Abstract

Recycling of nutrients between urban areas and farmland is a critical step towards an ecologically sustainable development. Human urine is the most nutrient-abundant part among the domestic waste components and urine separation has been proposed to achieve maximum recovery and recirculation of nutrients in Sweden. Several types of toilets and small-scale separation systems have been installed and tested. Storage and transportation of large amounts of urine, as well as spreading and hygiene, are the main obstacles in achieving system efficiency. The biggest problem today is reuse of anthropogenic nutrients on arable land.

The objective of this thesis was to evaluate and - if its possible - to optimise three different urine processing techniques:

- Volume reduction and nutrient concentration by partial freezing
- Recovery of nutrients as solid minerals, mainly as struvite
- Capacity and behaviour of zeolite, wollastonite and activated carbon as nutrient adsorbent materials in urine, and

to test plant availability of the resulting fertilizers in short-term pot trials on wheat under climate chamber conditions.

The results are presented in seven (I-VII) papers, which are the basis for the following conclusions:

- A volume reduction and nutrient concentration from human urine can be obtained by partial freezing. By these means more than 80% of both N and P can be concentrated in 25% of the original urine volume. Partial freezing can be used combination with struvite precipitation and adsorbtion.
- By addition of small amounts of MgO to human urine, struvite was obtained and identified as the main component. With struvite precipitation 98-100% of P, 22-64% of K and 2-5.6 % of Ca was recovered. C:a 25% of the N recovery is also due to struvite crystallization.
- Both natural zeolites (especially clinoptilolite) and wollastonite adsorbed ammonium rapidly, and the quality of the minerals, their grain size and the ion strength of the urine are important for the adsorption. Mineral adsorption used in combination with struvite precipitation could recover 64-80% of the N in laboratory tests. The N recovery from fresh and stored human urine was dependent upon both the amounts of MgO and zeolite added. The P recovery was 98-100% and mainly affected by MgO addition, but it was also affected by zeolite addition. Active carbon adsorbed N, reduced smell and colour, but did not adsorb P. Optimum combined recovery of N and P occurred at added concentra-tions of 0.1 g of MgO and 15-30 g of zeolite per liter stored and diluted urine. The optimal additions are dependent on the initial N and P concentrations of the urine.

In the tests on wheat (*Triticum aestivum* L.) the struvite/adsorbent mixtures showed better nutrient availability than the struvite alone, probably due to a synergistic effect between the struvite dissolution and zeolite ion exchange or active carbon release of nutrients. Both struvite, struvite/zeolite mixtures and struvite/active carbon mixtures acted as slow-release fertilizers. In tests with five substrates and five nutrient sources (two of them commercial fertilizers) the struvite/zeolite mixture from urine was similar to DAP and CaP as slow-release P-fertilizer.

Keywords: urine, partial freezing, struvite, zeolite, wollastonite, active carbon, mineral adsorption, nutrient recycling, *Triticum aestivum* L., fertilizer, sustainable, ecosan

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