Biochemical Response of Landfill with Manufactured Aggregates as a Daily Cover

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KEYWORDS: manufactured aggregates, alternative daily cover, biological landfill decomposition

INTRODUCTION

In 2001, 230 million tons of municipal solid wastes (MSW) were generated in the United States, of which 56% were landfilled [1]. Soto (2004) reported that 3.6 million tons of MSW were generated in Puerto Rico (PR) in 2003, of which 75% were disposed of in landfills [2]. Most of the landfills in the northeast of PR were going to be closed within 3 to 5 years. Very recently, the EPA issued orders to close landfills in Toa Baja, Aquadilla, Santa Isabel, Florida and Vega Baja within three years. The EPA orders were due mainly to substantial concern of the drinking water quality associated with the landfill problems [3].

Landfill daily cover is applied over the compacted waste cell to (1) keep waste from blowing away, (2) restrict access to rodents, birds, and insects, (3) minimize water infiltration, and (4) provide additional overburden pressure. Six inches of inorganic soil is put on 2-ft compacted waste cell, therefore daily covers take approximately 20% of total landfill volume initially. However, it will be decreased to about 5% due to the compression under self-weight and the absorptive migration into the waste voids [4].

The use of alternative materials instead of soil for daily cover has drawn significant interests to landfill owners and operators. Alternative materials could conserve landfill space and soil resources while also meet environmental and operational requirements.

This research aimed to address: (1) applicability of MAs as alternative daily cover (ADC) materials replacing expensive soil excavation and transportation off-site which often degrade environmental quality; (2) extent and rate of biodecomposition and settlement of landfills with MAs as ADC materials; and (3) operational protocols of MA application and provision for technology transfer to any public or private sectors. To meet these objectives, laboratory-scale physical landfill models (PLMs) were constructed.

MATERIALS AND METHODS

Manufactured Aggregates

Manufactured aggregates (MA) are solidified mixture of fly (FA) and bottom ashes (BA). This material gains strength with time due to cementitious reactions and physiochemical properties of the MAs can be found in a previous study [5]. Briefly, main chemical components, by weight, are: 51% of (SiO_2 + Al_2O_3 + Fe_2O_3), 30% lime (CaO), and 15% SO_3. Bulk MAs were sampled at a local coal burning power plant in PR. Since the particle sizes are in a wide range, they were crushed and sieved in the laboratory. The MAs were first oven dried at 105^oC overnight, crushed with a mechanical mixer, and sieved to collect the MA sizes of 2.36 ~ 9.53 mm.

Sand and Gravel

Natural clean sand sampled in Isabela, PR was used as the daily cover for the control. It was determined that the sand was composed of 92.6 % sand and 7.4 % of fines (silts and clays). It had a specific gravity of 2.83, a specific surface area of 16.9 m^2/g, cation exchange capacity of 2.1 mg/100g, and a pH of 8.8. It contained 0.07% organic carbon and 0.47% soil organic matter. It was categorized as a SP in accordance to USCS Classification. Gravels as the supporting materials on the bottom of the landfill reactors were purchased from a local hardware store. They were sized from 1/2" (12.5mm) to #8 mesh (2.36mm) and washed prior to use.

Artificial Solid Wastes

Artificial solid wastes simulating actual solid wastes produced in PR were prepared in accordance to the "Final Report Waste Characterization Study" prepared by Autoridad de Desperdicios de Sólidos (ADS) in 2003. This report contains the characterization solid wastes for the months of June and September 2003 (Table 1). The final composition of the artificial solid wastes was comprised of the average values of these months. The organic materials were replaced with composts which were obtained from the composting plant in the municipality of Mayagüez.

Physical Landfill Model

Biochemical decomposition and settlement was simulated using laboratory-scale PLMs in a temperature-controlled environmental chamber. The PLMs was equipped with a gas extraction port and a water spraying system on the top and a leachate drain port on the bottom. For settlement monitoring, the PLMs had a side-wall window of transparent Plexi-glass. The dimension of PLMs was 12 in diameter and 39 in long.

The orders of the layers in the PLMs were (from bottom to top): gravel, sand, solid wastes, daily cover (MAs or Sand), solid wastes, daily cover (MAs or Sand), solid wastes, daily cover (MAs or Sand), and sand as the final layer. One PLM used sand cover over compacted waste (i.e., control), whereas the other PLM used MAs as an ADC.

