

The Water, The Waste and the Wetland

An environmental study that analyzes the effects of biochar and calcium oxide soil additives on the qualities of acid mine drainage.

Table of Contents

Contents

Background _____	Error! Bookmark not defined.
Problem/Hypothesis/Materials _____	1
Procedure _____	4
Data Analysis _____	6
Conclusion _____	8
Abstract _____	9
Application _____	9
Bibliography _____	10

Background Research:

Wetlands have filtered runoff from overflowing rivers and streams, absorbing the pollutants, such as excess nutrients and sediment, before they can reach other, larger bodies of water. The U.S. alone loses about 60,000 of these habitats per year. Most of this is due to development and channelization of rivers. This increases runoff and decreases infiltration. These fragile ecosystems can only stand so many pollutants before contamination of its delicate balance begins.

Biochar, a solid material created from the carbonization of biomass, has been historically used as a fuel and as a soil amendment in the Amazon. It has recently been discovered in this country as a possible amendment for soil enhancement. The process of creating biochar sequesters carbon in an inert form, thus reducing the emissions from dead organic matter. Because biochar is very porous it helps to retain nutrients in the soil instead of leaching into the ground water and becoming pollutants. Reduced nitrogen leaching, reduced emissions of nitrous oxide, moderation of soil acidity, increased water retention, retention of carbon, soil fertility and increased number of beneficial soil microbes are a few of the benefits of this substance.

Calcium oxide (quicklime) is an effective soil stabilizer. Quicklime reacts with water to form calcium hydrate. The environmental effects of this substance are minimal. It neutralizes clays through pozzolanic reactions, a procedure that causes clays to become compounds similar to cement. This occurs through the exchange of ions and the basic rearrangement of alumino-silicate mineral. It also consumes water and calcium oxide causing both moisture content and pH to drop. Afterwards, any extra hydrated calcium oxide is converted naturally to harmless minerals. Calcium oxide is used in such activities as mine reclamations.

The clay soils around the southwest corner of Colorado are slightly basic. If water is run through this soil it results in a higher, more basic, pH. Rainwater is the best quality water found in a natural state. Clay is the best filter for surface water and sand is the best for groundwater.

Problem

Does the natural wetland filtering process improve the water quality of contaminated water, and if so, does the addition of biochar or calcium oxide to a wetland's soil enhance filtering success?

Hypothesis

If contaminated waters such as mine tailings waste water or agricultural waste water are filtered through a wetland, then the overall water quality will improve because research shows that wetlands are a key instrument in removing toxins from waste water.

If soil amendments such as biochar or calcium oxide are added to a wetland's soil, then they will improve the quality of mine tailing waste water and agricultural waste water, because biochar reduces nutrient leaching and calcium oxide will precipitate with the acidic heavy metal compounds and cause pH to become more basic.

Materials

($\pm 0.01\text{m}^3$) biochar

($\pm 0.05\text{m}^3$) heavy clay soil

(66.54cm^3) Espoma® Organic® Garden Lime (29% calcium oxide)

(9) aluminum trays (475mm x 279mm x 89mm)

(27) plugs of *carex aquatalis* (water sedge)

(27) plugs of *nasturtium officinale* (water cress)

(27) plugs of *phalaris arundinacea* (reed canarygrass)

(5) gallons of Mine tailings water

(5) gallons of Agricultural water

(6) gallons of Rain water

(1) centimeter ruler

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- (1) sharpie
 - (1) clean mixing tub/can
 - (1) knife
 - (3) 5cm x 5cm x 90cm boards
 - (9) 3 ¾ cm square screens
 - (36) standard tacks
 - (1) roll of grey standard duct tape
 - (5) 33cm high buckets
 - (5) 9 cm high boxes
 - (10) 1 quart sized mason jars
 - (1) Minerals and Nutrients Water Panel test kit from
Sciencefaircenter.com
 - (1) 69 cm high by 180 cm long by 90cm wide table or surface
 - (1) board 2cm high x 18cm wide x 180cm long
 - (1) board 2cm high x 18 cm wide x 90 cm long
 - (1) pH meter

Procedure

Control Treatment

- fill tray 2 cm full with clay soil
- Place three of each plant on top of the soil
- Fill the tray 3 cm more with soil, ensuring the roots of the plants are well covered, resulting in 5cm soil depth

Biochar Treatment

- Fill tray 2cm deep with a half biochar, half clay soil mixture
- Place three of each type of plant on top of mixture
- Continue to add the half biochar, half soil mixture until total soil depth is 5cm. Ensure the roots of the plants are well covered.

