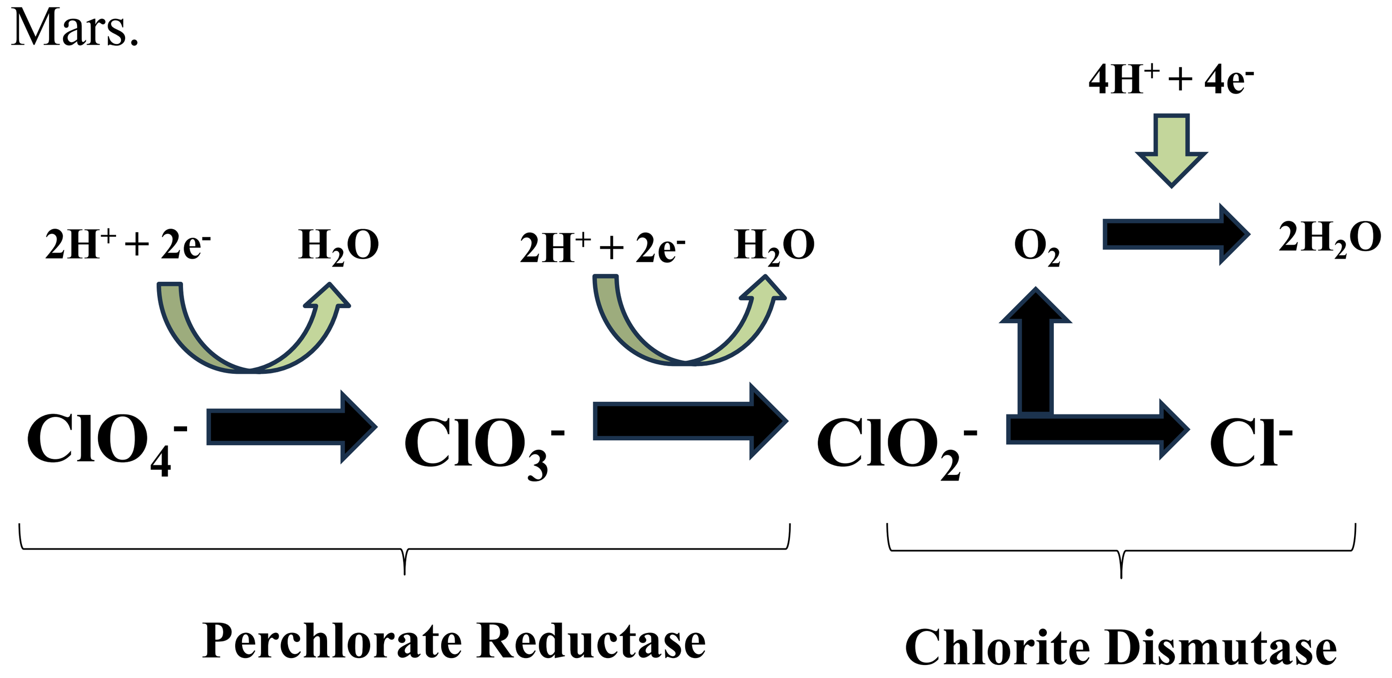
Large-scale Detoxification and Bioweathering of Martian Regolith

Paulina Lopez Torres, Environmental Engineering
Mentor: Dr. Anca G. Delgado, Alba Medina Benitez
School of Sustainable Engineering and the Built Environment

Background

The dominant presence of perchlorate (**ClO_4^-**) in Martian regolith at documented concentrations of ~0.4-1 wt. % [3] poses a difficulty for its use in agriculture due to associated risks to human health [2]. Microbial perchlorate reduction serves as a suitable alterative for remediation of regolith as specialized microorganisms detoxify perchlorate into harmless chloride and oxygen under anaerobic conditions similar to those in Mars [1]. This approach also promotes bioweathering by producing organic material that transforms the sterile regolith into a functional growth medium. Previous phases of this project using MARC (**M**artian **A**nalogue **R**emediation **C**ulture) have achieved effective perchlorate removal up to 5 g/L in solution in small-scale serum bottle experiments, but these systems may not reflect larger, more complex environmental conditions. Up-scaling microbial treatment to kilogram-level reactors is necessary to more accurately simulate conditions relevant to in situ resource utilization for upcoming missions to Mars.