Table 1. Waste Characterization Results Average Composition of Solid Waste Discards in Puerto Rico (June and September 2003).

Component		% by weight (June 2003)	% by weight (Sept 2003)	%Average
Plastic	Type 1- Polyethylene	1.1	0.8	0.95
	Type- HDPE	2.9	3	2.95
	Type 3-7 (PVC, LDPE, PP,PS, Mixed)	6.5	6.7	6.6
Paper Cardboard	High quality paper	1.3	1	1.15
	Low quality paper	8.7	8.7	8.7
	Corrugated	9.3	8.8	9.05
Metals	Ferrous Metals	9.4	9.4	9.4
	Non- Ferrous Metals	1.1	0.7	0.9
Yard	Yard waste	20.4	22.1	21.25
Organic	Organic waste	12.9	12.8	12.85
C&D	Construction debris	17.1	14.9	16
Glass	All types glass	2.4	2.4	2.4
HHW	Household Hazardous Waste	0.5	0.5	0.5
Other	Not Otherwise Defined	6.3	9	7.65

Environmental chamber was equipped a thermal circulator to facilitate landfill biochemical processes so as to facilitate the quantification of the effectiveness of MAs as an ADC in a shorter period of time. Rainfall was simulated through the water spray port.

The PLMs were subject to fourth stages with respect to hydrological sequences. First two sequences represented rainfall simulations. The third sequence represented dry period. The last sequence was for leachate recirculation. A detailed description of each sequence is shown below:

First Sequence: This stage represented a wet season; the rainfall applied at an intensity of 2 inches per hour on two different days. Water was sprayed with a nozzle installed on the top cover of the PLMs on Mondays for an hour and Fridays for a half hour. This stage lasted for five weeks.

Second Sequence: The rainfall was applied only one day (Fridays) at an intensity of 2 inches per hour for an hour. This period lasted for four weeks, representing a moderate rainfall season.

Third Sequence: This stage was for a dry (no rainfall) season. This stage was last three weeks.

Fourth Sequence: This stage was for leachate recirculation. This stage lasted five weeks and the collected leachate was recirculated to the PLMs.

The sequence of hydrologic simulation was repeated. The leachate samples were collected and water quality parameters were analyzed. Gas production was also monitored. Physical settlement was assessed through the side-wall window on the PLMs.

EXPERIMENTAL RESULTS

Hydraulically, the PLM with MA daily cover produced very similar amount of leachate to the control PLM with sand daily cover as shown in Figure 1. This was probably attributed to great void fractions in the MA particles, especially small-sized ones, where the water could be held at a greater extent. To further evaluate potential water holding capacity of the MAs, blank systems were constructed with the same amount (100 g) of the MAs or sand and were sprayed twice a week with total 50 mL of water per each spraying event. The MAs had greater water holding capacity than sand over the 29-day experiment with total 450 mL of water sprayed: the MAs blank reactor produced 248 mL of percolated water, whereas the sand blank reactor produced 276 mL.

