Biochar Effectiveness By Metal Reduction in Leachate and Plant Growth Height As Factors of Successful Land Remediation

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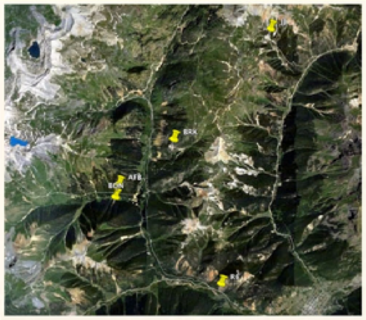
~Abstract~

A significant difficulty of historic mining in the San Juan Mountains is the soil and water quality degradation associated with abandoned mine tailings, waste rock piles and draining adits, which have drastically effected local watercourses. These display highly mineralized soil from the erosion of metals in soil solution partly due to a lack of vegetation in these areas. A proposed solution to remedy this situation effectively and frugally is the introduction of biochar, a stable solid, rich in carbon that can endure in soil for thousands of years. Biochar was evaluated by Mountain Studies Institute and Animas High School through the comparison of plant growth after the introduction of biochar to its usefulness at mitigating metal toxins in leachate solution. At specific percentages of biochar introduced to soil, our measurement of the plant vegetation in soil was based on the height of plant growth, not density or true health of the vegetation. As a means of remediation, the percent change of metals in



~Methods and Materials~

Soil for this trial was taken from five different abandoned mine sites in the Silverton, Colorado area: Joe/John (JJ), Bonner (BON), Road Cut (RC), Across from Bonner (AfB), and Brooklyn (BRK); all of which have acidic soil quality.

This analysis was based on Mountain Studies Institute (MSI) experiments, which measured soil water content, soil water toxicity (pH), and plant growth response as investigation of biochar effectiveness to land remediation. This particular paper focuses on whether biochar can be considered an effective land remediation strategy based upon the plant growth response and leachate levels of soil samples. Over the course of 55 days an analysis of various biochar effects including metal levels in leachate solution, plant growth height, and percentage of biochar introduction, (0, 10, 20, and 30 % biochar in soil) was conducted.

A total of 60 samples were used; 3 samples from each biochar percentage: 0%, 10%, 20%, and 30% at each mine site (JJ, BRK, BON, RC, and AFB). On start date, January 27th, leachate samples of the amounts of biochar and mine sites were collected from soil samples and analyzed at Animas High School. Metal levels in the leachate solution were found using an ICP-AES machine with MSI. The same technique was used at the end date, March 5th, of this experiment and metal levels determined once again. This allowed us to determine the effectiveness of biochar at reducing the level of specified metals in leachate.

The ICP-AES tool is an emission spectrophotometric technique, that uses energy emitted from excited electrons at given wavelengths as they return to their ground state. Each element emits energy specific to wavelengths and chemical character. This technique can determine the wavelengths emitted in from the samples by analyzing its intensity compared to an Animas Watercourse average.

An analysis of plant growth at the four different levels of biochar was also compared. Plant height data was collected from a larger greenhouse/container experiment, which measured the mass of pre-watered sample, the average height of all green vegetation (mm), and the volume and pH of drained irrigation water. After 55 days, of all green vegetation in each of the samples was collected, labeled, weighed, dried then re-weighed.

The greenhouse/container experiment measured soil water content, soil water pH, and plant growth response, also in 55 days. Each container was correctly labeled and placed in its respective 3.5 inch containers. Biochar, which was sifted to less than 2mm, was added to its respective container and mixed thoroughly with its soil. The mixes were watered to saturation and drained overnight. The samples were then remixed with seed mix and lupine seeds, and carefully added to the top quarter inch of soil. Prepared samples were allowed to germinate over a 72-hour period where they were kept warm and covered. Twice a week samples were watered, weighed before and after their watering, measured for height of green vegetation, volume taken, and the pH of water used to irrigate before and after the irrigation of each container.

