Enzymatic and abiotic hydrolysis of glucose-1-phosphate adsorbed on goethite: Kinetics and molecular mechanisms

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Hydrolysis is usually a required step in order to make phosphorus in organophosphates bioavailable as only orthophosphate or small organophosphates may cross cell membranes. This process is catalyzed by extracellular enzymes present in soil solutions, or by an abiotic process at mineral surfaces. In this study we have investigated the enzymatic and abiotic hydrolysis of glucose-1-phosphate adsorbed at the water-goethite interface. Glucose-1-phosphate is produced in glycogenolysis and it has also been used in soil bioassays as a model substrate where the bioavailability was shown to be on the same order as orthophosphate.

To characterize the kinetics and molecular mechanisms of the hydrolysis of glucose-1-phosphate adsorbed on goethite surfaces in presence and absence of an enzyme (acid phosphatase) we have used a combination of wet-chemical and spectroscopic methods. Concentrations of solutions species were determined by means of ion chromatography while the surface reactions were monitored by infrared spectroscopy using the ATR sampling technique.

The spectroscopic results show that glucose-1-phosphate forms two surface complexes on goethite in the pH range 3 – 10. Below pH 7 these complexes are stable with respect to hydrolysis whereas at higher pH values a small extent of hydrolysis is detected. Maximum rate of abiotic hydrolysis is between pH 9-10 where ca. 4% of the adsorbed ligand is hydrolyzed after 48h. In presence of phosphatase the hydrolysis of adsorbed glucose-1-phosphate increases dramatically; at pH 4.8 17% is hydrolyzed after 26h. IR data indicate that hydrolysis is related to the co-adsorption of enzyme at the glucose-1-phosphate covered goethite particles. Furthermore, the amount of glucose-1-phosphate adsorbed has a profound effect on enzyme adsorption and thus the enzymatic hydrolysis. This will be further discussed.

The use of Low Earth Orbit to select for extremophilic cyanobacteria

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Cryptoendolithic cyanobacteria can survive long periods of desiccation, low temperature, and UV radiation; which are all prerequisites for life in space and on Mars. Although several extremophilic cyanobacteria have been exposed to space conditions, this is the first communication that uses LEO to select for extremophilic cyanobacteria from a natural, non-extreme, cryptoendolithic environment.

A cryptoendolithic community from cliffs in Beer, Devon, UK was exposed to LEO. 16S rDNA analysis demonstrated that the cyanobacteria community consisted of the orders Pleurocapsales, Oscillatoriales, and Chroococcales. The rocks were sent into LEO for 10 days as part of the ESA funded BIOPAN VI mission and returned for analysis.

An extremophilic cyanobacterium, which was coccid in nature and phylogenetically identified as a member of the order Chroococcales, survived 10 d in LEO. Ground based experiments showed that the isolate was also able to survive 28 d of exposure to desiccation and Mars simulated conditions, 10 d of exposure to vacuum, and ionization radiation (3 KGy). The isolate was unable to survive exposure to UV radiation. Additional cyanobacteria were isolated after the ground based experiments but none of these isolates survived exposure to LEO.

Little is known about the microbial requirements for survival in space. Extremophilic microbes isolated on Earth are not necessarily capable of surviving in this adverse environment. Consequently, the use of LEO as a selection factor, as demonstrated in this communication, is an ideal approach for isolating extremophilic microbes that can be used to study the physiological requirements for life in space.