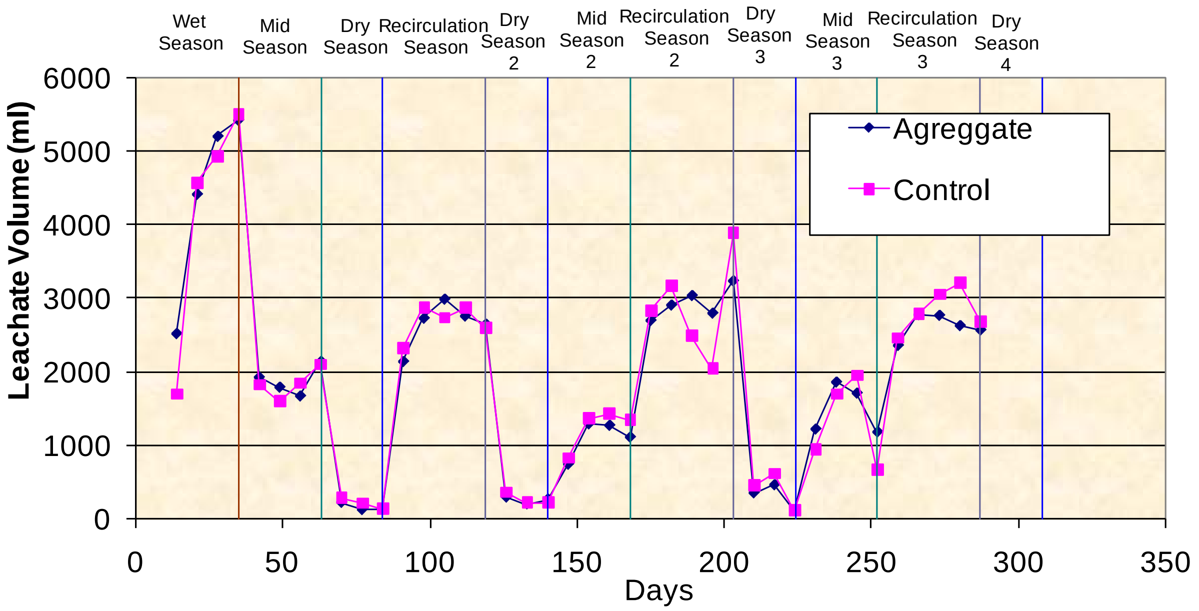
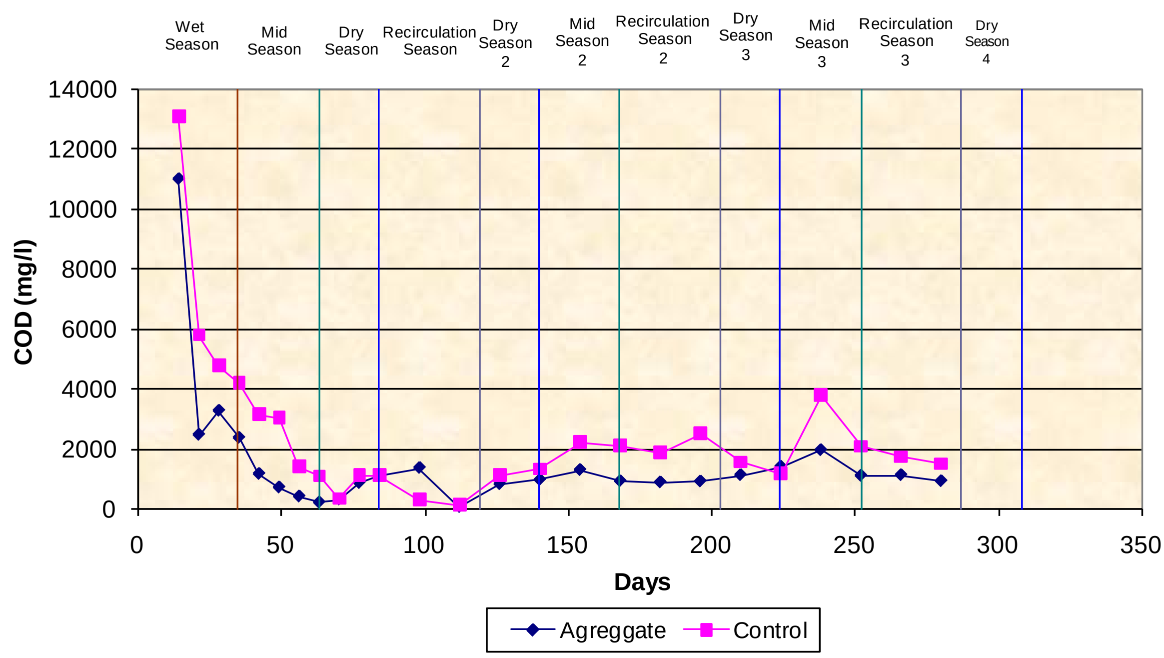


Figure 1. The amount of leachate produced from the PLMs.

Both COD and BOD were found lower in the PLM with MA daily cover than the control PLM (Figure 2). Coal bottom ash produced from a thermal power plant was used in a batch experiment to investigate the adsorption characteristic of this bottom ash [6]. The adsorbate solutions were synthetic wastewaters contained copper and COD and a sanitary landfill leachate. The experimental results showed that coal bottom ash had a good adsorption capacity for copper and COD and could reduce the concentrations of various pollutants in the leachate.

