1st Quarterly Report

Open Pit Quarry Restoration to Bio-Viable Land

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Introduction

As the magnitude of civil, transportation and construction infrastructure has expanded since the industrial revolution, demands for construction-grade sand and gravel has subsequently increased. These aggregates are heavily being exploited in PR today and used for concrete, general fill, and road subgrade material, bridges, airports, road surfacing, and aqueduct and sewer systems. This, in turn, affects health and safety of human beings if not appropriately managed.

The objective of this study was to investigate the feasibility of coal combustion ash aggregates (CAA)-based refill in the open pits in Santa Isabel. The site is planned to be used as an agricultural land after restoration. Therefore, another objective was to assess the potential risks in relation to contamination of soil and groundwater associated with the use of industrial byproducts CAAs. To meet this end, laboratory feasibility tests and computational modeling were proposed to perform for the period of 2 years.

Materials and Method

Materials

The open pit site was filled with dredged sandy sediments on the bottom at a depth of 0.3 m. As the site will be eventually used as an agricultural area, an organic-rich soil from Coamo Lake will used as a top soil at a depth of 1 m. In these regards, two soils were sampled on site. After being transported, the soil samples passed a sieve size 3/8” were collected for the experiment.

Figure 1. Soil Sampling.

Coal ash aggregates were obtained from a local coal burning power plant. It is a solidified mixture of fly and bottom ashes with water. Main chemical components, by weight are: 51% of (SiO_2 + Al_2O_3 + Fe_2O_3), 30% Lime (CaO), and 15% SO_3. CAAs were first oven dried at 105°C, crushed with a mechanical mixer, and sieved to collect the CAA sizes of 2.36 ~ 9.53 mm.

Method

As shown in Figure 2, initial focus was given to the volume of CAAs that can be utilized as a substitute subsoil material. The column reactors were designed, performed, and analyzed by a statistical design with three factors containing two levels each for the assessment of the unsaturated-zone fate and transport phenomena (Table 1).

The volumetric ratio of the CAAs to the organic top soil is a treatment factor with two levels of 8:4 and 4:8. Simulated precipitation was made three times a week by spraying tap water on the top of the reactors. Precipitation rates are another treatment factor with two different levels: high rainfall 60 mL each application, low rainfall 30 mL each application. Half of the reactors were assigned to the smaller particle sizes (2.36 ~ 4.75 mm) of CAAs and the remainder to the greater particle sizes (4.75 ~ 9.53 mm). Thus, the particle size of the CAAs is another treatment factor containing two levels.

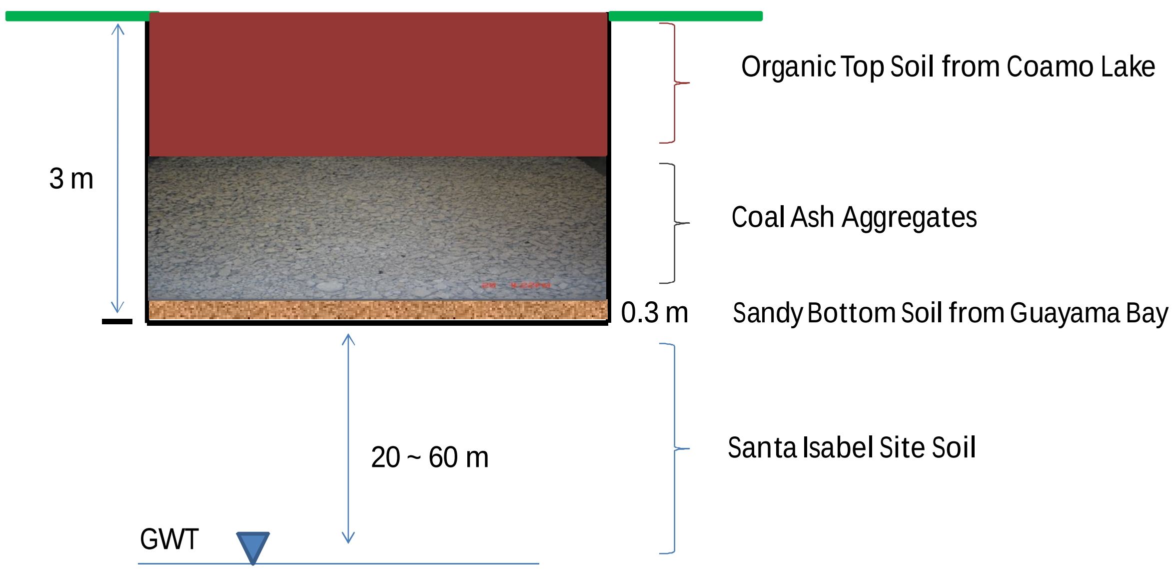

Figure 2. Schematic of backfilling.

