Fertilizer made from urine could enable space agriculture

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Manuring with man urine: researchers from Japan electrochemically create ammonia from urine to grow plants in space. Credit: Freepik

In extreme environments, even the most ordinary tasks can seem like unsurmountable challenges. Because of such difficulties, humanity has, for the most part, settled on grounds that were favorable for harvesting crops, herding cattle, and building shelters. But as we seek to expand the limits of human exploration, both on earth and in space, the people pioneering this search will undoubtedly face conditions that, for all intents and purposes, are not conducive to human habitation.

One of the foremost challenges facing any intended long-term settlement, be it in the Antarctic or on Mars (perhaps in the near future), is achieving some degree of autonomy, to enable isolated colonies to survive even in the event of a catastrophic failure in provisioning. And the key to achieving this autonomy is ensuring food sufficiency and self-sustenance. Unsurprisingly, therefore, space agricultural technology is one of the research topics currently being undertaken by the Research Center for Space Colony at Tokyo University of Science. The researchers here hope to spearhead the technological development for safe and sustainable space agriculture—with the aim of sustaining humans for a long time in an extremely closed environment such as a space station.

To this end, an innovative study was conducted by a team of Japanese researchers led by Junior Associate Professor Norihiro Suzuki from Tokyo University of Science—this study, published as a "Letter," made the front cover of the prestigious *New Journal of Chemistry* of the Royal Society of Chemistry. In this study, Dr. Suzuki and his team aimed to address the problem of food production in closed environments, such as those in a space station.

Realizing that farmers have used animal waste as fertilizer for thousands of years, as a rich source of nitrogen, Dr. Suzuki and his team have been investigating the possibility of manufacturing it from urea (the main component of urine), to make a liquid fertilizer. This would also simultaneously address the problem of human waste treatment or management in space! As Dr. Suzuki explains, "This process is of interest from the perspective of making a useful product, i.e., ammonia, from a waste product, i.e., urine, using common equipment at atmospheric pressure and room temperature."

The research team—which also includes Akihiro Okazaki, Kai Takagi, and Izumi Serizawa from ORC Manufacturing Co. Ltd., Japan—devised an electrochemical process to derive ammonium ions (commonly found in standard fertilizers) from an artificial urine sample. Their experimental setup was simple: on one side, there was a reaction cell, with a boron-doped diamond (BDD) electrode and a light-inducible catalyst or "photocatalyst" material made of titanium dioxide. On the other, there was a "counter" cell with a simple platinum electrode. As current is passed into the reaction cell, urea is oxidized, forming ammonium ions. Dr. Suzuki describes this breakthrough as follows, "I joined the 'Space Agriteam' involved in food production, and my research specialization is in physical chemistry; therefore, I came up with the idea of 'electrochemically' making a liquid fertilizer."

The research team then examined whether the cell would be more efficient in the presence of the photocatalyst, by comparing the reaction of the cell with and without it. They found that while the initial depletion of urea was more or less the same, the nitrogen-based ions produced varied both in time and distribution when the photocatalyst was introduced. Notably, the concentration of nitrite and nitrate ions was not as elevated in the presence of the photocatalyst. This suggests that the presence of the photocatalyst promoted ammonium ion formation.

Dr. Suzuki states, "We are planning to perform the experiment with actual urine samples, because it contains not only primary elements (phosphorus, nitrogen, potassium) but also secondary elements (sulfur, calcium, magnesium) that are vital for plant nutrition! Therefore, Dr. Suzuki and his team are optimistic that this method provides a solid basis for the manufacture of liquid fertilizer in enclosed spaces, and, as. Dr.

Suzuki observes, "It will turn out to be useful for sustaining long-term stay in extremely closed spaces such as space stations."

Humans inhabiting Mars might still be quite a distant reality, but this study surely seems to suggest that we could be on a path to ensuring sustainability—in space—even before we actually get there!

More information: Norihiro Suzuki et al, Formation of ammonium ions by electrochemical oxidation of urea with a boron-doped diamond electrode, *New Journal of Chemistry* (2020). DOI: 10.1039/d0nj03347b

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