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Resource Recovery and Recycling in Sanitation is key to Health, Water and Food Security

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Abstract

The present study argues that the issue of sanitation and the solutions to it extends far beyond its mere access; any envisioned improvement in sanitation technology must strive to rectify the shortcomings in centralized wastewater treatment wherein end-of-pipe technologies have been favored. It is evident that with the concurrent trends of projected population growth and urbanization, the provisioning of improved sanitation facilities will necessitate greater efforts and socio-technical innovations than those in place today. We thus illustrate that simultaneous provisioning of 'access' and 'improved sanitation' through urine diversion and resource recovery can help create multiple-win scenarios in developing countries especially in terms of health, food and water security. As a pathway for initiating circularity in flow of resources from sanitation to agriculture, we demonstrate a process that enables continuous recycling of nutrients (urea) following the source separation of urine from a urine diversion toilet. To do this, we look towards cyclical adsorption-desorption systems in a fixed-bed column packed with renewable agro-waste based activated carbon. The study places emphasis on the sorption optimization for which a Box-Behnken experimental design with Response Surface Methodology was applied. It was concluded that a column bed depth of 45.45 cm, urine flow rate of 2 $L.h^{-1}$ and initial concentration of 20% allows 87.53% recovery of urea from human urine.

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Keywords: Sustainable agriculture; Circular economy; Ecological sanitation; Human urine; Column optimization; Activated carbon

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1. Introduction

Despite the widespread recognition of the importance of sanitation and hygiene for human survival and development, the progress in increasing its access and furthering its improvement have been markedly poor in the global south [1]. Human population, estimated to reach around 9.2 billion in 2075 [2] along with the concurrent increase in urbanization point towards a scenario wherein, the provision of improved sanitation facilities will necessitate greater efforts and socio-technical innovations than those of today. The World Health Organization defines improved sanitation as the 'connection to a public sewer, connection to a septic system, a pour-flush latrine, a simple pit latrine or a ventilated improved pit latrine' [3].

However, it must be acknowledged that while increasing the scope and reach of access to sanitation is necessary, sanitation and more importantly, hygiene does not end at the toilet, our barrier to microbial pathogens but extends far beyond it [4]. In implementing end-of-pipe treatment of human wastes at centralized municipal facilities served by a system that carries these waste through water-based sewerages we have unknowingly magnified the scale of possible disease transmission [5]. Nevertheless, what should not come as a surprise is the consequential contamination of water through the dumping of poorly treated or untreated human wastes that accounts for 1.7 million deaths every year, most of which are concentrated in the developing world [6]. In rural areas of the developing world open defecation, improper storage of wastes in pits, or wastes flushed into water bodies pose a daily threat to human health with nearly 44% of the population following these practices [7].

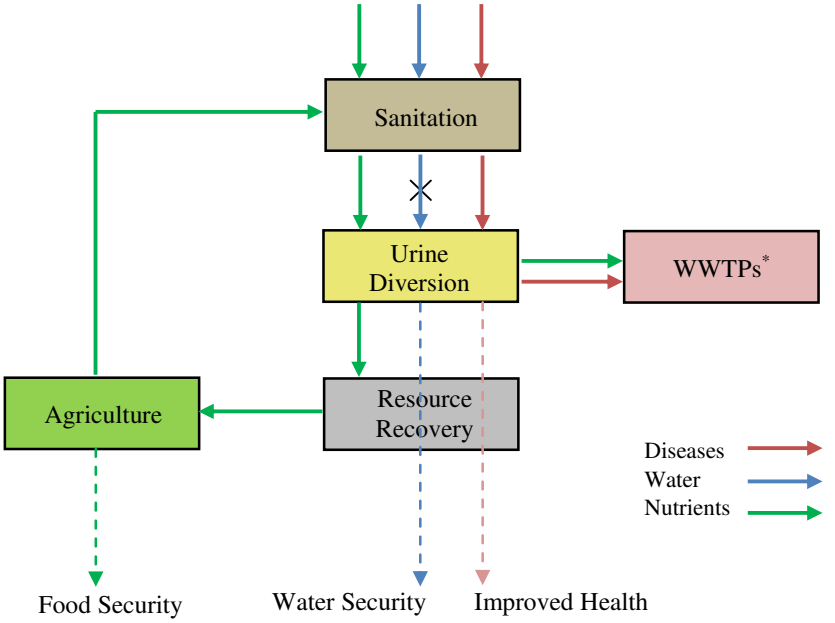

Fig. 1. Illustration of the Interlinkage between Resource Recovery and Health, Water and Food Security; *WWTPs: Wastewater Treatment Plants

An alternative to the business-as-usual approach to sanitation perceives human wastes as nutrient-rich resources that can be safely recovered and channeled back to agriculture where it can not only be assimilated but also serve to fertilize food crops. In this vein, human urine has been promoted as a potentially free and rich source of plant-required macronutrients to supplement agricultural productivity [8–10]. Indeed, an average person producing 500 L of urine annually could derive fertilizer value amounting to 5.6 kg of Nitrogen, 0.4 kg of Phosphorous, and 1 kg of Potassium [11]. Although human urine has been applied as a liquid fertilizer (diluted or otherwise) to derive agronomic value and increase plant yields in several areas, it has failed to live up to its potential to replace synthetic