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R. Sharma
Arkansas State University, rsharma@astate.edu

K. Arnoult
Arkansas State University

K. Hart
Arkansas State University

G. Phillips
Arkansas State University

S. Knight
Saline County Regional Solid Waste Management District

See next page for additional authors

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Authors
R. Sharma, K. Arnoult, K. Hart, G. Phillips, S. Knight, and M. Grappe

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R. Sharma[1*], K. Arnoult[1], K. Hart[1], G. Phillips[1], S. Knight[2], and M. Grappe[2]

[1]*College of Agriculture and Technology, Arkansas State University, Jonesboro, AR*
[2]*Saline County Regional Solid Waste Management District, Benton, AR*

*Correspondence:rsharma@astate.edu

Running title: Biomass Suspension as Alternative Daily Cover Material for Landfills

Abstract

Biomass makes up approximately 16% of the landfills (this number can vary significantly depending upon the geographical location and time of the year). A majority of the biomass disposed in landfills is comprised of yard waste including grass and leaf clippings. This is becoming a problem as most landfills are running out of space and it is expensive to build new landfills. Twenty-four states have prohibited the disposal of yard waste in landfills with more states likely to follow suit. To conserve landfill space it is important to identify processes and methods for effective utilization and disposal of yard waste. It has been shown in this research that conformal coating of a biomass suspension can be utilized as an alternative daily cover (ADC) for the landfills. The biomass is ground into fine particles ($d \leq 2$ *mm*) and suspended in a surfactant solution. This approach can reduce the cost of daily operations for the landfill and provide a solution to the problem of yard waste disposal.

Introduction

Sustainable waste management is critical to the future of the planet. This is an issue which has an impact on every person. Still, it is surprising that we do not even have an accurate estimate of municipal solid waste (MSW) generation in the country. As per EPA fact sheet on municipal solid waste, Americans generated about 254 million tons of trash in 2013 (EPA 2015). Almost 52.8% of the MSW was discarded in landfills. Remaining MSW was recovered, recycled, composted or combusted for energy recovery (waste-to-energy or WTE). Approximately 16% of the MSW is composed of biomass (yard trimmings, wood etc.). Almost 60% of this biomass is recycled (20.6 million tons of yard trimmings composted or wood waste mulched in 2013). Remaining biomass ends up in landfills. According to some other reports the amount of MSW generated as well as going to landfills was significantly higher. (Shin 2014, Arsova et al. 2008). Irrespective of the discrepancies in the reported data, we know that there is a large tonnage of MSW going in the landfills and biomass makes up a significant percentage of this MSW.

Landfills typically use a daily cover of approximately 15 to 23 cm of compacted soil, which acts as a barrier for odors, blowing trash, fires and keep birds and insects away. The drawbacks of using soil as daily cover have been well known. It reduces the fill capacity of landfills. According to an estimate the volume taken up by soil in a typical land fill is about 20-25% of its capacity (Solan et al. 2010). Decreasing availability of new landfill sites along with space in existing landfill is of concern to solid waste management community worldwide. Using soil as a daily cover increases the operational expenses due to labor and fossil fuels costs for excavating and moving the soil. This has resulted in a search for alternatives for daily cover. EPA conducted a study in 1993 where they investigated several alternative daily cover (ADC) materials. Several materials such as foams, spray-on, geosynthetics and a variety of other materials which are disposed in landfills were identified which can replace soil as daily cover (Pohland and Graven 1993).

Application of yard waste as an alternative daily cover material has tremendous potential. Yard waste is not only widely available, waste management companies have to spend money and efforts in disposing yard waste. A significant amount of yard waste (average composition by weight is about 50 percent grass, 25 percent brush, and 25 percent leaves) is disposed in landfills. It has become an operational challenge as the existing landfills are filling up and building new landfills is capital intensive task. The disposal of yard trimmings in landfills is not a good choice due to its high organic matter content (López et al. 2010). In addition to the capacity issues, there are regulatory challenges. Twenty-four states representing about 39 percent of the population of the United States have banned the disposal of yard waste in landfills and it is expected that several other states would also do the same (EPA 2015). Even though the amount of yard waste sent to landfills has decreased by 50% in past two decades (Miller 2013), there is need to reduce this amount even more. It is important to develop new methods and processes for effective management of waste biomass that would prolong the life of landfills.

One such approach could be to use yard waste to create ADC that could replace the daily cover of soil. It has been shown that the use of organic waste material as ADC is a better strategy in terms of greenhouse gas emission reduction as compared to that of composting (Kong et al. 2009). This was true even when there was no collection system is in place for landfill gasses. A life cycle analysis study compared the use of yard waste for ADC versus the composting (Haaren et al. 2010). It was shown that the using yard waste for composting is far more expensive than its use as ADC. It was also determined that the use of yard waste as ADC in place of soil is environmentally preferable. Another study also concluded that using vegetative mulch as daily and intermediate landfill cover is an option that is more environmentally friendly as compared to composting or combustion (Haddad 2011).

