Coal Ash Concrete Blocks for Reduction of Algal Growth and Ammonia Toxicity

Sangchul Hwang, Perla Torres, and Carlos Colon

Department of Civil Engineering, University of Puerto Rico, Mayaguez, PR 00681

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INTRODUCTION

Algal blooms have been a major problem in water systems due to the nuisance, toxicity and water quality deterioration. Cyanobacteria, also known as blue-green algae, are present in pond mostly during the summer period. These organisms may impair the environment in various ways such as deoxygenation by decomposing in the water becoming potentially toxic to fish. Fertilizers are added to fish ponds to increase the production of fish and could accelerate the development of cyanobacteria. Reduction of cyanobacteria present in a pond was achieved by increasing the nitrogen to phosphorus ratio to 5 or more [1].

High concentration of nitrogen in water systems could become dangerous if it is dominated by ammonia (NH_3) and nitrite (NO_2) species due to their toxicity [2,3]. Nitrification of NH_3 to NO_2 and then to nitrate (NO_3) is favored by the presence of sufficient alkalinity to neutralize the hydrogen ions produced during the process. Cell attachment to surfaces appeared to favor the growth of nitrifiers as well.

Manufactured aggregates, which are a solidified composite of fly ash (FA) and bottom ash (BA), decreased the concentration of aqueous phosphorus [4]. This would increase of the ratio of nitrogen to phosphorus. Coal ash concrete (CAC) can be utilized as the source of alkalinity and surface area, resulting in favor of nitrification. In these regards, the current study was conducted to test potential of CAC blocks to reduce algal bloom and ammonia toxicity, leading to enhancement of freshwater quality.

MATERIALS AND METHODS

Fish

Cichlids (5~7 cm) were collected from a pond on campus. Food provided to the fish was from Wardley® Pond Food Flakes. Pond water was sampled and used for some experiments to introduce algae into the system.

Coal Ash Concrete (CAC)

FA and BA were collected from a local coal-burning power plant (AES Puerto Rico) located in Guayama, Puerto Rico. Figure 1 shows their chemical composition. The plant combusts coals in a circulating fluidized bed. Selective non-catalytic reaction, circulating dry scrubber with limestone, and electrostatic precipitator are used for reductions of nitrogen oxides, sulfur dioxide, and particulate matter, respectively, in flue gas emission.

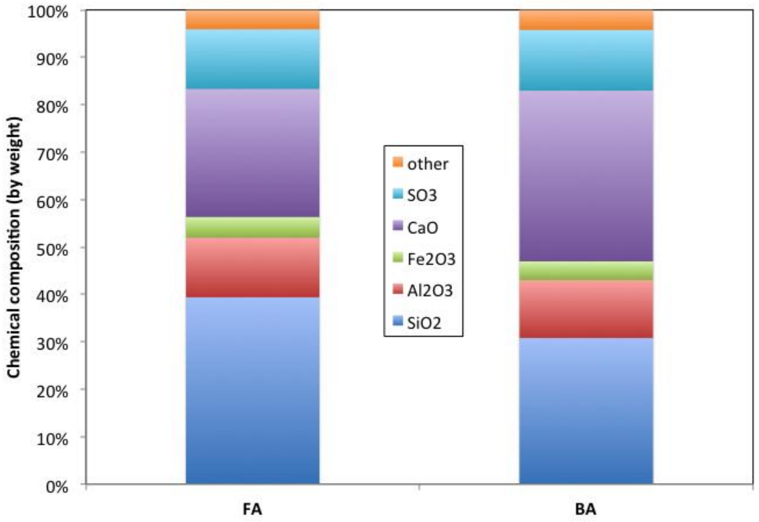

Figure 1. Chemical composition of FA and BA.

CAC blocks were prepared by mixing a same mass of a Portland cement (Ponce cement), FA and BA, unless otherwise stated. Using identical ice trays as the mold, CAC blocks of approximately 2.54 cm x 3.81 cm x 3.18 cm were prepared. A consolidation period of 24 hours was provided in the mold. Then, the dried structures were taken out of the mold and allowed additional 7 days of dry-curing in the air prior to use for the experiment.

