Urine separation accomplished, what comes next? - Newest experiences of on-site treatment and transport by pipe or truck -

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Abstract

Urine diversion (UD) systems are an innovative concept towards a resource-oriented and water saving sanitation system. From Sweden the technology spread over Europe. Firstly, installed in some buildings where the users had a specific "environmental" motivation, the technology widened and is reaching now a broader public (e.g. SolarCity in Linz, Austria (Oldenburg et al., 2009), office building of the Swiss Federal Institute of Aquatic Science and Technology (Larsen and Lienert, 2007), main building in the GTZ headquarters in Eschborn, Germany (Winker and Hartmann, 2010)).

First investigations show that users appreciate the urine diversion concept (recycling of nutrients and water savings) but are unhappy with the inconveniences caused by the technical design of the UD flush toilets installed so far (Lienert and Larsen, 2010; Blume and Winker, 2011). Nevertheless, the technology implementations so far show that urine diversion is a realistic option for future sanitation planning in buildings (von Muench and Winker, 2009). Urine separation of 60-75% can be achieved (Larsen and Lienert, 2007). However, the remaining questions and discussions are targeting the next steps.

The relevant options for the subsequent management of the urine are

- direct treatment within the building or in the direct neighbourhood to achieve nutrient recycling and volume reduction. Potential treatment processes are steam stripping, evaporation, MAP precipitation and crystallization;
- transport towards a central treatment unit. Transport can be undertaken by means of a piping system, gravity or pressure based, as well as a wheel based pick-up system including collection tanks and pick-up trucks;

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- or transport to a reuse site for direct application.

Most of the potential treatment processes are tested in lab and pilot scale only. However, MAP precipitation is a process implemented in various treatment plants for phosphorus recovery from wastewater; e.g. treatment of process water of anaerobic sludge digestion (Berliner Wasserbetriebe, 2010), within the AirPrex procedure (P.C.S., 2010) and by the NuReSys technology (AKWADOK NuReSys, 2010). Moreover, also the recovery of phosphorus by struvite production out of the urine stream is brought further e.g. by the Dutch company GMB who call their struvite product SaNiPhos (GMB, 2010) and by the German company HUBER SE (Antonini et al., 2009).

On-site treatment

The potential of MAP precipitation as onsite treatment installed at the GTZ headquarters in Eschborn, Germany (Winker et al, 2010) is described as the main treatment option in this paper.

The collected urine is treated in a precipitation reactor of HUBER SE with a treatment capacity of 400 l of urine per day. The reactor is equipped with remote control and consists of a precipitation chamber with stirring device, a dosing unit for magnesium oxide (MgO), and an application and a filtration unit holding five filter bags. After addition of MgO magnesium ammonia phosphate (MAP) is formed (from added magnesium and ammonia and phosphate contained in the urine). The crystals can be separated and recovered easily from the liquid phase by settling and subsequent drying.

Currently the reactor is filled with 30 l of urine per cycle. 9 g MgO is added to each cycle. Approximately 1 kg of paste-like MAP can be taken out of each filter bag after the liquid dripped of in the drying box. The composition of the dried MAP (determined in first samples) is 110 g P kg^{-1}, 42 g N kg^{-1} and 100 g Mg kg^{-1}. The pharmaceutical residues contained in urine are not included in the precipitated MAP.

The energy consumption of the reactor is minor, as energy is only needed for the MgO dosing unit, the stirring unit and the rotation of the filter bags in the reactor. Operation costs for filter bags, which have to be replaced from time to time, as well as for magnesium oxide have to be considered. The filling of the MgO conveyer, the exchange of the filter bags and the emptying of the filter bags are currently manual work resulting in high labour costs. A detailed economic analysis is in process.

Transport

The option of transport by pipe or by vehicle towards a central treatment unit was investigated by Oldenburg (2007). He found that the multiple sewer system which is required for a pipe-based transport system would result in higher investment costs. This finding can be confirmed by an investigation performed for the in-house sanitation installations at the GTZ headquarters (Lazo Paéz, 2010). Oldenburg (2007) who calculated the costs for a system including separation of urine, brown- and greywater even concluded that the higher investment costs control the total project costs. The costs for connection pipes and the sewer for a separate urine transport in a 3-piping system were found to be at least about twice as high as the conventional solution. From the investigated scenarios the one with urine collection at household level and pick-up from thereon was in terms of total project costs and compared to the other new sanitation scenarios also in terms of investment costs the one with the lowest costs.

So far, the investigations performed (Tettenborn, in preparation; Tettenborn et al. 2009) show that the most reasonable transport system for cities seems to be a combination of short distance piping systems to collection tanks and a pick up and transport from thereon with trucks. Tettenborn (in preparation) showed that independent of the level of collection (each household, neighbourhood, community) in an European context personnel costs were higher than fuel costs. Also costs for vehicles accomplishing collection and transport were always higher than costs for collection tanks.

