Experimental Investigation on the Effects of Granulated Coal Ash (GCA) on the Water and Sediment Quality of Estero de San Miguel

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Introduction

In the Philippines, eutrophication is considered as one of the most serious environmental problems in enclosed water bodies. Due to rapid increases in economy and population in Metro Manila, the quantity of pollutants discharged into the rivers has also increased, causing the water bodies to become turbid and odorous. Excessive nutrient loads as well as nutrient dissolution from eutrophic sediments would mean abrupt growth of algae, thus, inducing the hypoxic water due to the decomposition of the dead cells in stratified seasons (Asaoka et al. 2014).

In 2004, Pasig River was declared biologically dead, with average dissolved oxygen levels plummeting to zero most parts of the year (World Bank, 2004). Since then, the Pasig River Rehabilitation Commission (PRRC) has been implementing various technologies to improve the water quality of the Pasig River and its major and minor tributaries. While recent technologies can improve the water quality in estuaries such as mitigation of external pollution sources and advances treatment of wastewater, sediments can continuously release pollutants to the overlying water, thus delaying the recovery of eutrophic environments. In Japan, experimental and pilot studies have proven the use of Granulated Coal Ash (GCA) to effectively remediate sea bottom sediments through the neutralization of acidified sediments due to hydrolysis of CaO, and adsorption of nutrients and hydrogen sulfide resulting to decrease of oxygen consumption. (Yamamoto 2013)

However, the efficiency of the GCA in improving water and sediment quality in estuaries in the Philippines has not yet been investigated. The present study will be helpful in proposing and designing strategy for the remediation of organically-enriched sediments in the Philippines using GCA.

Materials and Methods

The sediment and water samples used in the study were obtained from Estero de San Miguel in Metro Manila, Philippines. The coarse-grained GCA used in this study is a commercially-sold product named 'Hi-beads' from Energia Eco Materia Co. Inc. in Japan. The GCA used in the present study is mainly composed of SiO_2, CO_3, Al_2O_3, CaO, C and Fe_2O_3 (Asaoka et al., 2009). Batch studies were performed by mixing actual water and sediment from the estero with varying dosages of GCA as shown in Table 1. The physico-chemical parameters (pH,

Oxygen Reduction Potential (ORP), Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Electric Conductivity (EC), Turbidity, Color and Odor) and nutrient concentrations (PO_4, NH_3, NO_3, NO_2, SO_4) in the overlying and pore water were analysed. The pH, ORP, Ignition Loss (IL), Particle Size Distribution of the sediment were also measured at the start and end of the experiment. The GCA used in the experiment was subjected to SEM analysis after 60 days. The average values and standard deviations of three replicate samples were calculated

Results & Conclusion

Initially, the physical properties of GCA were responsible in the accumulation of small particles from the overlying water onto its mircopores. The rapid accumulation resulted to less turbid and clearer water in the initial stage of the experiment. The results of the SEM analysis of GCA after the experiment confirmed the physical adsorption of organic matter at the surface of the GCA as shown in Figure 1.

The results also demonstrated that the improvement in overlying and pore water is mostly evident in decreased concentrations of nutrients after 60 days. Case 3 recorded 46% phosphate removal and 94% ammonia removal concentrations compared to control case in pore water. While in overlying water, Case 3 also recorded 77% phosphate removal and 97% ammonia removal. Moreover, the pH of the sediment with the highest GCA dosage was relatively higher compared to the controlled case which is mainly due to the hydrolysis of calcium oxide (CaO) from the GCA.

Accordingly, the GCA is suitable for adsorbing phosphate under reduced conditions. The phosphate precipitates as calcium phosphate over time due to the high calcium oxides in the GCA (Asaoka et al. 2009). Based on the previous studies, due to high pH in the GCA layer, the sulfate-reducing bacteria which are responsible for the formation of hydrogen sulfide can be suppressed thus resulting to less pungent odor (Kong et. al. 2011).

Due to enhanced decomposition of organic matter, the oxygen available in the pore water and overlying water may be rapidly consumed, but with the addition of GCA, the oxygen consumption was lowered as confirmed in the previous studies. In this experiment, the nitrification of ammonia to nitrite and nitrate was successfully enhanced due to various oxidants from GCA. Moreover, the dissolution of ions from the GCA can increase the electric conductivity and total dissolved solids over time. Considering the results of batch experiment, GCA has high remediation efficiency in improving water and organically enriched sediment as shown in Table 2.

References

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Tables and Figures

Table 1. Experimental Design Composition for Stage 1 and Stage 2

Treatment	Composition (Stage 1: Day 0-30)	Composition (Stage 2: Day 31-60)
Control	1L Water + 300g Sediment	1.5L New Water + 300g Sediment
Case 1	1L Water + 300g Sediment + 150g GCA	1.5L New Water + 300g Sediment + 150g GCA
Case 2	1L Water + 300g Sediment + 225g GCA	1.5L New Water + 300g Sediment + 225g GCA
Case 3	1L Water + 300g Sediment + 300g GCA	1.5L New Water + 300g Sediment + 300g GCA

Table 2. Summary of Effects of GCA to experimental parameters on overlying and porewater

Parameter	Effect of GCA
pH	Increases pH of the sediment due to hydrolyis of CaO from GCA
DO	Increases due to oxygen diffusion thru micro pores of GCA
ORP	Sediment ORP decreases due to reductive condition as OM decomposes
COD	Decreases as the sediment oxygen consumption in the porewater decreases
Turbidity	Decreases due to the micropores in the GCA surface
TSS	Decreases due to the micropores in the GCA surface
Color	May increase over time due to the colored dissolved organic matter
Odor	Decreases due to the reduction of H2S, Phosphate and Ammonia
EC	Increases due to the dissolution of ions from GCA
TDS	Increases due to the dissolution of ions from GCA and dissolved organic matter
Phosphate	Formation of Calcium Phosphate due to Adsorption
Ammonia	GCA enhances nitrification of NH3 to NO2
Nitrite	GCA enhances nitrification of NO2 to NO3
Nitrate	Denitrification of NO3 to Nitrogen Gas was not confirmed
Sulfate	GCA oxidizes of H2S to Sulfur and Sulfate
Ignition Loss	GCA enhances humification of organic matter
Particle Size	No significant changes

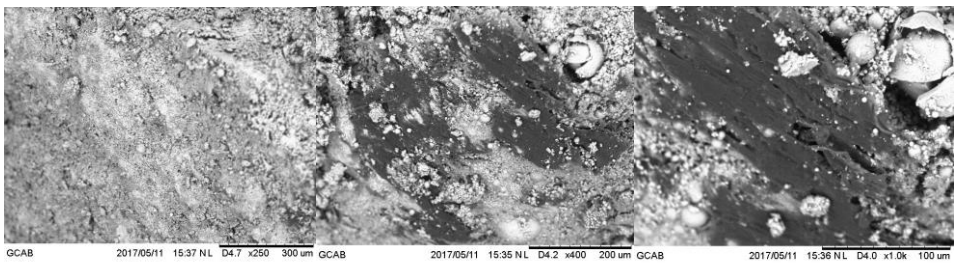

Figure 1. Images of GCA Surface through Scanning Electron Microscopy (SEM) Analysis