Table 1. 3-factor, 2-level design matrix.

Reactors	Top Soil (in)	CCPs (in)	Bottom Soil (in)	Site Soil (in)	CCPs Size	Rain Intensity
R_1	8	4	4	10	A	High
R_2	8	4	4	10	A	High
R_3	8	4	4	10	A	Low
R_4	8	4	4	10	A	Low
R_5	8	4	4	10	B	High
R_6	8	4	4	10	B	High
R_7	8	4	4	10	B	Low
R_8	8	4	4	10	B	Low
R_9	4	8	4	10	A	High
R_{10}	4	8	4	10	A	High
R_{11}	4	8	4	10	A	Low
R_{12}	4	8	4	10	A	Low
R_{13}	4	8	4	10	B	High
R_{14}	4	8	4	10	B	High
R_{15}	4	8	4	10	B	Low
R_{16}	4	8	4	10	B	Low

Figure 3. Column Reactors.

Analysis

Heavy metals, lead (Pb) and cadmium (Cd), were monitored with the Leadtrak (HACH) and an ion specific electrode (Orion), respectively. The value of pH was measured with an Orion pH meter. Specific conductivity was analyzed with Orion Specific Conductivity Meter Model 162. Turbidity was measured with LaMotte 2020 Turbidimeter. Nitrate (NO_3^-) was analyzed with an ion specific electrode (Orion).

Results and Discussion

The water volume infiltrated in each reactor weekly is shown in Figure 4. Apparently, it seems the rainfall intensity influenced greatly on the infiltrated water volume.

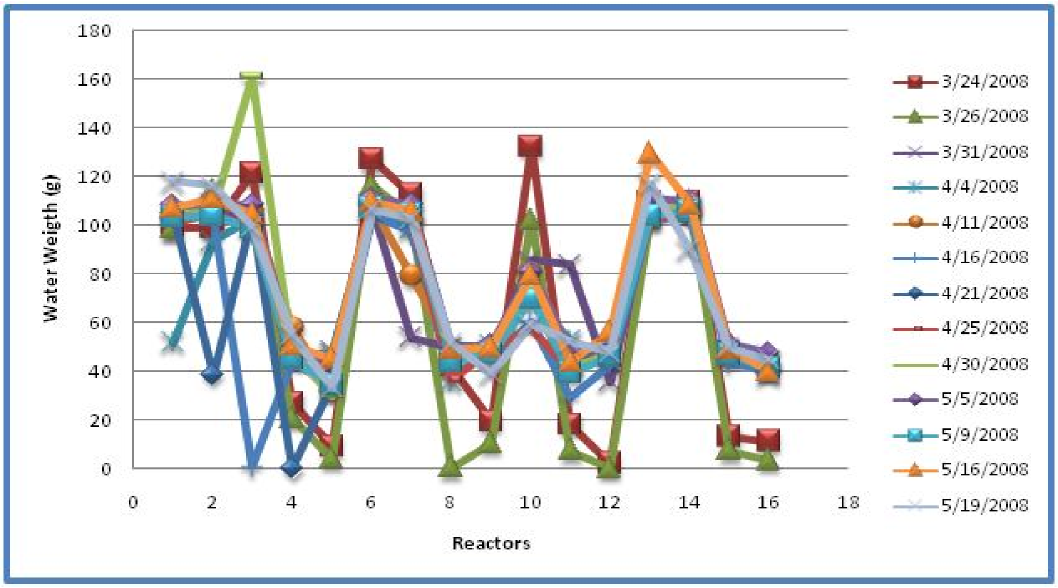

Figure 4. Volume of water infiltrated weekly in each reactor.

Except for the pH value for the first samples (i.e., 3/17/2008), the infiltrated water from each reactor had a slightly basic pH (~8.5) throughout the experiment, as shown in Figure 5.

