Plant Leachate Nutrient Recovery with Biological, Thermal, and Photocatalytic Pretreatments

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Introduction

Plants are ideal for long term space travel

- Provide essential resources: oxygen, water, food

Water soaked plants expel soluble nutrients in a leachate solution

- Toxins and wastes are also expelled and inhibit growth

Biological, thermal, photocatalytic coupled with an acid digestion treatment will hopefully maximize recovery and remove wastes
Materials

- VOA vials act as mini-bioreactors for our test cases
- Magnetic stir plate allows for sufficient mixing during the residence time
- Centrifuge and syringe filtering for separation
Acid Digestion

- Reduce factorial size, we did acid digestion first to narrow down the number of treatments

- 1 g of dried plant matter + 9 mL water + 1 mL desired acid concentration @ 10 mins, 2 hours, 24 hours
Results - Initial Acid Digestion

Effect of Acid Concentration on Acid Digestion
Displays average fractional recovery of the different ions for the acid digestion organized by the retention times. Legend units are in hours.

Effect of Duration on Acid Digestion
Displays the average fractional recovery of the acid digestion organized by HCl concentration. Legend units are in molarity (M).
Methods-Biological Inoculum

- Water (control), mixed heterotrophic/ nitrifying bioreactor effluent or Trichoderma vessei fungi @ 4, 24, 168 hours should help liberate nutrients

- 1 g dried plant matter + 8 mL water + 1 mL inoculum

- Final acid digestion to maximize recovery using 0M and 1M HCl
Results - Anaerobic Biological

Effect of Inoculum on Anaerobic Biological (0M Acid Digestion)

Effect of Inoculum on Anaerobic Biological (1M Acid Digestion)

Effect of Duration on Anaerobic Biological (0M Acid Digestion)

Effect of Duration on Anaerobic Biological (1M Acid Digestion)
Results – Aerobic Biological

Effect of Inoculum on Aerobic Biological (0M)

Effect of Duration on Aerobic Biological (0M)

Effect of Inoculum on Aerobic Biological (1M)

Effect of Duration on Aerobic Biological (1M)
Methods - Thermal Heating

Dried plant matter (1 g) subjected to 90°C, 180°C, 360°C @ 1, 4, 24 hours aids in nutrient gain

Final acid digestion: add 9 mL water, 1 mL 0M and 1M HCl
Results - Thermal

Effect of Temperature for Thermal (0M Acid Digestion)

Effect of Temperature for Thermal (1M Acid Digestion)

Effect of Duration for Thermal (0M Acid Digestion)

Effect of Duration for Thermal (1 M Acid Digestion)
Methods - Photocatalytic Oxidation

Photocatalytic TiO₂ allows water to photolyze and create a highly oxidative hydroxyl radical.

Dried plant matter subjected to TiO₂ slurry with pH 4, 7, 10 @ 1, 8, 24 hours.

Final acid digestion: 0M HCl and 1M HCl to maximize recovery.
Results – Photocatalytic (0M)

Effect of pH on Photocatalytic (0M)

Average Fractional Recovery

Effect of Duration on Photocatalytic (0M)

Average Fractional Recovery

Control (0M Acid Digestion)

Average Fractional Recovery
Results – Photocatalytic (1M)

Effect of pH on Photocatalytic (1M)

Effect of Duration on Photocatalytic (1M)

Control (1M Acid Digestion)
Methods-Quenching

- Resulting solution is centrifuged and supernatant is decanted
- Supernatant is diluted to 50 mL and syringe filtered
- ICP (inductively coupled plasma) is used to analyze for specific ion recovery
Pellet Data

Effect of Duration (Acid Treatment) on Pellet Size

Effect of Acid Concentration on Pellet Size

Effect of Pretreatment on Pellet Size

Pellet Mass
Conclusion

Thermal, aerobic, and photocatalytic pretreatments look to be relatively effective, anaerobic biological not too effective.

Acid digestion gives a significant boost in nutrient recovery, especially calcium.

Recovery “ceilings” were seen at 70% in many ions.

More testing or a procedural change may be necessary to maximize ion recovery.
Conclusion Cont’d

- Multiple leaches may be needed to overcome solubility issues
- Series leaches with different pretreatments
- Oxygen feeds for photocatalytic and biological
- More powerful UV lamp for photocatalytic
- Cover crucibles for the thermal pretreatment
- Need to completely digest remaining pellets with nitric acid to determine how much more ions are trapped
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