Optimization of cation exchange capability of hydrothermal synthesis smectite by Taguchi method

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Bentonite has a wide range of industrial applications due to its ability of excellent cation exchange. Since bentonite’s cation exchange capacity will affect its application value, the synthesis of bentonite with higher cation exchange capacity has its value on theoretical research and practical application. In this study, the cation exchange capacity of hydrothermally synthesized bentonite were extensively investigated by the experiment with the effects of eight factors simultaneously. The eight factors included: mineralizer species, Zn source species, Al source species, reaction time, mineralizer quantity, Al_3^+ substitution in octahedron site, ratio of Zn/Mg divalent cations in octahedron site, and Al/Si substitution in tetrahedron site. The Taguchi method was introduced to deal with the condition that many factors were considered at the same time, in order to synthesize a bentonite with optimized cation exchange capacity. Bentonite were then hydrothermal synthesized based on the factors planed with L18 orthogonal table and the ideal equation of $Na_{Z+3X}(Al_{2(1-X)}(Mg_{3X*(1-Y)},Zn_{3X*Y}))(Si_{4-Z}Al_Z)O_{10}(OH,F)_2$. The experimental results show that the cation exchange capacity of all 72 products ranged from 56.96 to 125.12 $cmol_c/kg$ with an average of 82.60 $cmol_c/kg$ and a standard deviation of 15.65. In terms of products of the each 18 groups, the average cation exchange capacity ranged from 64.77 to 106.27 $cmol_c/kg$ with a standard deviation of 2.38 to 24.52. The average of the best group was 106.27 $cmol_c/kg$ with the standard deviation of 14.72, showing large deviation of experimental results. Through the variation analysis of Taguchi method, the most important three factors affecting the cation exchange capacity of the bentonite in this study are: Al_3^+ substitution amount in the tetrahedron site, Al source chemical species, and reaction time. As the result of the study, within the initial design factor levels, the optimal combination of factors is as follows: mineralizer: NaF, Zn source: $Zn(CH_3COO)_2{\cdot}2H_2O$, Al source: $Al(OH)(CH_3COO)_2$, reaction time: 48h, the amount of mineralizer: 1.43 mmol, octahedral replacement of Al: X=6/7, the proportion of different types of divalent cations in the octahedron: Y=0.25, and Al substitution in tetrahedronsite Z=0.3. The average cation exchange capacities of the bentonite synthesized with the optimum parameters increased to 122.65 $cmol_c/kg$, 1.48 times the original average, and the standard deviation reduced to 7.228.

Keywords: smectite, hydrothermal synthesis, cation exchange capability, Taguchi method

