ABSTRACT
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Extraction of Potable Water from Urine via Freeze Concentration
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Resource recovery, including that of urine water extraction, is one of the most crucial aspects of long-term life support in interplanetary space travel. This effort consequently examined an innovative approach to processing raw, undiluted urine based on low-temperature freezing. A strategy uniquely different from NASA's current emphasis on either 'integrated' (co-treatment of mixed urine, grey, and condensate waters) or 'high-temperature' distillation processing strategies, whereby this liquid freeze-thaw (LiFT) procedure avoids both chemical and microbial cross-contamination concerns while at the same time securing highly desirable reductions in likely energy requirement levels. In essence, this research effort investigated an innovative, first-generation eutectic freeze concentration strategy for extraction of potable water from urine. The existing project's experimental unit, which couples the sequential steps normally associated with conventional eutectic freeze crystallization (e.g., seed crystal growth followed by ice ripening, concentration, washing, extraction, and final ice-water recovery), has proven capable of generating high-quality product water, (i.e., greater than 99% reduction of contaminant concentrations; inorganics, organics, biological and antibiotics). However, the attainable levels of percentile water recovery have been constrained to ~30-35% levels due to sub-optimal conditions with the existing batch-type push-and-pull plunger steps used for the critical ice concentration and washing steps. Despite this fact, a theoretical water recovery value between approximately 85 and 95% for a continuously operating system has been determined based on the experimentally determined eutectic point of a binary urea / water solution, since the theoretical eutectic of urea is the major limiting contaminant in eutectic freeze concentration of a urine waste stream. Overall, this research effort focused on several aspects of freeze concentration, including an overview of the basic technology and its various pragmatic applications, a comparison of percent contaminant removal between a ternary urine solution and an ersatz urine solution, and the possibility of urea extraction for downstream crop fertilization use.