EGU21-13410, updated on 26 May 2022
https://doi.org/10.5194/egusphere-egu21-13410
EGU General Assembly 2021

Phosphorus interactions with Martian soil simulants

Sofia Manimanaki[1], Dimitris Mitrogiannis[1], Ioannis Baziotis[1], Maria Psychoyou[1], Ioannis Papanikolaou[1], Stamatios Xydous[1], Constantinos Mavrogonatos[2], Thomas Bartzanas[1], and Brad Sutter[3]

[1]Department of Natural Resources Management & Agricultural Engineering, School of Environment and Agricultural Engineering, Agricultural University Of Athens, Athens, Greece (s.manimanaki@aua.gr)
[2]Faculty of Geology and Geoenvironment, National and Kapodistrian University of Athens, Athens, Greece
[3]Jacobs Technology, Astromaterials Research and Exploration Science (ARES) Division, NASA Johnson Space Center, Houston, USA

Phosphorus (P) is an essential nutrient for plant growth. According to the vision of circular bioeconomy, the management of nutrient-rich wastewaters should include both treatment and utilization goals (Battista & Bolzonella, 2019). Consequently, the application of in-situ resources utilization (ISRU), using typical Martian soil (e.g., Yen et al., 2005), is vital for the sustainability of future long-term settlements on Mars.

Martian soil simulants, provided by The CLASS Exolith Lab from the University of Central Florida, were tested for their phosphorus sorption capacity. Sorption of phosphate anions (PO_4-P) from aqueous solutions (AS) of KH_2PO_4 and sodium bicarbonate, as well as from hydrolyzed human urine (HU) was examined at a preliminary stage, using three Martian soil simulants (MGS-1; Rocknest soil, MGS-1S; M-WIP Reference Case B and MGS-1C; M-WIP Reference Case C; Cannon et al. 2019). In particular, isothermal, kinetic, pH, temperature, initial sorbent concentration (5 g soil simulant/L AS or HU, 10 g/L and 15 g/L) and desorption experiments were carried out, the duration of which ranged from five days to three weeks.

The percentage of phosphorus removal was up to 60 % for the aqueous solutions and 24 % for the hydrolyzed human waste. The sulfate-rich simulant (MGS-1S) exhibited the best results. The major phases of MGS-1S are: gypsum, plagioclase, basaltic glass, pyroxene, and olivine. Temperature and the initial pH seem to be the dominant factors affecting P sorption. Equilibrium between sorbent and AS was achieved between five and seven days, as indicated by kinetic experiments. Isothermal experiments at 25 ^{0}C with AS of different P concentrations displayed a linear correlation between adsorption capacity (q) and P-concentration (r^2=0.98). Maximum q was observed at 8.5 and 27 mg/g for AS and HU experiments respectively, when 5 g/L of initial sorbent concentration was used. X-ray diffraction (XRD) of the sorbents treated with AS showed the presence of the newly formed phases berlinite and brushite. Perhaps due to hydrolysis of the pre-existing illite, aluminum bound with the solution's phosphates, forming berlinite and buffering AS's pH to lower values. Formation of brushite is possibly indicative of gypsum (predominant phase in the raw material) dissolution subsequently releasing sulfate anions. In a similar approach, XRD evaluation of the sorbents treated with HU revealed the newly formed phases calcite and hannayite. Phosphate and ammonia ions were likely to bind to the sample and were precipitated within newly formed calcium-bearing phases.

These experiments form a preliminary study of Martian soil simulants, and initial results indicate a possible use of Martian soils as waste recipients or as fertilizers in future missions.

References

Battista, F., & Bolzonella, D. (2019). Waste and Biomass Valorization, 10(12), 3701-3709.
Cannon, K. M., Britt, D. T., Smith, T. M., Fritsche, R. F., & Batcheldor, D. (2019). Icarus, 317, 470-478.
Yen, A. S., Gellert, R., Schröder, C., Morris, R. V., Bell, J. F., Knudson, A. T., ... & Blaney, D. (2005). Nature, 436(7047), 49-54.