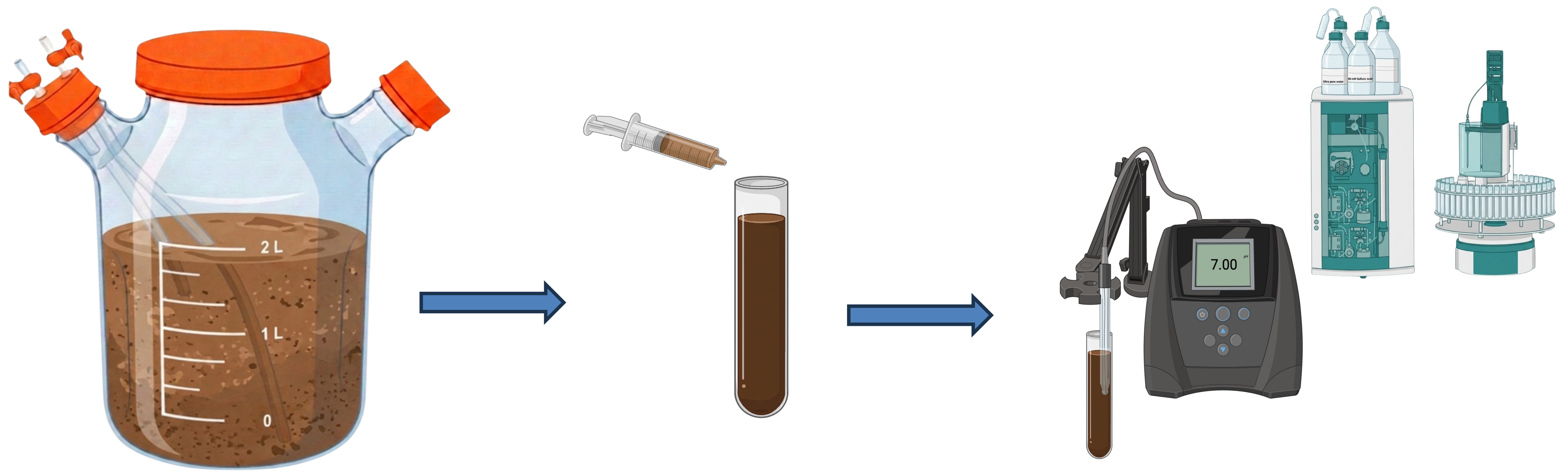


Purpose

This research project aims to evaluate scaling microbial perchlorate reduction to kilogram level reactors to enable the use of remediated regolith for growing crops that require larger soil volumes, such as potatoes.

Methods

Bioreactor Setup | **Sampling** | **Perchlorate Analysis**



Bioreactor Setup
- MGS-1 regolith (1kg)
- Freshwater perchlorate growth medium (1L, ClO_4^- spiked)
- Acetate (Ca/Na; electron donor)
- MARC inoculum (50mL)

