Effective Removal of Strontium from Seawater by Coprecipitation with Barite ($BaSO_4$)

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Strontium-90 (^{90}Sr: half-life 28 years) is a fission product of uranium, which has been released to the environment from nuclear plant accidents, such as those that occurred in Chernobyl and Fukushima. The Fukushima Daiichi Nuclear Power Plant accident (2011) has led to serious ^{90}Sr contamination in seawater, but there has been a lack of effective removal techniques for removing Sr from seawater because of the strong inhibition of Sr uptake by the high concentration of sodium and other competitive ions in seawater. In the present study, we examined the removal efficiency of Sr by using barite ($BaSO_4$) under various experimental conditions to develop techniques for the direct removal of Sr from seawater [1]. Barite is a commonly found in nature and it can be used to remove toxic and/or radioactive elements from aqueous solutions. However, it has not been widely used in environmental studies despite its useful properties [2],[3]. In this work, barite was precipitated from a mixture of (i) Na_2SO_4 aqueous solution and (ii) $BaCl_2$ aqueous solution. The effects of pH, ionic strength, coexistent Ca^{2+} and Mg^{2+} ions, and $[Ba^{2+}]/[SO_4^{2-}]$ ratio in the initial solution were investigated for determining the optimum condition. Figure 1 shows the removal efficiency of Sr by coprecipitation with barite according to the experimental parameters. It is found that Sr uptake by barite depends on the pH and $[Ba^{2+}]/[SO_4^{2-}]$ ratio of the initial aqueous solution, but it seems relatively independent of ionic strength, $[Ca^{2+}]$ and $[Mg^{2+}]$ in the initial solution. The most effective parameter on the removal efficiency was the $[Ba^{2+}]/[SO_4^{2-}]$ ratio in the initial aqueous solution because Sr was able to be removed completely from the aqueous solution under the condition that the $[Ba^{2+}]/[SO_4^{2-}]$ ratio was low. In addition, the negligible effects of ionic strength and competitive $[Ca^{2+}]$ and $[Mg^{2+}]$ ions in the initial solution were observed, suggesting the effectiveness of its application to removal of Sr from seawater. From this observation, it is expected to provide a good estimate of its ability to effectively remove Sr from the aqueous solution by using the optimized experimental design (Figure 2). It would be possible to remove Sr from the real seawater by 93 % within 70 hours regardless of small solid concentration (0.15 g/L).

Based on the results, it is found that Sr is efficiently and selectively incorporated into barite compared to other cations and minerals. This high efficiency may be due to the dependence of ionic radii on the partition behavior of trace elements. Previous studies have shown that the trace elements having similar radii to the host ion are strongly incorporated into the crystal structure. The distribution coefficient (K_d) values of Mg^{2+}, Ca^{2+}, Sr^{2+}, Rb^{+}, and Cs^{+} are 2.8×10^{0}, 7.9×10^{2}, 5.8×10^{6}, 2.6×10^{1}, 2.6×10^{0} L/kg, respectively, showing the dependence as suggested above between K_d and ionic radius. These findings revealed that Sr can be incorporated into barite significantly more than other ions because of its similar ionic size of Sr^{2+} (1.21 Å) to Ba^{2+} (1.44 Å). Thus, barite is considered to be an effective material and to show a better performance in seawater.

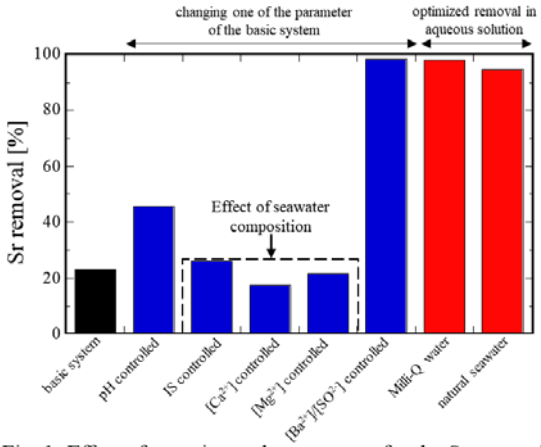

Fig. 1. Effect of experimental parameters for the Sr removal

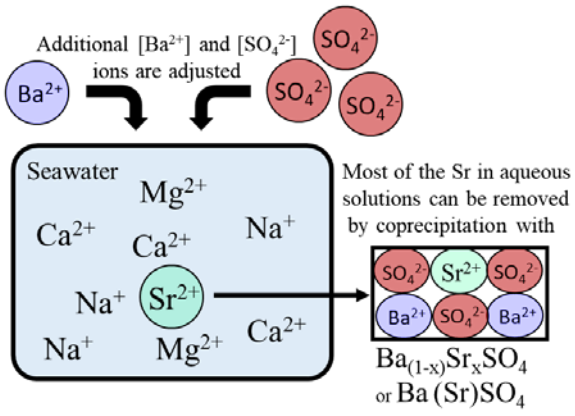

Fig. 2. Experimental design for removing Sr from seawater

References

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