CO_2 Mineralization of Brine Discharged by Desalination Plant

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ABSTRACT

Climate change and global warming are among the major environmental challenges associated to increased global carbon dioxide emissions. furthermore, the world in general and he Gulf region in particular suffer from scarcity of clean water sources. Therefore, this research focuses on addressing these two crucial problems by applying mineralization process. CaO and MgO are among the divalent cations that contribute significantly for carbonation process. The carbonation reaction between CO, MgO, and CaO produces carbonate minerals such as calcium carbonate(CaCO3) and magnesium carbonate (MgCO3). Hence, brine coming out of a reverse osmosis unit as reject containing significant amount of Ca and Mg ions can be used for this application. In this study the effect of brine concentration, contact time, temperature and pressure on CO2 mineralization by brine has been investigated. The results of the experiments showed that the carbon dioxide mineralization rate depends mainly on three factors, which are temperature, concentration and time, and does not depend mainly on pressure. Through the experiment, it became clear that the optimal conditions for the occurrence of the mineralization process are when the temperature is 70 °C and the experimental time is 3 hours. The effect of carbon dioxide mineralization on Resistance, Capacitance, Impedance, pH, EC, Index (Brix) and Salinity were also studied.

Introduction

Climate change one of the most serious environmental challenges of our time is mainly because of increase in global CO_2 emissions. On the other hand, the Gulf region is suffering from scarcity of pure water sources. To provide pure water in the gulf, the companies need to treat sea water. Seawater treating process runs by removing salts by distillation and membrane separation to get water drinkable and for industrial purposes. Most of companies which desalinate seawater are located near power stations because desalination process consumes high amount of energy so that's lead the emission of carbon dioxide increase. Human respiration is negatively affected with the continued increase in the proportion of carbon dioxide in the atmosphere. Respiratory carbon dioxide toxicity occurs when a person breathes in a high concentration of carbon dioxide, but it is not known what levels will affect human health when people are exposed to carbon dioxide permanently. Blood samples were taken from people who live near to factories, where it was noted that the ability of thinking was decreased and health symptoms of people above 600 parts per million for short-term exposure. Therefore, stopping carbon dioxide emissions or removing it from desalination plants is important. One of the ways in which it is possible to remove or reduce carbon dioxide is mineralization. In this way, carbon dioxide reacts with magnesium and calcium to form calcium carbonate and magnesium carbonate, and when the reaction occurs in water, the rate of carbon dioxide mineralization increases. Another

way to reduce carbon dioxide emissions is to use zeolite for physical absorption. A 1000m2 experimental plant was built to continue the scientific research. A more than 20% improvement was observed in this field, as the plant exceeded 400 total operating hours, and the effectiveness of the zeolite did not decrease. There are several ways of carbonization and one of these methods is the process of biomass. This process is made by raising the organic cluster temperature until its temperature reaches 400 ° C. This process produces coal and activated carbon. An organic substance called Biochar is also used for the carbonization process, where the carbonation process occurs at a temperature of more than 500 degrees Celsius. This method is one of the methods used to reduce greenhouse gases such as carbon, as biochar can retain carbon and remain in its shape for hundreds of years. Another method of carbonization called hydrothermal carbonization is also used. This process uses heat to convert biomass feedstock into hydrocarbons. This process takes place inside a reactor at a temperature ranging from 180 to 250 degrees Celsius and the organic matter remains inside the reactor for a period of up to 8 hours. When the organic matter comes out of the reactor, carbon dioxide and a water slurry are produced, where the aqueous slurry is disposed of either by centrifugation or the filtration process, and then the wet slurry is produced where it is dried to produce carbon-saturated hydraulic coal. Many desalination plants rely on different types of desalination processes, and one of these processes is reverse osmosis and is the most common desalination process. In the event that the brine was organic matter or hydrocarbons, the electrodialysis reversal (EDR) process is used, since this process operates at low pressure, as the salts flow through ion exchange membranes. There are also other systems such as FlEXEDR Organix, where in these systems reactions occur between organic substances, hydrocarbons, and salts in brine. Sodium hydroxide is produced through desalination processes, and another substance called hydrochloric acid is also produced. Just as the brine contains a quantity of dissolved oxygen in it, and therefore this brine is treated to remove the dissolved oxygen and salts because it will cause corrosion to the equipment. Carbon dioxide mineralization is a process that captures carbon dioxide, where it is stored and used in other processes so that the rate of its emission to the atmosphere is reduced. In one of the experiments, the brine was injected with a solution of NaOH so that the solution reached a pH of 10.5, and the same process was repeated until the pH reached 8. Precipitation of approximately 99% of calcium and 86% of magnesium in the form of $CaCO_3$ and $Mg_5(CO_3)_4(OH)_2$. Through this experiment, it is clear that by injecting carbon dioxide into the brine saturated with calcium and magnesium, this will cause the carbon dioxide to react with the calcium and magnesium in the brine, and thus large amounts of calcium and magnesium will be deposited in the brine.