Lower nitrogen and phosphorus were quantified in the leachate from the PLM with MA daily cover. Other water quality parameters such as pH, turbidity and hardness were found similar regardless of the type of daily covers.



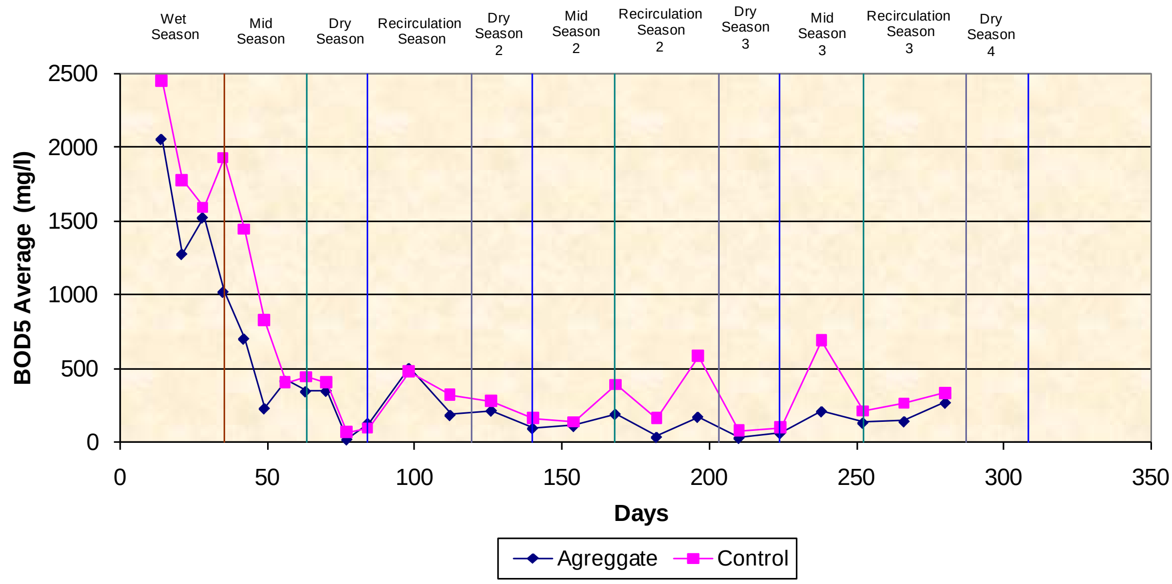


Figure 2. Profiles of COD and BOD in the leachate from the PLMs.

More gases were produced from the PLMs with MA daily covers (Figure 3). Also found was an early start of gas production for the PLMs with MS daily covers. Although gases were not analyzed for their components, it is construed that more biological activity occurred in the PLM with MA daily cover which would produce more gases.