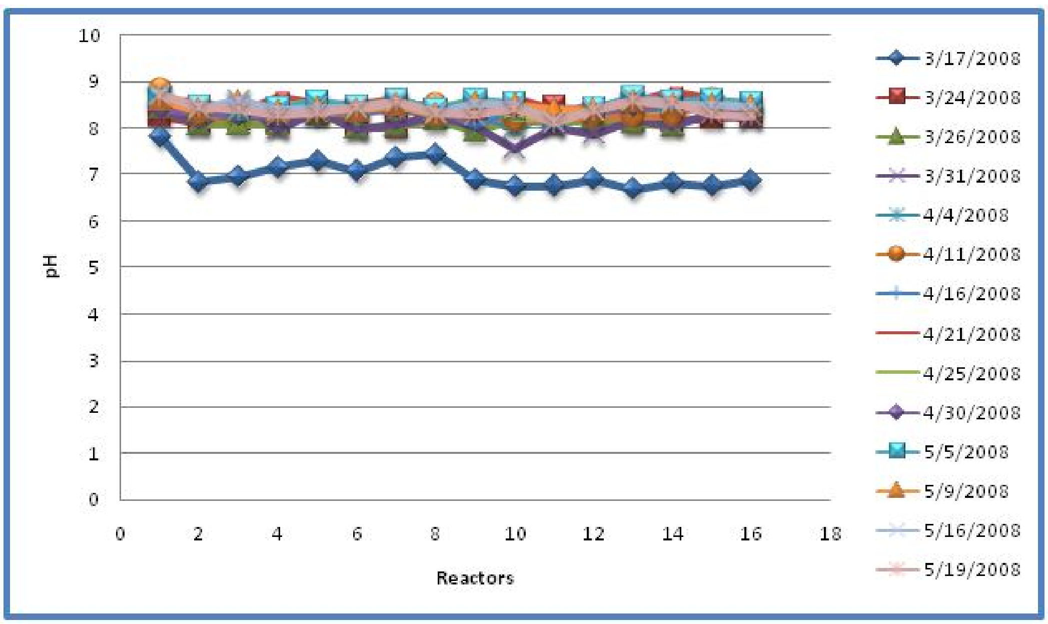

Figure 5. Value of pH in the water infiltrated weekly in each reactor.

Turbidity was close to 1 NTU, except for a couple of outliers, in the beginning of the experiment. However, it reduced to a value of less than 0.5 NTU as shown in Figure 6.

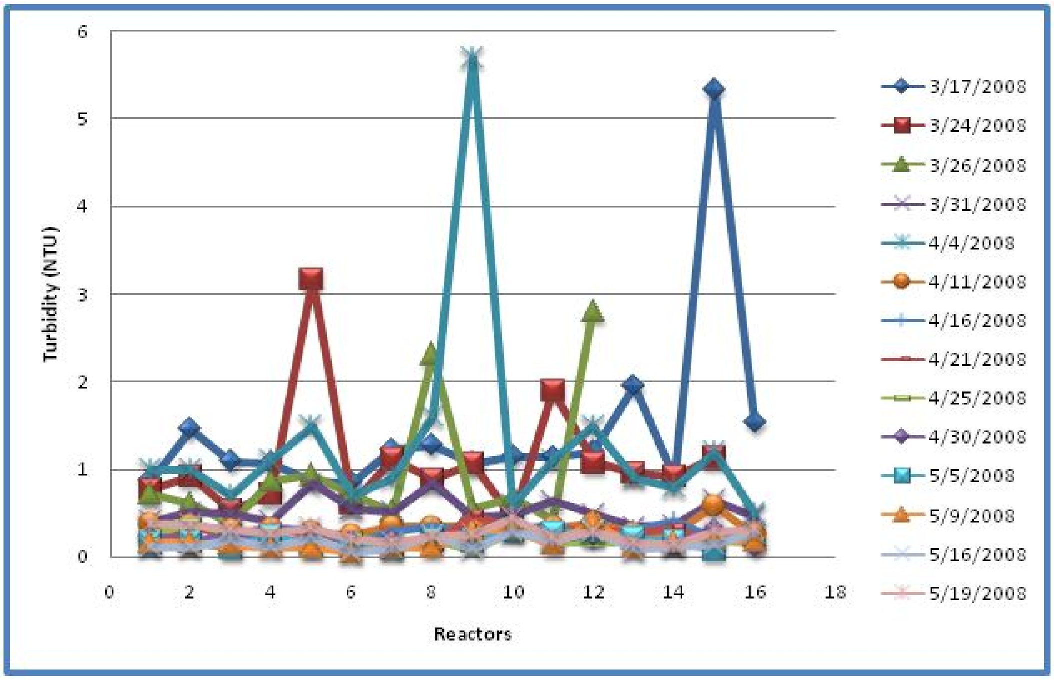

Figure 6. Turbidity in the water infiltrated weekly from each reactor.

On-going and Future Studies

Data logging is underway on the parameters of nitrate and specific conductivity. Sample analysis is still being performed on heavy metals (Pb and Cd) concentrations. A statistical data analysis is currently on-going using the Minitab software to assess which factors have the largest effects on the response, and whether there are interactions between factors. Based on the findings from the current statistical analysis, the factors of interest will further be examined in the future experiment.

Deliverables

Preliminary results obtained from the current research were presented at the XII Sigma Xi conference as follows:

Latorre, I., Hernandez, I., Fonseca, A., Hwang, S. "Restoration of Open-Pit Quarry to Bio-viable Land: Resource Recovery Approach", XIII Sigma Xi, University of Puerto Rico, Mayagüez, PR, April 10, 2008.