Experimental Approach

The aquatic environment was simulated in 10-gallon fish tanks. The components of each tank included two artificial decorative plants, 5.0 gram of decorative stones, and a circulating filter for aeration and filtration. Light was provided to each tank with aquarium lights (Plants & Aquarium 20W, Phillips) that were mounted at 7.5 cm above the tanks. Artificial light was provided for a period of 12 hours per day. Acrylic covers were put on the top of the tanks to minimize water evaporation from the tanks. Figure 2 shows the basic setup used for the experiments. Tanks were filled with 30 L of tap water and aerated for 24 hours before fish were added.

Figure 2. An example of tank setup for the experiments.

The effect of the CAC blocks on water quality was tested, focusing on turbidity and apparent color, which would, in part, be caused by algal growth. One blank tank without the CAC blocks and two treatment tanks, one with 7 CAC blocks and the other with 28 blocks were prepared. All tanks received an equal amount of food (1.0 g per day) during the experiment. Water quality from each tank was tested for pH, turbidity, alkalinity, apparent color and other general parameters such as pH and DO.

For NH_3 nitrification tests, two experiments were developed: one was done with the CAC blocks in the presence of nitrifying bacteria but in the absence of fish and the other with the CAC blocks in the presence of 10 fish but no external addition of nitrifiers. For the first case, two tanks were set up: one was the blank without the CAC blocks and the other was the treatment with the blocks. For each tank, glucose ($C_6H_{12}O_6$) was added to attain an initial concentration of 100 mg/L, NH_3 was added to obtain an initial concentration of 1 mg/L, 3 mL of mixed liquor collected from a nitrification tank in the local wastewater treatment plant were added, and 1mL of each of four different nutrients ($CaCl_2$, $FeCl_2$, $MgSO_47H_2O$ and a solution containing KH_2PO_4, K_2HPO_4, NH_4Cl) were added. Each week $C_6H_{12}O_6$, NH_3 and nutrients were added to the systems. For the second test, two tanks were prepared with fish and CAC blocks: one received the mixed liquor aforementioned, and the other did not. Ten fishes and 28 blocks were added to each tank. However, neither $C_6H_{12}O_6$ nor nutrient was added to the systems. Instead, 1.0 gram of fish food was provided once a week. The concentrations of NO_3 and NH_3 were analyzed.

Analysis

Several variables were monitored to evaluate water quality in the tanks during the experiments as shown in Table 1.

Table 1. Analytical methods.

Parameters	**Methods**
pH	pH meter (Orion Model 720A)
Temperature	Portable meter (Extech Instruments)
Alkalinity	Standard Method (2320B Titration Method)
Conductivity	Portable meter (Oakton CON 6)
DO	Portable meter (Extech Instruments)
Turbidity	Portable meter (HACH 2100P Turbidimeter)
Apparent Color	HACH DR Spectrophotometer Method 8025
Hardness	HACH DR Spectrophotometer Method 8030
Total Phosphorus	HACH DR Spectrophotometer Method 8190
Total Nitrogen	HACH DR Spectrophotometer Method 10071
Ammonia	HACH DR Spectrophotometer Method 10023
Suspended Solid	Standard Method (2540D)
BOD	Standard Method (5210B)
Biomass on CAC	Guilbeau et al. (2003)
Nitrate	HACH DR Spectrophotometer Method 8039

RESULTS AND DISCUSSION

Turbidity and Apparent Color

The trend of turbidity was similar to that of apparent color. Effect of the CAC blocks on two parameters was noticeable. Both parameters in the systems with the CACs were found greater than the blank system in early stage of the experiment (<18 days), but they were much lower in the later part of the experiment.