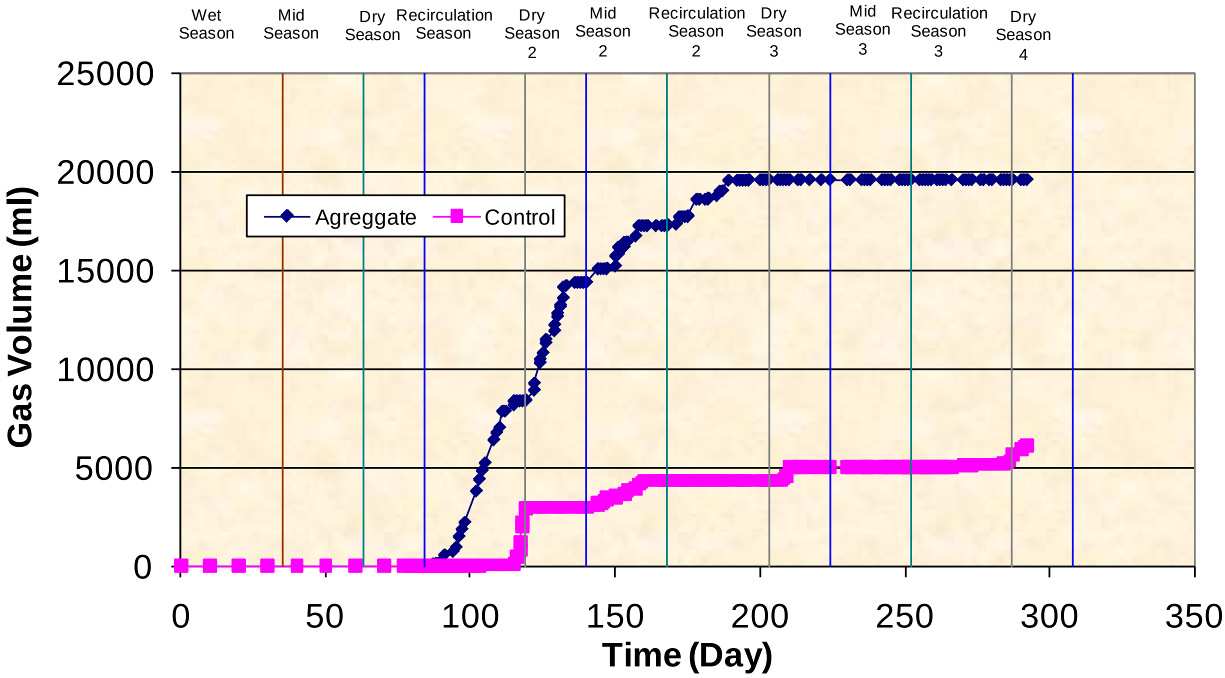
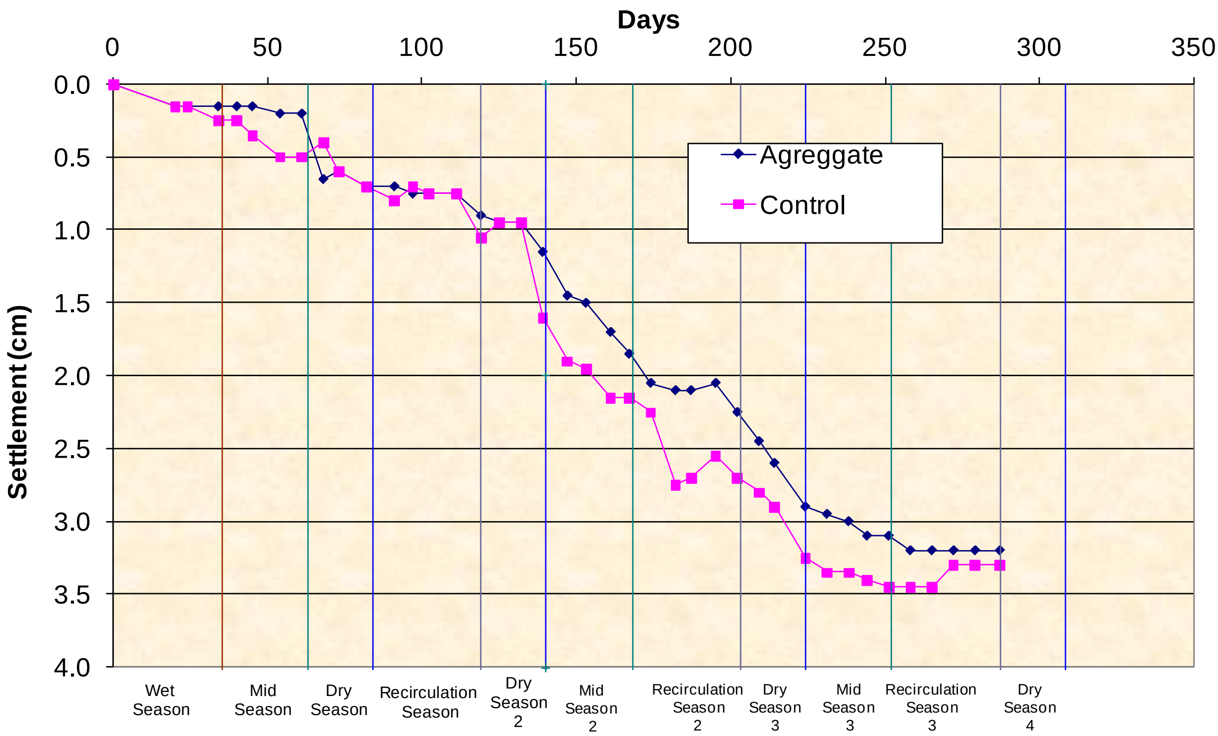


Figure 3. Gas production from the PLMs.

