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Options for urine treatment in developing countries

W. Pronk*, D. Koné

Eawag: Swiss Federal Institute of Aquatic Science and Technology Überlandstrasse 133, 8600 Dübendorf, Switzerland;
Tel. +41 (0)44 823 53 81; Fax +41 (0)44 823 53 89; email: wouter.pronk@eawag.ch

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Abstract

Interesting prospects of a urine-based product exist as a fertilizer in agricultural applications in developing countries. However, removal of pharmaceutical residues is essential to prevent long-term environmental hazards. In this paper, the perspectives of urine collection and treatment are discussed with a perspective of the developing countries. Scenarios are drawn up and discussed around the processes of electrodialysis, precipitation and evaporation. A new process combination is presented consisting of nitrification in sand filters and solar evaporation, which could potentially be implemented in developing countries. Such a scenario enables good perspectives for local business development, which is an important prerequisite for the implementation of new technologies in the developing countries.

Keywords: Source control; Urine; Nutrient recycling; Developing countries; Micropollutants; Fertilizer production

1. Introduction

In recent years, investigations with regard to separate collection and treatment of urine and faeces received increasing attention. Most of these investigations are aimed at areas where wastewater treatment is common practice, improving the environmental sustainability by removal of micropollutants or by recovering nutrients from urine. In developing countries, urine separation is often applied because of socio-economic reasons [1–3]. Traditionally, urine has been collected and used as a fertilizer in agricultural applications. This practice is still continued on a large scale, because of the high costs of commercially available fertilizers. Recently, the application of human-based fertilizers has attracted increasing attention, due to the strongly increasing prices of chemically produced fertilizers [4,5].

So far, there has been little attention to treatment options of urine for developing countries. The costs of treatment were considered to be prohibitive for application of complex technologies in many cases. A range of pollutants can occur in urine, including pharmaceutical compounds, natural and artificial hormones, pathogens. In view of the fact that the application of pharmaceuticals in developing and transition countries is increasing, the application of untreated urine on a large scale could lead to unforeseeable

* Corresponding author.

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Table 1
Concentrations and standard deviation (SD) of inorganic compounds in fresh urine

	Concentration (mol l^{-1})	(±SD)
Ammonia	0.034	0.01
Urea	0.27	0.05
Phosphate	0.024	0.003
Magnesium	0.0039	0.0008
Sodium	0.12	–
Calcium	0.0046	0.001
Potassium	0.056	–
Sulphate	0.016	0.005
Chloride	0.11	–

environmental risks [6]. Therefore, implementation of urine treatment methods deserves more attention.

As well as pharmaceuticals, it is important to notice that the largest part of nutrients in wastewater stem from urine, with about 80% of the nitrogen and 50% of the phosphor in wastewater originate from urine [7]. A typical composition of the inorganic compounds of fresh urine is shown in Table 1 (derived from [7,8]). Among these components, the elements of nitrogen (in ammonia and urea) and phosphor have a value as fertilizer compounds and are available in considerable concentrations.

Since phosphor is a depletable raw material, its recovery contributes to environmental sustainability. Nitrogen is not a depletable raw material, but it is present in urine in the form of ammonia or urea, which is a valuable material for use as a fertilizer. This would replace the chemical synthesis of these compounds, which requires energy and auxiliary materials. Therefore, nitrogen recovery from urine can result in a lower ecological burden in comparison to the use of chemically produced fertilizers [8].

The nutrients in urine reflect the components necessary for plant growth, which makes it suitable as a fertilizer in agricultural applications [9,10]. Application as raw materials for industrial purposes is in principle an alternative, but this possibility will not be discussed here.

Ultimately, in the case that also the faeces would be treated separately, the capital intensive structure of sewers and central WWTP infrastructure could become redundant. This could lead to cost savings on a longer term [11].

2. Goals of urine separation and treatment

As discussed above, micropollutants and pathogens impose a major threat on application of untreated urine. Besides from the removal of micropollutants, the concentration of nutrients in urine is low in comparison to commercial fertilizers. In the case where urine treatment facilities would be built in a centralized manner, transport distances can become important and larger storage capacities should be available at the point of application (farmers).

During storage of urine, urea hydrolyses spontaneously, resulting in the formation of ammonia and the pH increases to around pH 9 [12]. The pK_a of ammonia amounts 9.24 and thus, around pH 9 a considerable fraction of the ammonia (37%) occurs in the deprotonated form, which has a low solubility and a high Henry coefficient, and thus volatilization occurs when in contact with air. When urine is applied as a liquid fertilizer, volatilization results not only in ammonia loss, but also in an environmental burden due to acidification. Volatilization during application of a liquid fertilizer is a function of the liquid composition, the method of application (spraying, injection, irrigation, or other), soil composition and weather conditions. Fertilizer distribution systems exist which decrease the volatilization (e.g. by using injectors or irrigation), but such systems are relatively cost-intensive. Therefore, the intrinsic stabilization of ammonia in the fertilizer product should be preferred.

As indicated above, the concentrations of nutrients in urine are low compared to commercial fertilizers. The transport and storage volumes of untreated urine are consequently relatively high, which results in higher costs. Therefore, it is important that urine treatment processes increase the concentration of nutrients. In principle, both solid and liquid fertilizers can be produced and applied.

The process costs and added value of the product is an important aspect. A market- and business-driven implementation is considered to be the only possible mechanism for widespread application of urine treatment technologies in developing countries [13]. The costs of urine treatment include collection of the urine