~Discussion~

Our results determined if biochar is effective for plant growth and metal reduction in leachate. For the first three weeks of plant growth, the average height of vegetation in the samples were similar across the trial. This similarity excludes samples from mine site¬¬¬ BRK, which had high Pb levels, which varied from the other sites. Our data suggests that in beginning stages of plant growth, biochar seemed ineffectual at provoking vegetation growth, as there were no discrepancies among the four biochar concentrations. This does not necessarily mean that biochar is ineffective, but suggests that vegetation does not immediately benefit from its introduction. By measuring other factors of plant growth response such as density, it is possible that our data would diverge from current results.

Leachate solution data indicated the metal level change after biochar was introduced. We compared the results of leachate contamination to the plant growth data to observe a possible coincidence. Graphs indicate metals in leachate solutions by numerical and percent change; biochar effectiveness is showed by percent increase or decrease by tested element. Samples that displayed increased levels of metals in leachate solution directly contradict the proposed influences of biochar as a means to remediation. From our analysis, biochar efficacy is not evident.

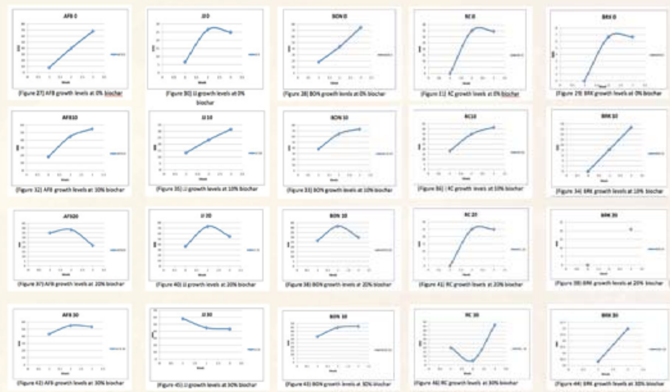
"Biochars are biological residues combusted under low oxygen conditions, resulting in a porous, low density carbon rich material. Their large surface areas and cation exchange capacities, determined to a large extent by source materials and pyrolysis temperatures, enables enhanced sorption of both organic and inorganic contaminants to their surfaces, reducing pollutant mobility when amending contaminated soils. Liming effects or release of carbon into soil solution may increase arsenic mobility, whilst low capital but enhanced retention of plant nutrients can restrict vegetation on degraded soils amended only with biochars; the combination of composts, manures and other amendments with biochars could be their most effective deployment to soils requiring stabilization by vegetation. Specific mechanisms of contaminant-biochar retention and release over time and the environmental impact of biochar amendments on soil organisms remain somewhat unclear but must be investigated to ensure that the management of environmental pollution coincides with ecological sustainability" (Moreno-JimÃ©nez).

As stated in comparison to the results of Beesley's biochar review, biochar is regarded as a possible remediation strategy to contaminated soils due to mine tailings but not necessarily abandoned mine sites. The data suggests that biochar may not be a beneficial land remediation strategy, evident in non-correlating and inconclusive data.

Outliers in our data may have mitigated our abilities to find conclusive correlations. The accuracy of our measurement techniques such as the ICP-AES machine could have affected the accuracy of our data.

~Results~

Al Ca Pb K Na Zn Mg



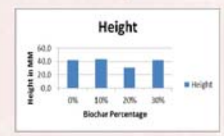
0% biochar

10% biochar

20% biochar

30% biochar

AFB JJ BON RC BRK



~Brief Explanation~

(The charts above indicate the metal levels found at each site in 0% biochar, percent change, numerical change and leachate levels for each metal, respectively).

(The charts to the left indicate plant growth (mm) from the samples of each site over the course of 3 weeks).

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"The free zinc ion in solution is highly toxic to plants, invertebrates, and even vertebrate fish."

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The Free Ion Activity Model is well-established in the literature, and shows that just micromolar amounts of the free ion kills some organisms. A recent example showed 6 micromolar killing 93% of all Daphnia in water.[187]

~Acknowledgments~

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