Calcium Oxide Treatment

SAFETY: Wear gloves when handling garden lime

- Fill tray 2cm deep with clay soil
 - Sprinkle 22.18 cubic centimeters of Espoma® Organic® Garden Lime over soil
 - Place three of each type of plant on top of the soil
 - Add clay soil until total soil depth is 5cm. Ensure the plants' roots are well covered.
1. Collect materials
 2. On one of the aluminum trays mark an X 11 ¾ cm from one side. The middle of the x should be 1 ¼ cm from the base and each arm 2 ½ cm long.
 3. Using the knife, cut along the x.
 4. Bend the edges of the x out, forming a hole.
 5. Place the screen over the hole, ensuring that its edge is just above the bottom tab.
 6. Tack the screen in place, one tack at each corner of the X.
 7. Bend the tip of the bottom tab over the edge of the bottom of the screen.
 8. Cut a 4cm by 1 cm strip of duct tape.
 9. Place strip over top edge of screen
 10. Repeat steps 2-9 on each of the trays
 11. Fill three of the trays using the Control Treatment (above)
 12. Label each tray
 13. Fill three trays using the Biochar Treatment (above)
 14. Label each tray
 15. Fill three trays using the Calcium Oxide Treatment (above)
 16. Label each tray

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17. Set up trays in a stable environment with a relatively even temperature and amount of sunlight in a grid three trays, one from each treatment, wide, on the table with the screened hole hanging 4 ½ cm off the longest edge of the table. Six trays should be on one side, three on the other. (See grid below.)
 18. Using a zigzag method, saturate each tray with 1 liter of rainwater.
 19. LEAVE WETLANDS UNDISTURBED FOR FOUR WEEKS, UNLESS WATER IS BEING ADDED. This gives the plants time to settle into their new environment and grow. Schedule a weekly watering day. (Everything is watered on a Wednesday, or a Tuesday, etc.) Water each tray with ½ liter of rainwater.
 20. Select one set (one tray from each treatment) for each water treatment. LABEL EACH TRAY WITH THE WATER TREATMENT TO BE USED. (The three wetlands to be used to filter rainwater would have an additional label that read rainwater.)
 21. Raise the unscreened ends of each set onto a separate board. Each set should take up one board.
 22. Place one bucket down mid way (90cm) down the longest end of the table, another across from it in the same position. The other four should be positioned at the beginning (0cm) of the longest end, another across from in the same position, and the last at the end (180cm) of the side containing 6 trays. See grid below.
 23. Place one box on top of each of the buckets.
 24. Lay the shorter board across the two supports (buckets) and the longer on the three supports (buckets).
 25. Remove 9 Whirl-Pak® bags from the water testing kit.
 26. Label each bag according to the water sample to be collected, the trial number, and the date . EX. rainwater-clay, 1, 12/01/12.
 27. Following the instructions provided, open each of the bags.
 28. Place each bag in a separate mason jar.
 29. Place each jar under its respective tray. (The rainwater-clay bag would be placed under the clay wetland filtering rainwater and so on) at the closest point, each jar should be 2 ½ cm from the edge of the table.
 30. Test each type of water before filtration according to instructions in kit.
 31. Record results.

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32. Wait until the scheduled watering day to begin filtration.
 33. Using a slow, side to side motion with only a small amount of water being poured at any given moment, pour one liter of rainwater at the top of each of the three rainwater trays (One control, one biochar, one calcium oxide).
 34. Wait one hour.
 35. Record observations.
 36. Remove bags and close according to instructions included in the kit.
 37. Using a slow, side to side motion with only a small amount of water being poured at any given moment, pour one liter of mine tailings water at the top of each of the three mine tailings water trays (One control, one biochar, one calcium oxide).
 38. Repeat steps 32-34.
 39. Using a slow, side to side motion with only a small amount of water being poured at any given moment, pour one liter of agricultural water at the top of each of the three agricultural water trays (One control, one biochar, one calcium oxide).
 40. Repeat steps 32-34.
 41. Test water according to instructions in kit. OMIT pH.
 42. Use pH meter to test pH of all waters.
 43. Record results.
 44. Repeat steps 32-42 twice more

Data recording

All data was recorded in an excel spreadsheet. Three individual trials were tested and recorded. The data from all three trials were averaged. The average of the three tests were graphed in bar charts and used to compare results to the control.

Method for Normalizing Data for Water Quality to Create Scatter Graphs

The purpose for data normalization was to compare the different elements tested of water quality to each other and to the control. Different elements had different ranges, and normalization made analyzing data easier. To normalize the data, all the data was placed on a scale from 0 to 1. For this to occur, the average tested value of each element (total dissolved solids, pH, ect.) was

divided by the highest value in its category. After division, each value was subtracted from the control for that particular variable. This showed the improvement or deterioration of water quality compared to the control.

Data Analysis:

The overall pattern of the data suggests that while calcium oxide improves certain areas of wetland filtration such as pH and iron content in acidic waters, biochar improves almost all areas. In the instances where contaminated water was filtered through the trial wetlands, the quality of that water improved. The independent variable (waste water), for the first piece of the experiment, partially affected the dependant variable (water quality). Tested compounds in contaminated waters such as pH went from 3.01 to 4.07 (mine tailing water) and from 7.95 to 7.79 (agricultural water). Other tested elements such as iron in mine tailings water. (the other two did not have measurable amounts of iron) went from .1 mg/L to .07 mg/L after filtration. However other tested variables such as dissolved solids and alkalinity did not improve. In the second part of the experiment, the first independent variable (biochar) affected the dependant variable (water quality). Water run through the biochar-clay wetland was closer to the control (rainwater) than any other tests and in some instances surpassed the control in quality. For instance, in mine tailing water, pH went from 4.07 (average) to 4.82 (average) in the biochar/clay wetland. The only areas in which biochar did not assist in improving water quality were in total alkalinity in mine tailings, going from 10 mg/L (average) to 25 mg/L (average) and pH in agricultural water, going from 7.79 (average) to 8.09 (average).

