WATER RECLAMATION IN SPACE

One way to supply enough water for astronauts on long-duration missions is to recover water from urine by using the cascade distillation system. The goal of this research is to identify a compatible nontoxic pretreatment agent that prevents clogging of the collection system.

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NASA has set a goal of returning to the moon by 2020. The Constellation program involves developing a vehicle and other hardware necessary to meet this goal. The Orion crew module will hold four to six crew members, and each mission to the moon will help to construct a lunar colony, which will allow preparations for human exploration of Mars. Urine will be collected in the crew module and water will be recovered using the cascade distillation system. Urine is a complex fluid that supports bacterial metabolism and quickly creates solid precipitants if left untreated. The constraints of a reduced-gravity environment require the collection system to be composed of small-diameter tubes. To prevent the tubes from clogging, one must pretreat urine with a chemical agent composed of sulfic acid and Oxone®. However, Oxone® can create toxic gases and could be detrimental to astronaut health over extended periods. This article will describe our efforts to identify a nontoxic pretreatment agent that prevents clogging of the collection system and is compatible with a cascade distillation system. Our work consists of laboratory tests to assess potential chemicals.

Introduction

The National Aeronautics and Space Administration (NASA) has set the goal of returning to the moon by 2020. Thus far, space exploration missions have not been long enough to require water reclamation: Missions take a crew to the International Space Station and return to Earth. In these cases, water is launched in the space shuttle, and wastewater is returned to Earth or dumped into space. The new Constellation program involves developing a vehicle and other hardware necessary to return to the moon. The Orion crew module, which will transport four to six crew members to the moon for long-duration missions, will require a water reclamation system to supply enough water for the astronauts.

The current plan is to collect urine in the crew module and to recover water by using the cascade distillation system. However, urine is a highly complex fluid that supports bacterial growth and quickly creates solid precipitants if left untreated. In space, the urine collection system consists of small-diameter tubes susceptible to clogging. To prevent clogging of the system, one must pretreat urine upon discharge with a chemical agent that inhibits growth of bacteria and precipitation of solids. The current pretreatment method, which astronauts call the “string of pearls,” uses a combination of sulfic acid and Oxone®. A “string of pearls” (row of tablets) is inserted into the urine collection hose, as shown in Figures 1 and 2, and the tablets dissolve upon urination. Oxone® is a highly reactive oxidizing compound that destroys microorganisms by oxidation, forming chlorine and other toxic gases.1 It
Figures 1, 2, and 3
A “string of pearls” (row of tablets) is inserted into the urine collection hose, as shown in Figures 1 and 2, and the tablets dissolve upon urination. This current pretreatment method utilized by the U.S. urine collection system in the International Space Station uses a combination of sulfuric acid and Oxone®. The toxicological effects of Oxone® have not been fully investigated, nor have the maximum allowable concentrations in potable drinking water been determined. This method is not compatible with the water reclamation system.
possible pretreatment chemicals

an acceptable urine pretreatment agent should preserve the biological, chemical, and physical characteristics of fresh urine.

background

selection of pretreatment agents

we established criteria for selecting pretreatment candidates to consider for laboratory testing. these criteria ensured that the pretreatment candidates would not be detrimental to an astronaut’s health and would comply with nasa safety guidelines. the current pretreatment agents, oxone® and sulfuric acid, do not meet this requirement. the candidates must also be compatible with the cascade distillation system.

we identified chemicals with low toxicity by using the hazardous materials identification system as well as data on acidity, toxicity, volatility, and solubility. (the delivery system for solid chemicals requires solubility.) the pretreatment chemicals chosen for testing were boric acid, lactic acid, phthalic acid, sorbic acid, and fumaric acid. these chemicals are less hazardous than oxone®. we tested boric acid, sorbic acid, and fumaric acid in fall 2008 and lactic acid and phthalic acid in spring 2009.

laboratory tests

we tested pretreatment chemicals by using urine collected from eight students. the urine was stored at 4°C before testing, in keeping with nasa urine collection procedures.6 at the start of the experiments, the urine from the eight students was mixed in a large bottle. portions of the mixed urine were placed in smaller bottles and treated with the respective chemicals. experiments were carried out in triplicate in continuously stirred capped bottles. each experiment lasted 1 week. samples were collected and analyzed at 0, 20, 40, 60, and 120 minutes the first day and at 24-hour intervals for days 2–7.

an acceptable urine pretreatment agent should preserve the biological, chemical, and physical characteristics of fresh urine. therefore, we monitored biological, chemical, and physical changes in the urine after pretreatment. biological conditions were monitored by protein assay, ammonia concentration measurement, and use of a dissolved oxygen concentration probe. biochemical changes were monitored by determining changes in acidity (pH). physical changes, specifically the formation of precipitates, were quantified by measuring turbidity and the concentration of total suspended solids.

results

the pH, concentration of total suspended solids, and turbidity increased with time in the treated samples, indicating that all the chemicals stabilized urine for short-term but not long-term storage. likewise, data on concentrations of protein and ammonia indicated that the tested chemicals effectively stabilized urine in the short term but not the long term. data on the concentration of dissolved oxygen indicate that some biological activity occurred in the first 2 hours.

conclusion

our results indicate that the chemicals that we tested meet pretreatment requirements for short-term but not long-term storage. during short-term storage for the constellation program, the pretreated urine will travel to the wastewater collection tank to begin the distillation process. pretreatment must eliminate precipitation and bacterial growth for the first 2 hours.

our team plans to test ultraviolet-light disinfection as a pretreatment method. ultraviolet light would damage the DNA of any bacteria growing in urine, preventing them from producing harmful proteins. this approach would prevent accumulation of bacteria and
precipitates. Although some preliminary research has been carried out, the optimum intensity, distance from light source, and exposure time still must be determined. We will design experiments to determine these conditions. The Space Engineering Institute team at Texas A&M–Commerce will assist our team once we develop the experimental design.

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References
