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Removal of boron from aqueous solutions using MgAl composition

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Abstract: *Although boron is an element of requirement for the growth of plants, animals and humans, environmental issues and health hazards are related to boron applications in various industries. Recently many techniques have been developed to remove boron from aqueous solutions; adsorption proved to be capable to treat solutions with low boron concentrations. Mg-Al bimetallic compound was synthesized and calcined. Then, was tested in a process to remove boron from aqueous solutions. Difference between calcined and non-calcined Mg-Al bimetallic compounds in removing boron from aqueous solutions were measured to determine whether the calcination process is of significant benefit. Experiments were conducted with variety of pH levels, temperatures dosage volume as well as initial boron concentration; thus finding the most suitable factors in the removing of boron in aqueous solutions using Mg-Al bimetallic compound.*

Keywords: Boron; Mg-Al bimetallic oxide; Hydrotalcite; Adsorption.

1. INTRODUCTION

Boron is necessary for plants only controlled amounts depending on the different types of plants otherwise there might be severe side effects such as retardation of growth; which was observed in arid and semi-arid areas in South Australia, Turkey, North America and Chile [1]. Humans' nerve system is also affected by consumption of large amounts of boron. Regulations have recently been set by the World Health Organization (W.H.O.) to determine the maximum concentration limits for boron in drinking water to be less than 1 mg/L [2]. Many methods were tested for the removal of boron and one of the common practices is adsorption process using hydrotalcite or hydrotalcite-like materials; in this paper Mg-Al bimetallic oxide compound adsorption properties will be investigated with boron (boric acid). Furthermore, a study about will calcination of the Mg-Al bimetallic oxide compound have any impact on the adsorption capability or not.

2. MATERIALS AND METHODS:

2.1 Preparation of Mg-Al bimetallic:

The hydrotalcite-like material was synthesized for Mg-Al bimetallic Oxide. The materials used for the synthesis are $Mg(NO_3)_2{\cdot}6H_2O$, $Al(NO_3)_3{\cdot}9H_2O$, NaOH [3][4]. Synthesis was carried out in the duration of three days; 700 mL aqueous solution containing 0.1 mmol (25.6406 g) of $Mg(NO_3)_2{\cdot}6H_2O$ and 0.05 mmol (18.7565 g) of $Al(NO_3)_3{\cdot}9H_2O$. Then, it was added drop wise to 1500 mL of 2 M NaOH solution stirred vigorously with a mechanical mixer at 400 rpm. The temperature was kept at 45-$^{+}$3 ℃ during the process. Slurry obtained was then heated for 2 hours (T=85-$^{+}$ 3 ℃) under slow mixing 200 rpm. The solution was kept in room temperature for 12 h. Next day; The solid product was separated by centrifugation and washed with deionized water several times until pH reached 8-9 and conductivity was constant. The solids were drying at 60℃ for 48. Part of the product was calcined at 550℃ for 4 h. The solids were dry enough to be crushed into powder-like form and measured. Then it was kept in a concealed container labeled into calcined and dried Mg-Al bimetallic oxide compound.

2.2 Batch tests:

Boron stock was prepared using H_3BO_3, 500mg/L. For every experiment 100 mL of solutions were used with boron concentration of 5 mg/L, pH 9 and Mg-Al bimetallic oxide dosage of 0.2 g; to find the optimum conditions for boron removal using the synthesized bimetallic oxide. First test was done between the calcined and dried Mg-Al bimetallic oxides, the separation of samples was initially conducted with two methods; centrifugation and syringe filters 2 µm to determine the clearest filtration; though no significant difference between the separation techniques were noted thus syringe 2 µm separation was employed hereafter. The time to take samples if the batch tests was conducted into two groups the first group of time intervals were focused on the changes happening in the first the three hours (10min, 30 min, 60 min, 2 hours, 3 hours and 24 hours) and the second group was conducted to find when will the equilibrium adsorption is reached (10 min, 3 hours, 6 hours, 12 hours, 18 hours, 24 hours, and 48 hours).

2.3 pH levels test:

First experiment was conducted to study the effects of different pH levels in the removal of boron with 5 mg/L concentration (pH levels 3, 6, 9, 12). Second experiment was conducted to study the effects of different pH levels in the removal of boron with 10 mg/L concentration (pH levels 3, 6, 9, 12). Both were prepared the same way but with only difference of boron concentration; where the first one was carried out with boron concentration of 5 mg/L and the second experiment with 10 mg/L. since 0.2 g of calcined MgAl compound were added to the flasks with boron solution. Stirring with 25 ℃ for 48 hours. Samples were taken in (10min, 3hrs, 6hrs, 12hrs, 18hrs, 24hrs and 48hrs).

2.4 Analysis of drawn samples:

Spectrophotometer was used for sample measurement; BoroVer 3 Boron Reagent Powder Pillow, Sulfuric Acid, concentrated, ACS and Deionized water were used.

