Simulation of the mineral carbonation process with metal ion separation using electrolysis of industrial wastewater

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INTRODUCTION

To build resilience against the drastic climate change, Kyoto protocol has enacted the treaty and United Nation Framework Convention on Climate change (UNFCC) has legislated the Paris Agreement on reduction of CO_2 emission. To meet the demand of CO_2 reduction, Carbon Capture Sequestration and Utilization (CCUS) technology has been introduced. Among different CCUS technologies, this paper mainly focuses on utilization of captured CO_2 by mineral carbonation using seawater based industrial waste seawater. In favor of mineral carbonation, conversion of industrial wastewater into feedstock gives advantages in stable metal ion source with reduction in operational cost for wastewater treatment. The proposed designed system is evaluated within engineering perspective and feasibility study were analyzed in benefit of optimizing the further scale-up studies and designing the carbonation pilot plant.

MATERIALS AND METHODS

Process Design

The mineral carbonation process is developed in the idea of metal ion separation in favor of higher yield present in the seawater based industrial wastewater. Electrolysis of industrial wastewater is done to produce sodium hydroxide and later used to capture CO_2. Using difference in solubility of magnesium and calcium ion, produced sodium hydroxide is used in metal separation via pH swing method. Each magnesium and calcium ions are precipitate out as a metal hydroxide and later reacted with captured CO_2 to form metal carbonates. The designed simulation process for evaluation of production rate and costs via seawater electrolysis and indirect carbonation of CO_2 using Aspen Plus is shown on figure 1.

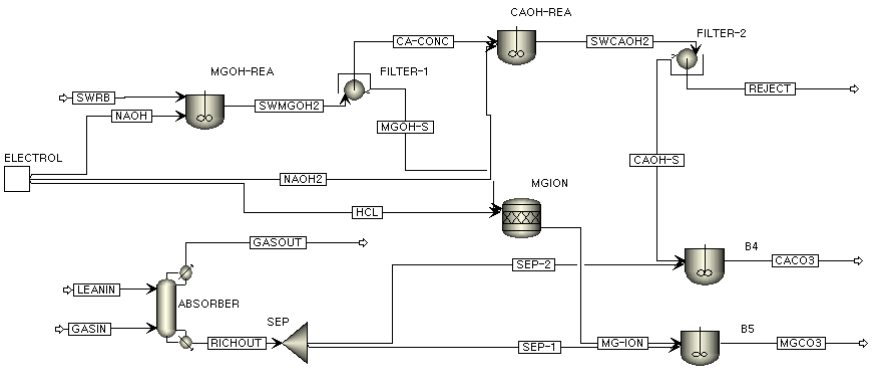

Figure 1 Schematic design of mineral carbonation process using rejected brine in Aspen Plus

RESULTS AND DISCUSSION

Table 1 Recovery percentage of carbon absorption process

Mechanism	Inlet (mol)	Outlet (mol)	Recovery
$CO_2 \rightarrow HCO_3^-$,	89.3	4.81	5.39%
$CO_2 \rightarrow CO_3^{2-}$	89.3	76.7	85.9%
$CO_2 \rightarrow HCO3^-, CO_3^{2-}$	**89.3**	**81.5**	**91.3%**

The result of CO_2 absorption process is shown in Table 1. 91.3% of CO_2 injected into the absorption tower is converted to either bicarbonate or carbamate with 5.39% and 85.9% yield respectively. Because the CO_2 is non-reactive in nature, it is reacted into ionic CO_2 for later metal carbonation reaction.

Table 2 Recovery percentage of metal ion separation and carbonation process

Mechanism	Inlet (mol)	Outlet (mol)	Recovery
$Ca^{2+} \rightarrow Ca(OH)_2$	27.6	27.1	98.9%
$Ca(OH)_2 \rightarrow CaCO_3$	27.3	27.2	99.6%
$Mg^{2+} \rightarrow Mg(OH)_2$	44.8	39.9	89.1%
$Mg(OH)_2 \rightarrow Mg^{2+}$	39.9	39.8	99.9%
$Mg^{2+} \rightarrow MgCO_3$	39.8	24.5	61.4%

The result of the metal ion separation and metal carbonation is shown in Table 2. The metal ions are selectively separated in a form of metal hydroxide for faster reaction rate and purification of the final product. The calcium ions were extracted as calcium hydroxide with 98.9% yield and further reacted with captured ionic CO_2 to form calcium carbonate with 99.6% recovery yield. While calcium undergoes spontaneous reaction with ionic CO_2, magnesium ions are difficult to precipitate due to kinetic hindrance. Thus, magnesium is once more extracted with acid into ionic state for faster reaction and 61.4% recovery yield were obtained.

CONCLUSION

This paper summarizes our research team's previous works based on the carbonation process using metal ions present in industrial wastewater. The proposed process design has enhanced its efficiency with metal ion separation and high purification of the final products has been speculated through the study of its morphology. Abundance of metal ion presents in industrial wastewater gives advantages in reliable feedstock and allows sustainable carbon emission cycle. The simulation has helped in identifying the optimal operating conditions for the further scale-up studies and designing the pilot plant of mineral carbonation.

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