Methodology

In this experiment, samples identical to brine were prepared with different degrees of salinity to carry out the carbonation experiments. An autoclave high temperature and high pressure reactor was used to investigate the carbonation of CO2 by brine containing Sodium Chloride, Magnesium Sulphate and Calcium Chloride with a purity of 0.995. Through this study, we conducted a number of experiments to investigate the effects that appear on the solubility of carbon dioxide in a brine solution as a result of high pressure, temperature

change, concentration, and time. Where initially, the brine was placed in the base of the autoclave, and hermetically sealed. After that, the effect of temperature investigated for the range of 25^0C, then 50^0C, then 70^0C, and the effect of time was investigated for the time range of 1hr, 2hrs, then 3hrs, as for the concentrations used in these. A thin dipping tube was attached to the autoclave, and carbon dioxide saturated brine was formed inside the autoclave. After that, the samples were placed in the reactor and the carbon dioxide coming from the carbon dioxide cylinder at a pressure of 2 bar was injected into the autoclave reactor. (Fig. 1.1). the CO2 absorption and carbonation effect was investigated by measuring the resistance, capacitance and other properties of the brine CO2 mixture.

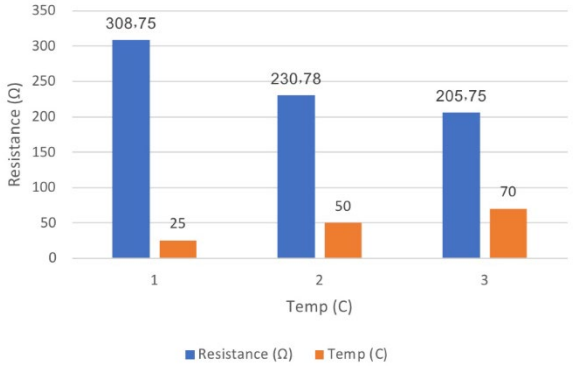
Figure 1. CO_2 mineralization process by brine using an autoclave reactor.

Results and Discussion

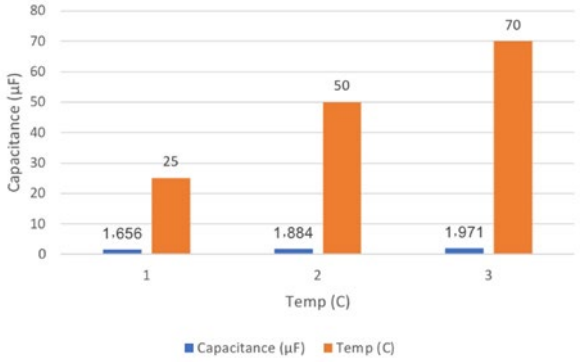
In this research, the effect of three factors on the rate of carbon dioxide mineralization in the prepared brine solution was studied. These three factors are temperature, time and concentration of salts, where a comparison was made between them to show the extent of the influence of each factor on the course of the process and the extent of its efficiency. Several variables such as resistance, conductivity, pH number, Impedance, Capacitance and Salinity. Also, a comparison was made between its values before and after the operation. In this study, we used different temperatures, different time periods, and different concentrations for each specific number of experiments in order to obtain the best conditions for completing the process, and thus obtain accurate results. The following table shows the variables that we chose in order to obtain the best conditions for the process.

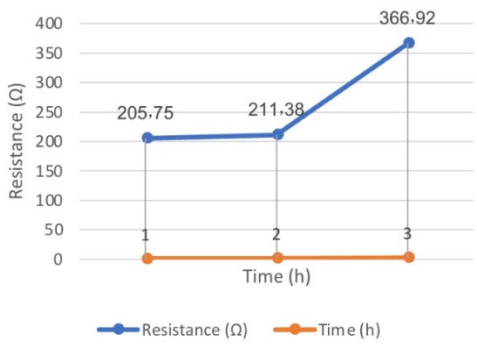
In order to distinguish the results of the experiments, we measured the parameters before conducting the experiments depending on the rate of change of the concentration of salt.

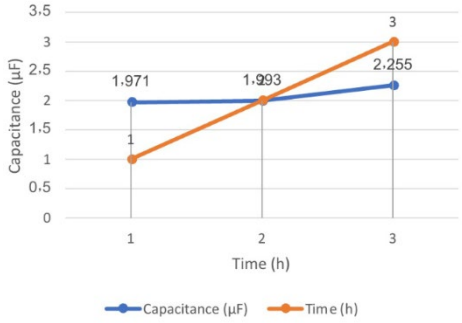
In addition, we found the relationship between the effect of changing each of the time, temperature and concentration of salts on a number of parameters in the carbon dioxide mineralization process, which are shown in the following graphs.