The second independent variable (calcium oxide) only slightly affected the dependant variable (water quality). Only a few impurities were filtered from the water. For example, in agricultural water, dissolved phosphate went from 0 in unfiltered water to 166.67 (average) after being filtered through the calcium oxide wetland. The only areas in which calcium oxide assisted in improving contaminated waters were for pH (from 4.07 to 4.87) and phosphate (116.67 mg/L to 100 mg/L) in mine tailings water, and nitrite nitrogen (0.73 mg/L to 0.1mg/L) and total alkalinity (240 mg/L to 160 mg/L) in agricultural water. See graphs and tables for a complete display of the data.

Data accuracy may be slightly off, due to the fact that the test kit used a comparison of colors, and at certain times, matching was difficult. However, it was not a major obstacle, and

sufficient data was collected through the multiple tests..

The data of this experiment may be limited due to the fact that a lab and a natural, outdoor wetland environment were not readily accessible. The data is also largely limited by the tests conducted. It would have been ideal to have access to a greater variety of tests and a laboratory with more precise measurements.

Conclusion

This investigation was conducted in order to discover if the natural wetland filtering process improves the quality of contaminated water, and if so, does the addition of biochar or calcium oxide to a wetland's soil enhance filtering success. Such an experiment is important because clean water is a limited resource critical to humans and the environment. As the human population grows, the amount of waste it produces also grows, much of which is then dispersed into rivers, streams, and lakes. It is essential to discover a natural method to deal with this problem.

The data collected partially supported the original hypothesis, due to the fact that the wetlands filtered out many contaminants for certain types of water. The addition of biochar enhanced the wetland's ability to filter contaminants from both types of tested water, with the exception of total alkalinity in mine tailings (10 mg/L to 25 mg/L) and pH in agricultural water (7.79 to 8.09). The addition of calcium oxide resulted in most contaminants staying the same or getting worse with the exception of raising pH (4.07 to 4.87) and decreasing phosphate (116.67:100) from mine tailings waste water and decreasing nitrite nitrogen (.73:.1) and total alkalinity (240:160) in agricultural waste water.

The independent variables (water type and soil amendments) affected the dependant variable (water quality). Both biochar and filtration improved the overall water quality of contaminated water, while calcium oxide generally harmed it.

A problem that was encountered during this investigation was that the test kit used a comparison of colors which did were sometimes hard to match and therefore data accuracy may be slightly off.

The unusual, but interesting observations that were noted during this experiment include the fact that while the plants in wetlands containing calcium oxide did not flourish, they contained the most diversity. Additionally, the plants in mine tailings wetlands progressively

went down hill as the experiment progressed, most likely due to the acidic nature of such water.

Abstract

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The purpose of this investigation was to determine if the wetland filtering process improves contaminated water quality, and, if so, do soil amendments enhance filtering success. Two hypotheses were required for this experiment. The first was that if contaminated water is filtered through a wetland, then the water quality will improve because wetlands are nature's filter. The second part was that if soil amendments are included in a wetland then they contaminated water quality will improve, because biochar reduces nutrient leaching and calcium oxide will lower heavy metal content and neutralize pH.

This experiment involved constructing nine different wetlands, three for each water type. Different contaminated waters were then run through their corresponding wetlands. The filtered water was collected and tested each week.

The data collected partially supported the original hypothesis. Filtration enhanced the contaminated water quality improving areas such as pH (3.01 to 4.07; mine tailing water and 7.95 to 7.79; agricultural water) and iron (.1 mg/L to .07mg/L; mine tailing water) after filtration. Biochar enhances filtration in most areas, only harming total alkalinity (10 mg/L to 25 mg/L; mine tailing water) and pH (7.79 to 8.09; agricultural water). Calcium oxide only improved pH (4.07 to 4.87) and phosphate (116.67microgrms/L: 100microgrms/L) in mine tailings water, and nitrite nitrogen (.73mg/L:.1mg/L) and total alkalinity (240mg/L: 160mg/L) in agricultural water. These findings led me to the conclusion that if contaminated water is filtered through a wetland then its quality improves and that biochar improves filtration in all areas of water quality.

Application:

The usage of wetlands in filtering environmentally harmful waters is a useful enterprise. Many countries with water purity issues and sites such as mine reclamation and agricultural contamination would benefit greatly if a cheap, natural environment was present to filter such water. Based on the collected data, the addition of biochar to a clay wetland should improve that

wetlands ability to filter contaminated water. This would assist those in mine reclamation, companies that produce waste water and organizations that participate in third world country projects. This information can be used in many areas of environmental restoration and the filtration of contaminated waters.

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