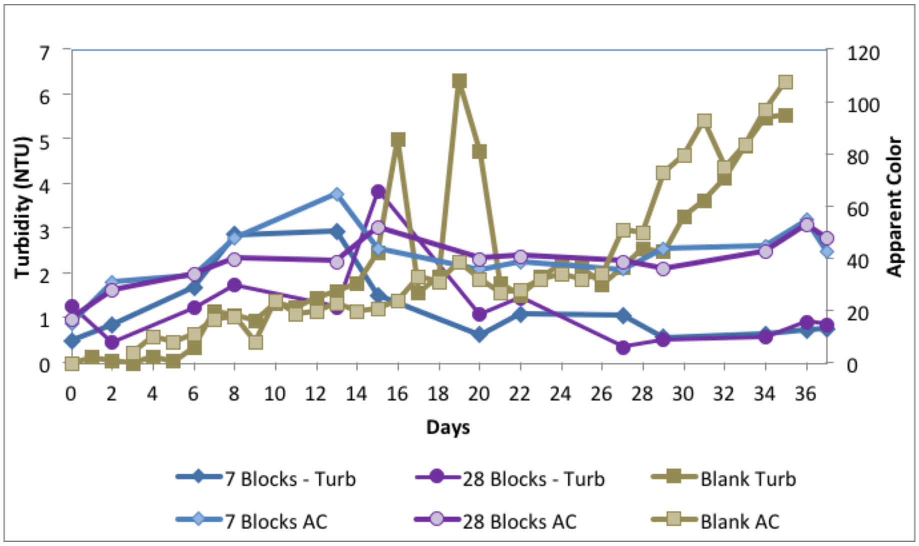

Figure 3. Effect of CAC blocks on turbidity and apparent color.

Suspended solids in water body and biomass grown on the surface of CAC blocks were measured (Table 2). The more had the system the CAC blocks, the lower SS concentration but the greater attached biomass on the surface of the CAC blocks.

Table 2. Suspended solids and attached biomass.

	System 1 (7 CAC blocks)	System 1 (28 CAC blocks)
Suspended solids (mg/L)	4.3	2.3
Attached biomass (mg/cm^2)	30	100

pH and Alkalinity

The values of pH started to decrease after 16 days in the blank system that was run without the CAC blocks (Figure 4). This corresponded to the increase of turbidity and apparent color (Figure 3), which might imply the growth of algae. On the contrary, the system with the CACs maintained pH values in the range of 7.5-8.0, with more CACs having higher pHs.

Alkalinity varied in a waving trend and the numbers of CAC blocs did not make differences until 26th day. However, greater alkalinity was developed in the system with more CAC blocks. The blank system had a negligible alkalinity. Nitrification would not be supported in the blank system due to the lack of alkalinity.

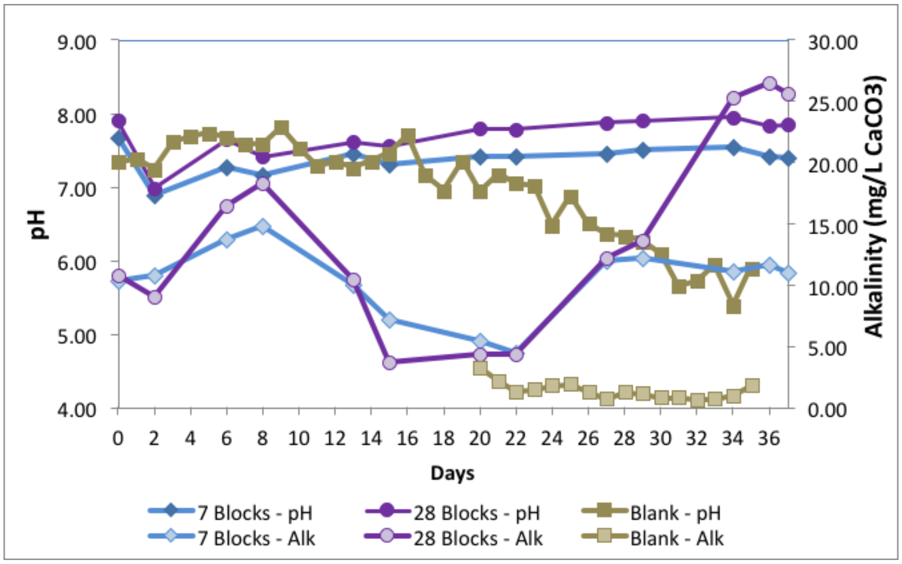

Figure 4. Effect of CAC block on pH and alkalinity.

Nitrification and Ammonia Reduction

Despite nitrifier inoculation, the blank system without the CAC blocks did not have noticeable NO_3 concentrations. But, there were substantial concentrations of NH_3

present in the blank system. This would be attributed to the lack of alkalinity in the system.