The objective of this study was to develop a method to prepare a durable protective biomass layer using yard waste and evaluate its performance for its potential application as an alternative daily cover for landfills. Biomass suspensions were prepared using yard trimmings particulate material and surfactants or surface-active reagents. Several different types of surfactants were tested for the stability of biomass suspensions. The biomass suspension was used to create a conformal coat that can be utilized as an ADC for the landfills.

Methods

Sample preparation

The biomass (yard waste) was collected from several residential neighborhoods in Jonesboro, Arkansas. Yard waste consisted of but not limited to pine needles, pine bark, pine cones, dried leaves, leaf clippings, dried grass and small limbs. Since the components of the yard waste were fairly large and varied in size, the first step in the sample preparation was size reduction of the yard waste collected. This was a two-step process. First step was to reduce the biomass to ¼ its size (small enough to fit into the grinder). We used a basic leaf shredder for this step. This allowed it to be further processed in the laboratory grinder. This biomass was ground using a laboratory mill (Thomas Wiley model 4) with a 2 mm sieve. The particle size of the reduced biomass was 2 mm or less. ($d \leq 2$ *mm).*

Biomass suspension and layer

A nonionic (Preference®, Winfield) and a cationic (Benzalkonium Chloride, Alfa aesar) surfactants were used to prepare the biomass suspensions. The active ingredients of Preference® consisted of Nonylphenol polyethylene glycol ether (55-65 % w/w), Isopropyl alcohol (10% w/w), and Poly(ethylene) oxide (<2% w/w). Benzylkonium chloride was a 50% w/w aqueous solution. Surfactants are known to have amphipathic structure. They have a hydrophilic as well as a hydrophobic component and can be used to reduce interfacial tension. They can adsorb on the surface of the biomass particles and impart a hydrophilic or hydrophobic characteristic to the surface depending upon the orientation of the surfactant molecule. The hydrophobic component of the surfactant can help keep the biomass particles apart and stabilize the suspension, whereas the hydrophilic group can reduce the interfacial tension and assist in formation of a cohesive layer. Stability of the suspension would be required during its application on landfills. It would be important to identify a surfactant that will have functionality for this task and is cost effective. Both of the surfactants chosen had very low toxicity and are used in several foods, pharmaceutical, and agricultural applications. It was important that these surfactants were environmentally safe chemicals. These surfactants are not very sensitive to the hardness of water that would be an important consideration if this process is adapted for the landfills.

A 0.125, 0.25, 0.5, 1, and 1.25% v/v concentration solutions of nonionic and cationic surfactants were prepared. A 1% solid loading solution was prepared to test the stability of the biomass suspension with both surfactants. A magnetic stirrer was used to stir the solution for 5 minutes. Settling time was recorded after the stirring was stopped.

A 25% solid loading slurry of biomass in a cationic surfactant solution was prepared to create a biomass layer. The slurry was spread on a test bed. The 30cm x 30cm (actual size: 1ft x 1ft) test bed was custom built and for these experiments. A fan was directed at the test bed to simulate the wind at a land fill (wind speed 0.5 m/s).

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Results and Discussion

Figure 1 shows the settling of biomass particles in a non-ionic surfactant solution. Settling time for biomass particles was highest in the control suspension (no surfactant). The settling time decreased with increase in surfactant concentration up to 0.5% in the suspension. This was followed by an increase in settling time up to 1.25% surfactant concentration (M =322.04, SD = 28.04). This indicates that the non-ionic surfactant had an adverse effect on the stability of biomass suspension. Since non-ionic surfactants do not have a surface charge on their hydrophilic groups they would not have a strong affinity towards the negatively charged biomass surfaces. They would still weakly adsorb on the particle surfaces reducing the interfacial tension. This will increase the rate of immersional wetting. This reduction in interfacial tension also increases the cohesion of biomass particles resulting in formation of agglomerates. The larger mass of the agglomerates would contribute to the faster settling of biomass particles in non-ionic surfactant solution. It has been shown that the hydrophobic component (chain) of the surfactant may form nonelectrical steric barrier to aggregation in aqueous medium at high concentrations (Rosen 1989). The presence of these barriers may increase the stability of the suspension. However, this may happen only when there is a closed-packed vertical monolayer of surfactant is adsorbed on the surface. The monolayer of the non-ionic surfactant was not realized until the surfactant concentration used in these experiments (1.25% surfactant solution). This could be the reason the suspension with nonionic surfactant was less stable than the control. It has been shown that the concentration of the surfactant has a strong correlation with it orientation on the substrate such an increase in the amount of surfactant being used and resulting interfacial behaviors (Shubin 1994). This monolayer of surfactant could possibly have been achieved at a higher surfactant concentration. However would be cost prohibitive for large-scale operations.