3. RESULTS AND DISCUSSION:

3.1 Batch tests:

A vast gap between the results of adding calcined and dried Mg-Al bimetallic oxides was very clear as shown in fig.1 where in the first three hours both dosages were at a boron concentration around 3.5 mg/L and 4mg/L; where the calcined samples a tad lower than that of the dried samples, but when both batches reached equilibrium the calcined samples dropped to 1.4 mg/L whereas the dried sample maintained a 4.2 mg/L. thus, eliminating the use of the dried Mg-Al bimetallic oxide.

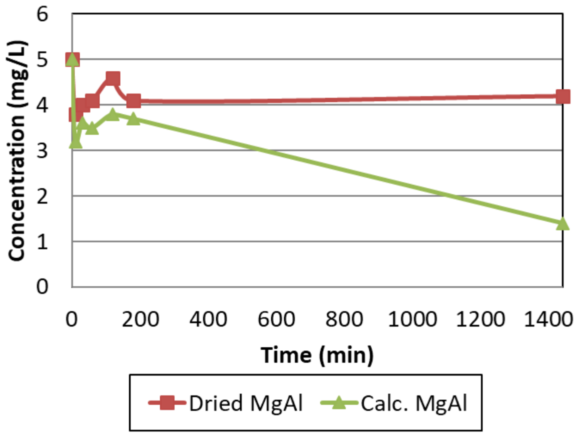

Fig. 1. Adsorption of boron using Mg-Al (dry-calcined).

From fig.1 we can also note that the times for sample taking were focused on the first three hours. Fig.2 shows the when the equilibrium is reached; that happened between the 3 and 6 hours' gap.

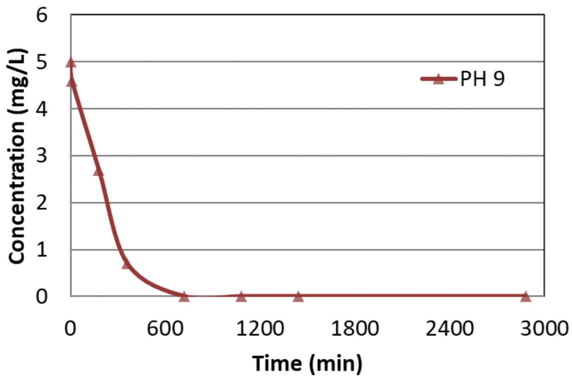

Fig. 2. Equilibrium time.

3.2 pH levels test:

First experiment in fig. 3 showed that with pH levels (3, 6, 9) complete removal of boron was reached; pH 3 was unstable whereas pH 6-9 have reached equilibrium in 3 to 6-hour time. pH 12 however, showed fluctuation and couldn't reach the removal capacity as the other pH values.

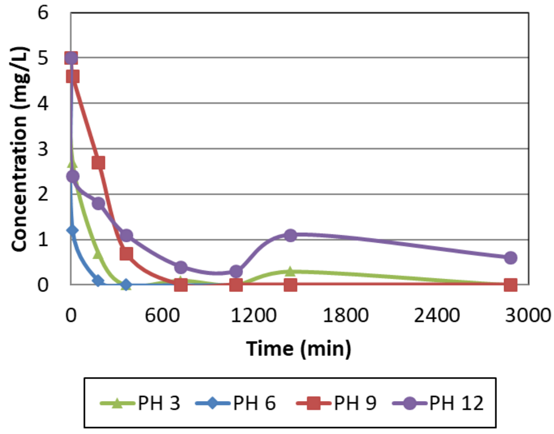

fig. 3. Effects of different pH values on B con. 5 mg/L.

Second experiment fig. 4 showed lower pH values (3-6) had slight fluctuation in the removal of boron, on the other hand pH 9-12 showed stable values and both reached equilibrium at 12-hour time.

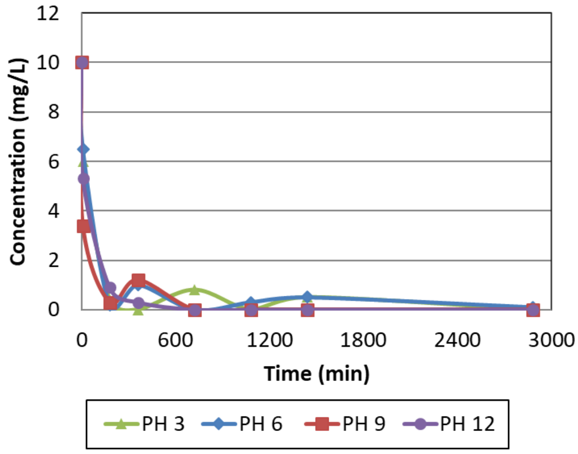

fig. 4. Effects of different pH values on B con. 10 mg/L.

4. CONCLUSION:

Calcined Mg-Al bimetallic oxide showed promising results in removing boron contamination from aqueous solutions although with different pH values in a boron concentration of (5-10) mg/L no significant differences were shown yet; perhaps with increased boron concentrations might there be an optimum pH value.

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