green nephrology

Urine: from waste to fertilizer

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Population growth is a defining challenge for the 21st century. According to the United Nations, the world's population is projected to reach 8 billion on November 15, 2022, and to increase to around 9.7 billion by 2050. These trends have far-reaching implications for basic human needs—food, water, and shelter—which are further stressed by the climate change and depletion of natural resources.[1]

The use of fertilizers in agriculture is a global response to the staggering demand for food. Although the application of mineral (synthetic) fertilizers is useful to enhance crop yields and sustain soil fertility, it is balanced by high energy demands and negative environmental impact.[2] It is estimated that fertilizer production consumes approximately 1.2% of the world's total energy on an annual basis, with 90% due to nitrogen fertilizer production.[3] The widespread use of synthetic fertilizers has driven a massive increase in the amount of man-made nitrogen compounds in the environment, leading the United Nations to set a goal to halve nitrogen waste by 2030 and to improve nitrogen use efficiency.[4]

What is the link between these global issues and the kidney?

Mineral fertilizers are based on nitrogen (N), phosphorus (P), and potassium (K), the 3 macronutrients (NPK) used by crops. Nitrogen is a component of proteins, phosphorus is a component of nucleic acids, adenosine triphosphate (ATP), and lipids, and is important for energy transfers, and potassium regulates numerous intracellular processes including enzymatic activities, osmosis, and photosynthesis. Yet, these very nutrients are also abundantly excreted, and lost, in urine (Figure 1).[5] Recycling urine to recover these nutrients for use as fertilizers, a practice known as urine diversion (UD), was recently featured in *Nature*[6] and the *New York Times*,[7] triggered by the impact of the war in Ukraine on the shortage of synthetic fertilizers. In addition to recycling, benefits of UD would include saving vast amounts of water and decreasing constraints on sewage systems and the environment. A recent modeling study at a city scale in Vermont, Michigan, and Virginia indicated that the use of UD technologies and fertilizer production systems would lead to reductions of 29% to 47% in greenhouse gas emissions, 26% to 41% in energy consumption, and approximately half the freshwater use compared with conventional wastewater treatment systems.[8]

A crucial step to recover nutrients from urine is to isolate the urine from the rest of the waste and collect it. That practice requires new types of toilets, such as waterless urinals or almost invisible "Urine Trap" functions that can be applied to various UD-toilet types, an effort promoted by the Bill & Melinda Gates Foundation (Seattle, WA) (Figure 1a). In addition to practical considerations (e.g., facility of use, types of containers, etc.), the practice of UD also faces social and cultural challenges, including the fact that men should sit down to urinate in some UD devices.

Once the urine has been separated and collected, nutrients must be extracted. Constraints include smell, possible contamination with pathogens or pharmaceutical residues, and cost for storage and transportation of large volumes of urine. In rural, low-income settings, urine can be stored in containers to eliminate pathogens before being used directly in the fields. This low-cost approach has been used by a farmer's union community in south-central Niger, where urine, either alone or with animal manure, increased yields of the staple crop by approximately 30%.[7] Alternatively, urine can be

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