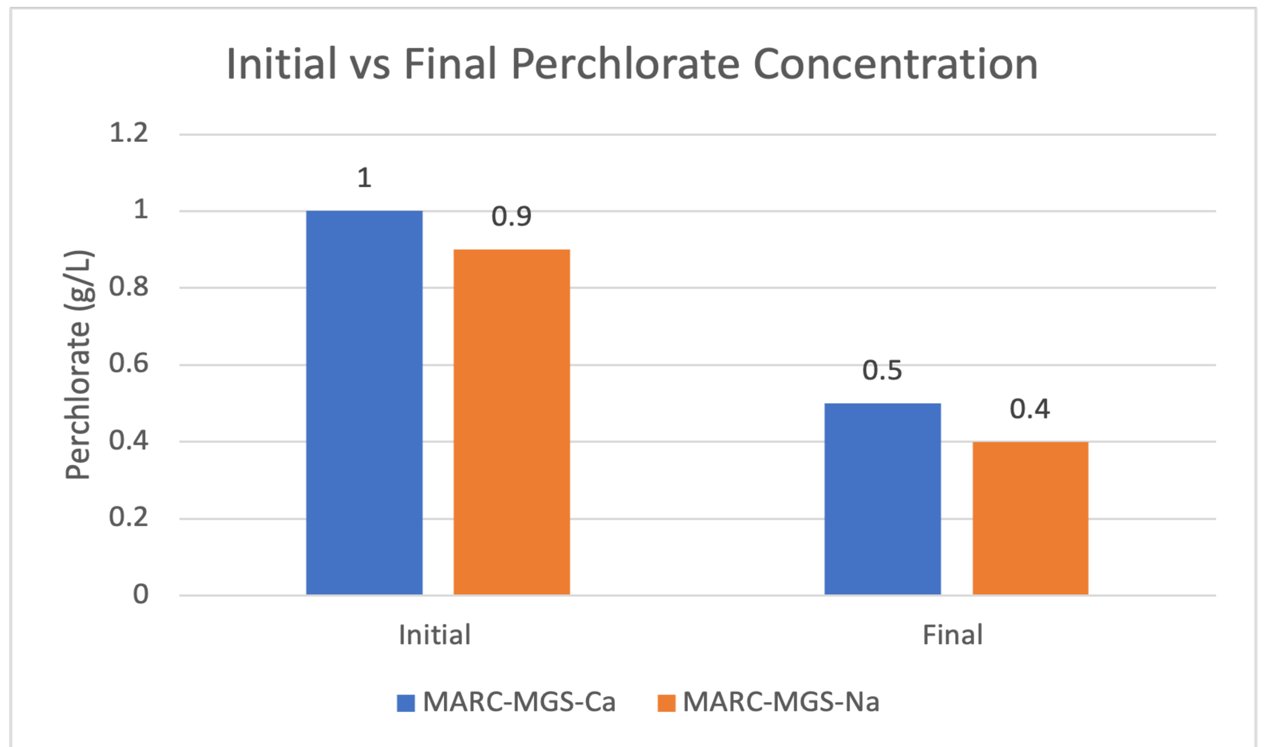
Sampling
- Periodic liquid sampling (5mL per sample)

Perchlorate Analysis
- Perchlorate reduction measured via Ion Chromatography (IC)
- pH monitored

Reactor Conditions

- Anaerobic
- Incubated under controlled conditions
- pH maintained in the range 6.8-7.2 to sustain microbial activity
- Two reactors with differing acetates used to compare electron donor effects on reduction efficiency

Preliminary Ion Chromatography Results



*Date Conducted: 01/23/26-03/02/26

The experiment is ongoing and reflects the early-stage behavior of the systems

- Preliminary IC data indicate a decrease in perchlorate concentrations over time for both Ca and Na reactor conditions.
- Minor fluctuations were observed between sampling points, and may be attributed to sampling differences or system-scale complexities

Key Findings

- Perchlorate concentrations **decreased** by approximately **50-55%** in both MARC-MGS-Ca and MARC-MGS-Na reactors for the months tested.
- pH remained near neutral range (~6.8-7.2) throughout the monitoring period.
- Similar trends between both reactors suggests comparable microbial performance.
- Partial perchlorate reduction remains insufficient for plant growth in regolith

Discussion

- At larger scales, incomplete detoxification of the regolith may be induced as microbes require more time and optimal conditions to significantly reduce perchlorate [4].
- Complete mixing of MARC within the regolith is difficult on larger reactors, potentially resulting in localized areas of untreated substrate material.
- Inconsistencies in recorded perchlorate concentrations suggests non-uniform conditions within the bioreactor.

Future Work

- Optimize controlled conditions such as mixing, microbial distribution, and evaluate performance over extended periods.
- Evaluate treated Martian regolith for residual perchlorate and plant growth potential.

References

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Ira A. Fulton Schools of Engineering
Arizona State University