higher than that of hypochlorite. It has been observed that the pH value of the effluent water has not changed much depending on the salt concentration.

Figure 1 includes a graphical representation of the disinfectant production results obtained experimentally.

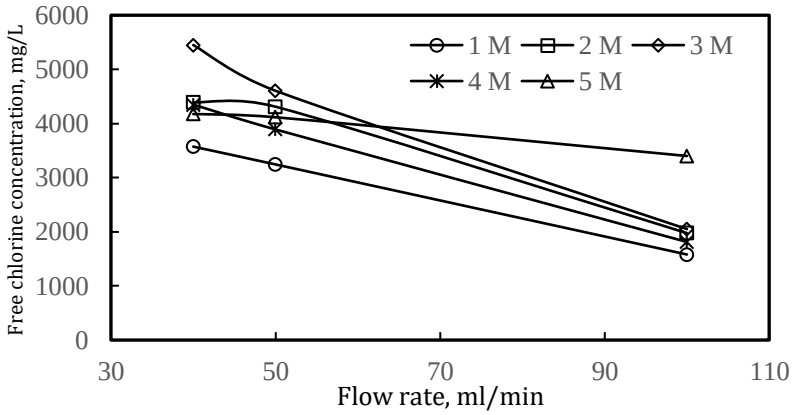

Figure 1. Effect of salt concentration and flow rate on disinfectant concentration at 20 A, pH 7

When Figure 1 is examined, increasing salt concentration from 1 M to 3 M caused an increase in disinfectant concentration to show the same trend for each flow rate. Increasing the 3 M salt concentration up to the 5 M salt concentration relatively reduced the free chlorine formation. In the experiments carried out with the more saturated 5 M solution, it is seen that the effect of the flow rate decreases as much as possible, and free chlorine concentrations close to each other are reached for almost all three flow rates. This is a positive effect as relatively high free chlorine production is achieved at high flow rates. The energy consumption values calculated based on the potential difference values that emerged in the trials in which the effects of salt concentration on free chlorine production were examined are given in Table 2.

As can be seen from Table 3, the change in salt concentration did not cause any change in energy consumption. Since even the lowest added salt concentration creates high electrical conductivity values, the potential difference values in the system showed a similar trend.

Table 2. Energy consumption values at the end of the reaction times for different salt concentrations

Salt Concentrations	1 M	2 M	3 M	4 M	5 M
40 ml/min	33,25 W	32,92 W	32,75 W	32,33 W	31,87 W
50 ml/min	27,33 W	26,93 W	26,73 W	26,65 W	26,59 W
100 ml/min	13,67 W	13,59 W	13,55 W	13,53 W	13,51 W

Discussion

The flow rate of the feed solution is considered as a parameter that needs to be examined as it determines the residence time in the reactor. The flow rate parameter has been selected as 40, 50, and 100 ml/min. The increasing flow rate has decreased the residence time in the reactor. As a result of this situation, significant decreases have been observed in the amount of disinfectant depending on the increased flow rate. Energy consumption values also have differed depending on the change in flow rate. The increase in flow rate led to a decrease in energy consumption values. Since both the highest disinfectant amount and low energy consumption values should be considered, a flow rate of 40 ml/min was determined as the optimum flow. One of the most important operating costs of disinfectant generation by on-site electrochemical methods is salt concentration. To keep this value in the lowest range, the salt concentration was chosen as 1, 2, 3, 4, and 5 M. The increase in salt concentration has caused an increase in the amount of disinfectant produced at the same flow rate up to 3 M. There was no increase in the amount of disinfectant at higher salt concentrations.

Conclusion

The study has been shown that a product containing approximately 5500 mg/L disinfectants can be obtained when the initial pH value is 7, the flow rate is 40 ml/min, the current intensity is 20 A, and the salt concentration is 3 M. This value has been chosen as the optimum operating condition for these operating parameters.

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