Outlook for the Future

Toshihiko Hiaki

Project Leader

Professor, Department of Applied Molecular Chemistry, College of Industrial Technology, Nihon University

Project members discussed how to incorporate the results of this research project into the current salt manufacturing process. An overview of the process flow is shown in the **Figure**.

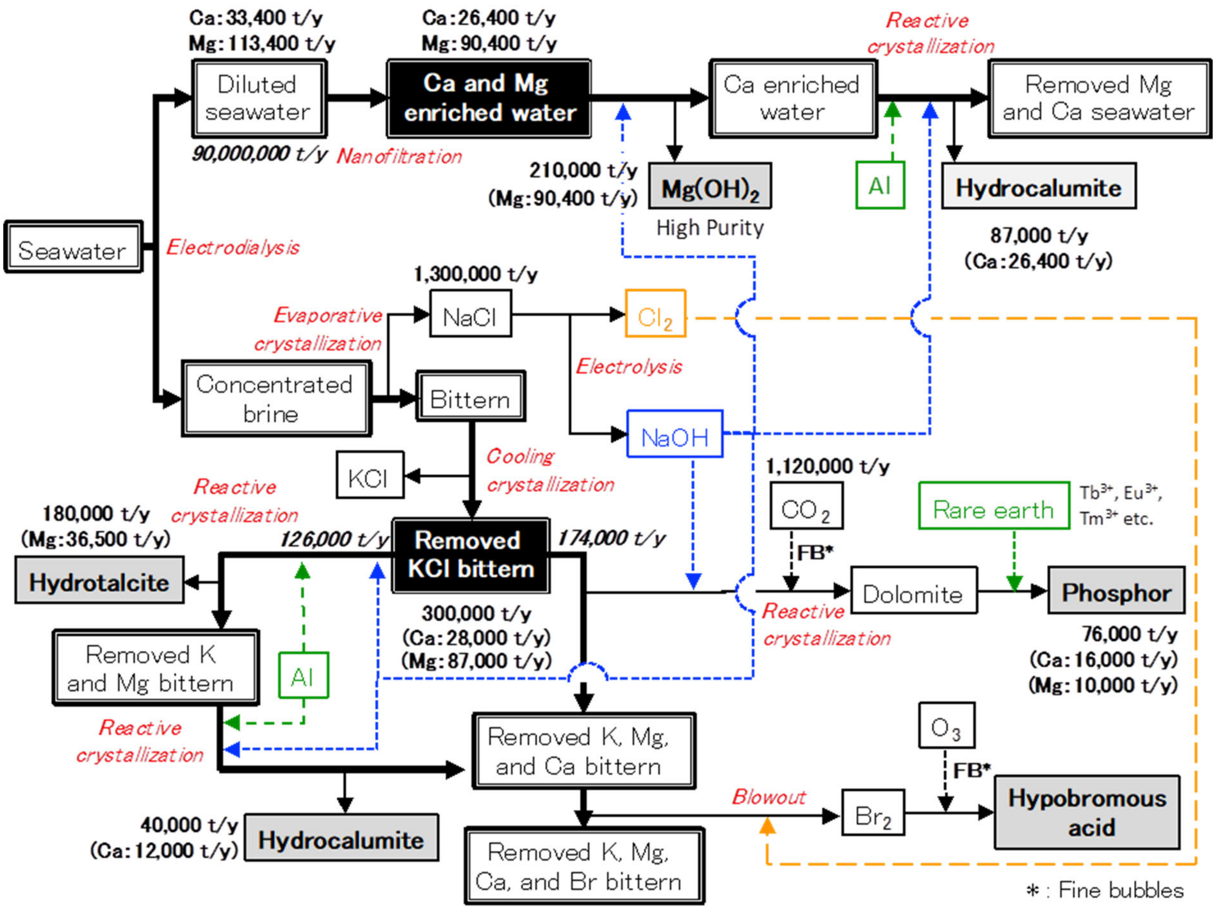

Figure Overview of a novel process flow proposed in this research project

In the first stage of the salt manufacturing process, seawater is separated into concentrated brine and diluted seawater (ED effluent) by electrodialysis. The ED effluent, which is discharged in large quantities, can be used as a raw material for the production of high-purity $Mg(OH)_2$ by adding alkali to the Ca and Mg enriched water obtained from the nanofiltration membrane developed by Akamatsu et al. It has been found by Hiaki et al. in this research project that dilute Mg concentration solution is advantageous to obtain $Mg(OH)_2$ with high quality and large crystal size. The Ca enriched water with Mg removed as $Mg(OH)_2$ is further increased in pH by adding alkali, and Al is added to produce hydrocalumite according to Shirakawa et al. Assuming that the annual production of NaCl in Japan is 1,300,000 t/y[1,2], the amount of each substance recovered can be estimated, 210,000 t/y of high-purity $Mg(OH)_2$ and 87,000 t/y of hydrocalumite can be produced from Ca and Mg enriched water obtained by nanofiltration.

On the other hand, bittern, which is the waste liquid after the production of NaCl through the process of boiling down concentrated brine to crystallize salt, becomes the raw material for the following process. KCl is obtained from the bittern by cooling crystallization. As shown by Hiaki et al., the recovery efficiency of KCl can be improved by optimizing the mixing operation, and the bittern without K (removed KCl bittern) contains high concentrations of Ca and Mg, which can be used as a starting material for the studied by Shirakawa et al. and Matsumoto et al. In the study by Shirakawa et al., hydrotalcite is produced by adding alkali and Al to the removed KCl bittern, and then hydrocalumite is produced. In the research of Matsumoto et al., alkali is added to the removed KCl bittern and CO_2 is supplied by fine bubbles to produce dolomite, which is then doped with rare earths such as Tb to synthesize phosphor materials. The Ca and Mg emissions determined from the amount of removed KCl bittern (300,000 t/y)[1,2] discharged after NaCl and KCl recovery from seawater are 28,000 and 87,000 t/y, respectively. Assuming that the annual growth rate of the phosphor market is 2.8%[3,4], the estimated demand for phosphor in 2025 will require 76,000 t/y of dolomite, the base material for phosphor. Therefore, 76,000 t/y of dolomite can be produced from 58 % of the removed KCl bittern, 42% (12,000 t/y for Ca and 36,500 t/y for Mg) can be used for hydrotalcite and hydrocalumite production to increase the efficiency of the process. The bittern without K, Mg, and Ca is used as a raw material for Br_2 production. The liberation of Br_2 is produced by supplying Cl_2 to removed K, Mg, and Ca bittern. By Wada's studies, hypobromous acid is produced by supplying O_3 to it with fine bubbles.

The alkali required in these processes is obtained from NaCl solution by electrolysis to NaOH. The Cl_2 obtained at the same time is used for the production of hypobromous acid. The CO_2 required for dolomite production is obtained from the exhaust gas of the boiler used in the evaporation process.

By incorporating the results obtained in this study into the current salt manufacturing process, new environment-conscious and energy-saving chemical process for manufacturing new products from unused resources is proposed.

References

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