Figure 2 shows the settling of biomass particles in a cationic surfactant solution. The settling time for biomass particles increased with increase in surfactant concentration up to 0.125% in the suspension. This was followed by a decrease in settling time (M =358.62, SD = 38.14). Another set of experiments was conducted between 0 and 0.125% concentration to determine if any lower concentration of surfactant can be used. Settling times were measured at 0.0125, 0.0250, 0.050, and 0.075% concentration. The settling time was highest at 0.05% concentration (429 s), which was slightly higher than 0.125% concentration (421 s). However, the noteworthy part of this test was reduction in surfactant concentration by 40% for almost similar stability. This suggests that the cationic surfactants can increase the stability of biomass suspension. Cationic surfactants have a positively charged surface-active polar group along with a hydrophobic tail. As a result of which they have attractive electrostatic interaction towards negatively charged biomass surfaces and preferentially adsorb on them. Since they adsorb with the polar group oriented towards the surfaces, the hydrophobic chains are oriented towards the aqueous phase imparting hydrophobicity to the surface. These hydrophobic chains deter the approach of particles to each other creating a steric barrier to coalescence. This keeps the particles apart preventing aggregation and slowing down the settling rate.

The next phase of this project was to generate a

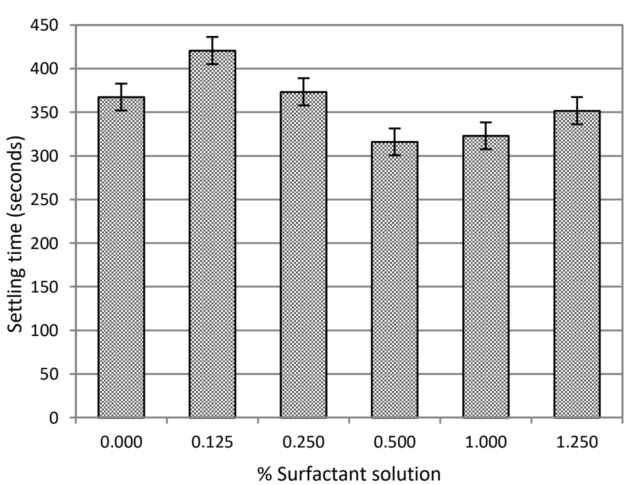

Figure 1. Settling of biomass particles in a non-ionic surfactant.

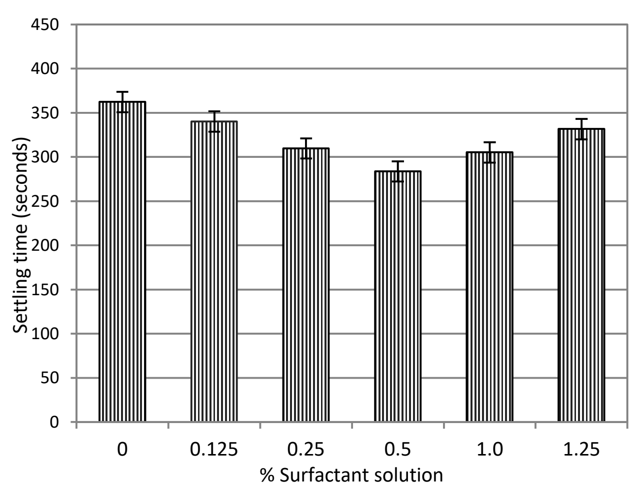

Figure 2. Settling of biomass particles in a cationic surfactant.

biomass layer using the prepared biomass suspension. A 0.05% cationic surfactant solution was used in this synthesis, which was previously determined as optimum concentration for stable biomass suspension. The biomass suspension was spread on a test bed and allowed to dry overnight. Figure 3 shows the testbed immediately after the slurry was spread and after it dried up. It was found that the biomass layer was quite sturdy and can possibly serve as effective protective cover over landfills. The surfactant reduced the interfacial tension between biomass particles allowing them to adhere together and resulting in a robust layer. It was also separately determined that this layer had hydrophobic properties as well. This was due to the hydrophobic portion of the surfactant molecules that were adsorbed on the particle surface. It did not disintegrate and held up well under the rain in an outdoor test.

A typical landfill has a footprint of approximately 111m^2 (Duffy 2005). Based on the amount of biomass used to generate a 2.54 cm thick layer in this study, it would take approximately 600 kg of biomass to cover the surface of a typical landfill. There are 1900 active landfills in this country (Zilmich 2015). If each of the landfill is covered with a 2.54 cm thick layer of biomass every day, it would require 416,100 metric tons of biomass per year. The total waste biomass generated each year is approximately 34 million tons (EPA 2015) which is significantly higher than what would be required for this approach.

Figure 3. Biomass layer immediately and after overnight drying.

Conclusion

This work demonstrated that waste biomass can be used to create sturdy and impervious layers. These biomass layers can be used as Alternative Daily Cover for landfills. It was found that a cationic surfactant provided with most stable biomass suspension. A 0.05% solution of this cationic surfactant was used to prepare biomass slurry which resulted in a robust layer. This can be a sustainable approach for utilizing waste biomass and generating daily cover for landfill operations.

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