For an absolute settlement, the control PLM achieved more settlement as shown in Figure 4 (top). However, when the extent of settlement was normalized to the density of daily covers, the PLM with MA daily cover showed much more settlement (Figure 4 (bottom)).

Various biogeochemical interactive processes occur simultaneously in a landfill. The most common resulting phenomena are the settlement of the landfill and the gases and leachate from biochemical decomposition of the wastes. These physical and biochemical phenomena are highly intermingled together. For instance, gas generation as results of biochemical waste decomposition changes the fill pressures in landfills, which causes physical settlements. Biochemical waste decomposition is known to account for a large part of the total landfill settlement [7].



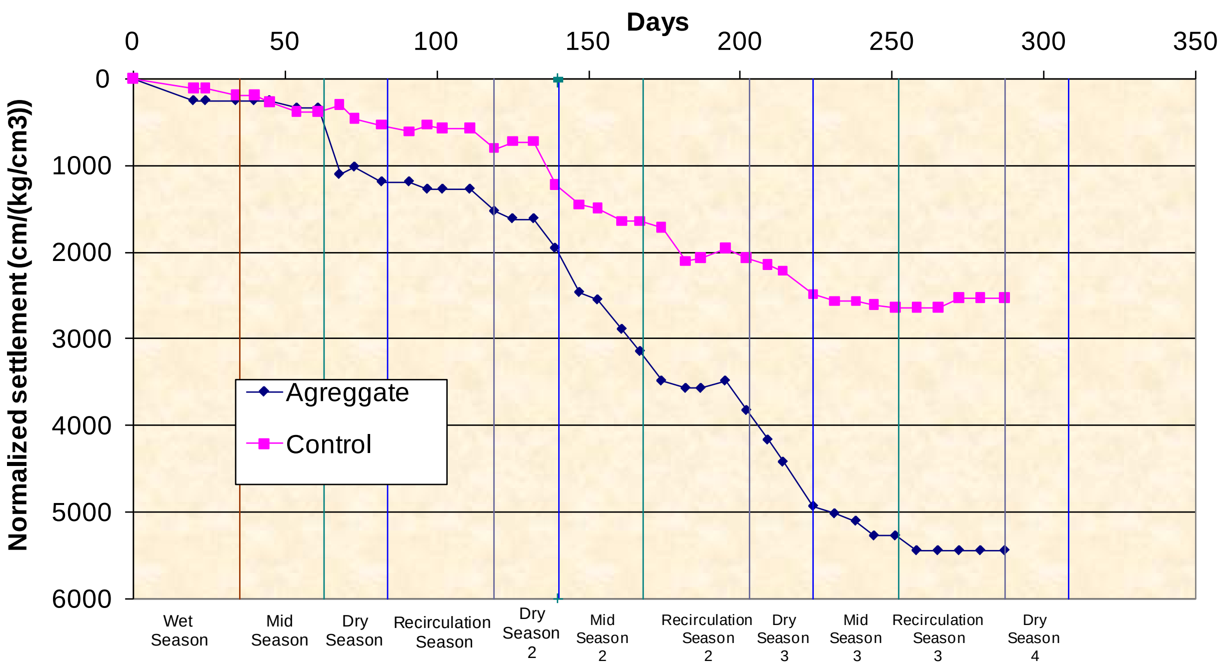


Figure 4. Absolute settlement (top) and normalized settlement (bottom) of the PLMs.

CONCLUSIONS

Experimental results showed that the MAs can be beneficially utilized as an ADC in landfills reducing leachate toxicity, enhancing biological decomposition of solid waste, and exerting earlier settlement to a greater extent. However, further study is warranted to develop engineering application protocols of the MAs for implementation at fields. Also, more scientific approach needs to be done for characterization of gases produced.

ACKNOWLEDGMENTS

The authors would like to express sincere appreciation to the AES Puerto Rico and the College of Engineering, University of Puerto Rico at Mayaguez for their financial support for the project.

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