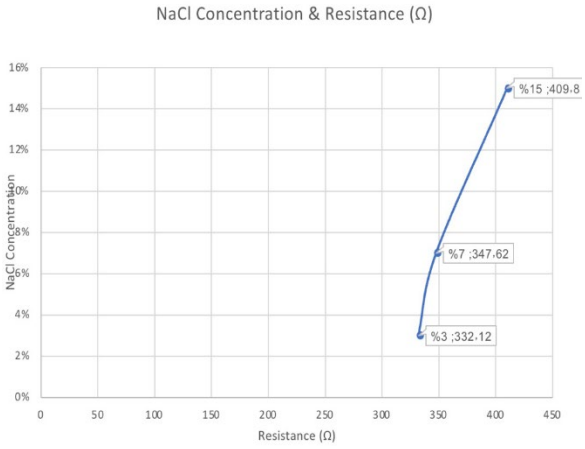
As it was concluded from the graphs that the resistance decreased gradually with increasing temperature, and this confirms to us that a carbon dioxide mineralization process has occurred.
Also, we noticed that when the temperature was increased, the capacitance of the sample gradually increased. When changing the time duration of the experiment we noticed that:

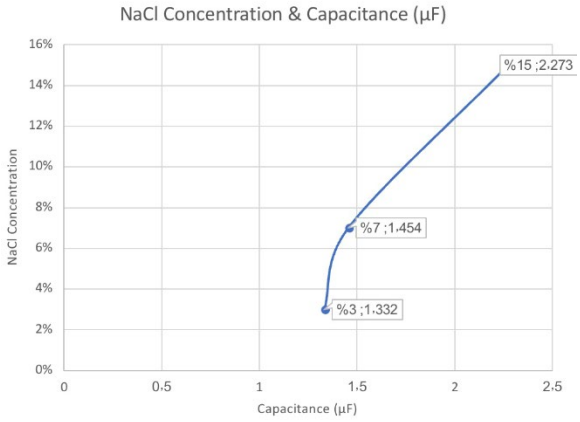




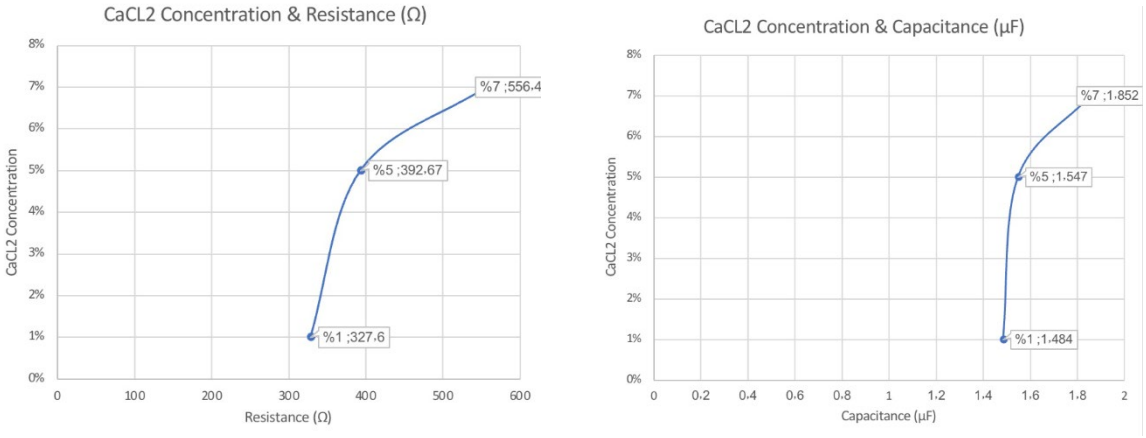


It was concluded from the graph that there is a direct relationship between the time and the rate of carbon dioxide mineralization, as with increasing time, the resistance of the sample increased. As it was concluded from the graph that the Capacitance of the brine increased. This confirms to us that a carbon dioxide mineralization process has occurred.





When changing the concentration of NaCl for experiments, It was observed from the graph that there is a direct relationship between the concentration of NaCl and the rate of carbon dioxide mineralization, as by increasing the concentration, the resistance of the sample increased. it was concluded from the graph that the Capacitance of the brine increased when we increase the concentration of NaCL. This confirms to us that a carbon dioxide mineralization process has occurred.



It was shown on the graph that there is a direct relationship between the concentration of CaCl and the rate of carbon dioxide mineralization, as by increasing the concentration, the resistance of the sample increased. As it was concluded from the graph that the Capacitance of the brine increased when we increase the concentration of CaCL. This confirms that a carbon dioxide mineralization process has occurred.

Conclusion

In conclusion, this research focused on the carbon dioxide mineralization process by a brine reject from a desalination plant the research investigated the effect of temperature pressure and duration of carbonation on the mineralization of the brine besides the effect of the various salts in the brine was also studied, where in this section several topics were raised such as the effects of carbon dioxide, the process of carbonation. The results showed that brine carbonation is a promising method for carbon storage and containment for temporary or permanent sequestration application.

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