In the presence of the CAC blocks, a sharp decrease in NH_3 concentration was noticed while rapid increase in NO_3 concentration was measure at the same time (Figure 5). In general, lower and higher concentrations of NH_4 and NO_3, respectively, were observed in the system with the CAC blocks than in the blank system without the CAC blocks.

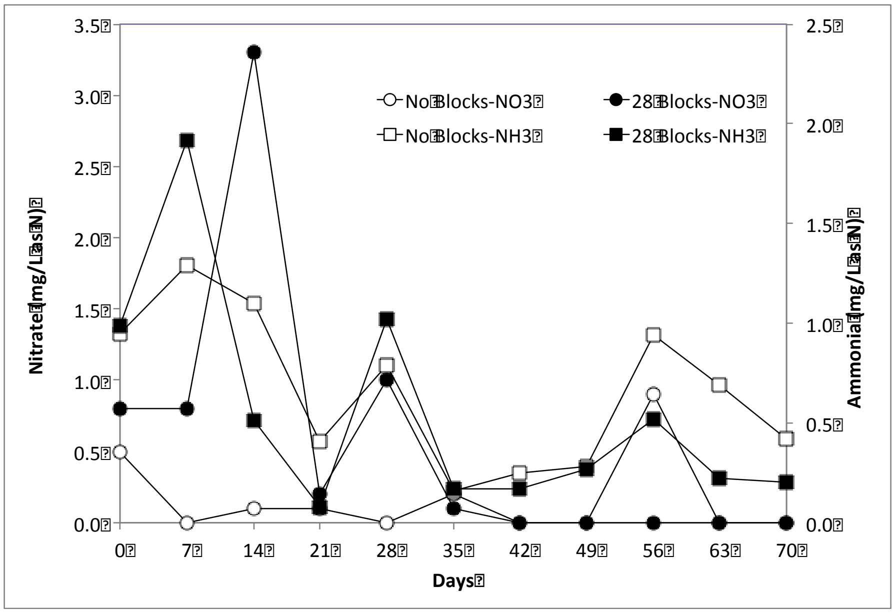

Figure 5. Nitrification influenced by CAC blocks.

In the presence of the CAC blocks that would provide alkalinity compensation during the nitrification process, nitrifier inoculation seemed to facilitate nitrification of NH_3 to NO_3 (Figure 6). And also, both systems showed very low concentrations of NH_3 after 24 days of the experiment, due probably to the continuing conversion of NH_4 to NO_3.

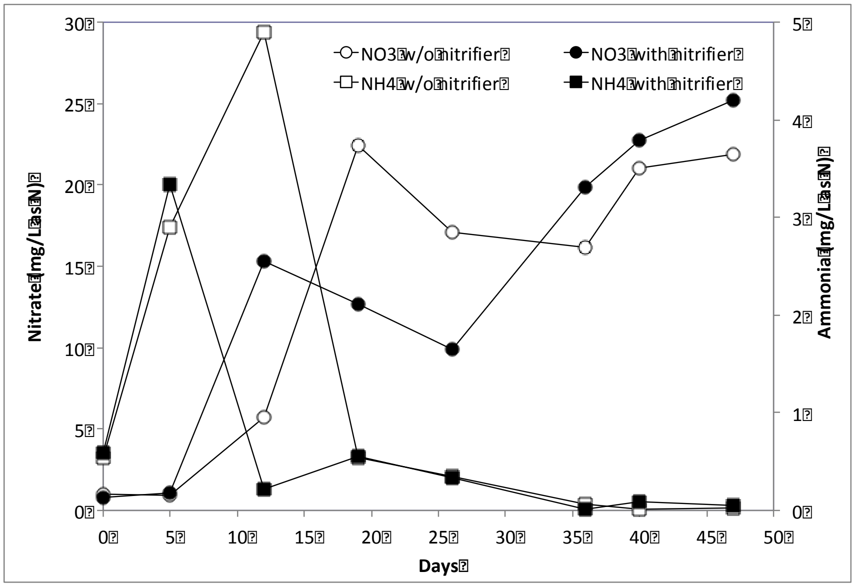

Figure 6. Effect of nitrifier inoculation on nitrification in the presence of CACs

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