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Review

Treatment processes for source-separated urine

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ABSTRACT

The separate collection and treatment of urine has attracted considerable attention in the engineering community in the last few years and is seen as a viable option for enhancing the flexibility of wastewater treatment systems. This comprehensive review focuses on the status of current urine treatment processes and summarises the properties of collected urine. We distinguish between seven main purposes of urine-treatment processes: hygienisation (storage), volume reduction (evaporation, freeze-thaw, reverse osmosis), stabilisation (acidification, nitrification), P-recovery (struvite formation), N-recovery (ion-exchange, ammonia stripping, isobutylaldehyde-diurea (IBDU) precipitation), nutrient removal (anammox) and handling of micropollutants (electrodialysis, nanofiltration, ozonation). The review shows clearly that a wide range of technical options is available to treat collected urine effectively, but that none of these single options can accomplish all seven purposes. Depending on the overall goal of the treatment process, a specific technical solution or a combination of solutions can be found to meet the requirements. Such combinations are not discussed in this paper unless they are explicitly presented in the literature. Except for 'evaporation' and 'storage', none of the processes described have so far advanced beyond the laboratory stage. Considerable development work remains to be done to optimise urine-processing techniques in order to create marketable products.

Contents

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1. Introduction

In the 1990s, various European groups began working on the same basic idea that separating urine at source could promote the sustainability of wastewater management (Kirchmann and Pettersson, 1995; Larsen and Gujer, 1996). All these approaches are based on the fact that urine contains most of the nutrients in domestic wastewater but makes up less than one percent of the total wastewater volume. Substantial separation of urine at source would thus allow nutrient recycling from a concentrated nutrient solution and at the same time obviate advanced nutrient removal, including nitrification, denitrification and phosphorus elimination (Wilsenach and Van Loosdrecht, 2004).

Urine-source separation presents many advantages, but also leaves many open questions. Besides the obvious advantages mentioned above, it also promises better ways of removing organic micropollutants originating from the human metabolism (Escher et al., 2006) and new ways of more efficient wastewater management when applied in the rapidly expanding and water-scarce cities in emerging countries (Huang et al., 2006; Medilanski et al., 2006). Furthermore, it offers increased flexibility and a possible shift away from investments in prototypic wastewater treatment plants towards mass-produced market goods (Larsen and Gujer, 2001). Flexibility is well illustrated by the many different treatment options discussed in this paper, ranging from nutrient removal to nutrient recycling, but the potential of mass-producing goods for wastewater treatment is seldom discussed. As an example, household treatment of urine seems inefficient and expensive with today's technology, but nobody has really examined how long it would take a market economy to develop smart mass-produced technology to do exactly that at competitive costs.

There are also many challenges in connection with source separation of urine. Once urine has left the body it becomes an unpleasant, smelly and unstable solution. It is locally produced and the present practise of dilution with large amounts of water is actually a perfect way of neutralising many of the more unpleasant aspects of urine. Furthermore, centralized wastewater management is a system with interdependent actors, and changing even a small part of it is extremely difficult (Larsen and Lienert, 2003). Finally, the question of transportation has not yet been solved. Larsen and Gujer (1996) suggested local storage and transport in sewers over night; the concept developed in Sweden is long-term local storage followed by truck transport (Hanaeus et al., 1997); in some pilot projects, multiple piping is tested (Peter-Fröhlich, 2002) and finally, on-site treatment may be possible in the future, provided that the technical difficulties can be overcome (Wilsenach et al., subm.). In the present paper, we concentrate on the possibilities and difficulties of the process engineering options.

Because the composition of urine reflects the average requirement of nutrients for plant growth (Heinonen-Tanski and van Wijk-Sijbesma, 2005), the use of urine as a fertilizer in agriculture is the most obvious application, but industrial usage or simple nutrient removal are other possible options. In this paper, we give an overview of the available technologies for treating source-separated urine, drawing on the experience gained with urine treatment in different situations (e.g. manned space flights) as well as on experience in the treatment of other high-strength liquid waste products.

2. Composition of urine

A large amount of data for urine is available in the medical literature. Urine from collection systems differs from these data, because (a) the composition is averaged over time and user group, (b) chemical alteration occurs in a non-sterile