Outlook

Such scenarios are especially interesting for a metropolitan area as Beijing. Here, a large amount of urine is produced in the urban area but can only be used in the farer districts of the Beijing region. Those districts play are key role in the food supply of the city. Based on the population in Beijing in 2006 (15.8 million), with 100% connection rate to urine-diversion systems, taking the nutrient loss during collection and treatment into account, 84% of nitrogen and 45% of the phosphorus demand of agriculture could be covered by MAP and a NH_3-solution produced by urine treatment (Tettenborn et al., 2009). Moreover, based on the developed scenarios, 57% of the energy involved in fertilizer production and nutrient elimination in WWTPs could be saved at the same time.

The techniques and models presented so far show the potential of source-separating systems as well as they point out existing barriers. Still no areas exist or are planned to collect urine of whole neighbourhoods or communities. And large numbers are required to organise a treatment or transport system. Moreover, the production costs for fertilizer products from urine are still higher than the prices they could yield on the market which range for MAP from 250 to 380 € t^{-1}. Also, prices on the market not necessarily reflect the product value. Esemen and Dockhorn (2009) calculated the theoretic for MAP. A theoretic product value of 763 € t^{-1} was determined which is about two to three times higher than prices for MAP products on the market. Production costs for MAP from source separated urine could be most likely covered by this theoretical product value. Additionally examples such as the one of Berliner Wasserbetriebe (2010) show new technologies can already be economical in first niches. Most likely it is only a question of time when also urine diversion systems become economical as well.

Reference

AKWADOK NuReSys, 2010. Nutrient recovery systems, recycling nature’s essentials. Company brochure, Deerlijk, Belgium.

Antonini, S., Paris, S. and Clemens, J., 2009. Nitrogen and phosphorus recovery from human urine. In: Arnold, U. and Gresens, F. (eds.). Closing nutrient cycles in decentralised water treatment systems in the Mekong Delta, final report of the SANSED project, University of

Bonn, Bonn, Germany. URL: http://www2.gtz.de/Dokumente/oe44/ecosan/en-sansed-report-final-2009.pdf

Berliner Wasserbetriebe, 2010. Berliner Pflanze. Der mineralische Langzeitdünger aus Klärschlamm. Company brochure, Berlin, Germany.

Blume, S. and Winker, M., 2011. Three years of operation of the urine diversion system at GTZ headquarters in Germany: user opinions and maintenance challenges. *Water Sci. Tech.*, accepted for publication.

Esemen, T. and Dockhorn, T., 2009. Ökonomische Aspekte der Phosphorrückgewinnung aus Abwasser und Klärschlamm. *Korrespondenz Abwasser - Wasserwirtschaft, Abwasser, Abfall* **56**, 790-796.

GMB, 2010. SaNiPhos. Obheusden, Netherlands. URL: http://www.saniphos.eu/

Larsen, T. and Lienert, J., 2007. Novaquatis final report. NoMix - A new approach to urban water management. Eawag, Dübendorf, Switzerland. URL: http://www.novaquatis.eawag.ch/publikationen/final_report_E

Lazo Paéz, A. 2010. Economic feasibility study of the new sanitation system in Building 1 in the GTZ headquarters. Master thesis, Institute of Wastewater Management and Water Protection, Hamburg University of Technology, Hamburg, Germany. URL: http://www.saniresch.de/images/stories/downloads/MasterThesisAndresLazo.pdf.

Lienert, J. and Larsen, T., 2010. High acceptance of urine source separation in seven European countries: a review. *Environ. Sci. Tech.* **44**, 554-566.

Oldenburg, M., Werner, C., Schlick, J. and Klingel, F., 2009. Case study of sustainable sanitation projects. Urban urine diversion and greywater treatment system Linz, Austria. Sustainable Sanitation Alliance. URL: http://www.susana.org/docs_ccbk/susana_download/2-66-en-susana-cs-austria-linz-solar-city-2009.pdf

Oldenburg, M., 2007. Final cost calculation report for the demonstration project "Sanitation Concepts for Separate Treatment of Urine, Faeces and Greywater" (SCST), OtterWasser GmbH, Lübeck, Germany. http://www.kompetenz-wasser.de/index.php?id=295&type=0&jumpurl=fileadmin%2Fuser_upload%2Fpdf%2Fforschung%2Fscst%2FSCST_Cost_Calculation_Report.pdf

P.C.S., 2010. AirPrex® procedure ...and the fertiliser is for free. Company brochure, Hamburg, Germany.

Tettenborn, F.; Stoll, N.; Wang, S.; Winker, M.; Otterpohl, R. (2009): Inventory of agricultural demand and value of the application of ecosan fertilizers in SWITCH demonstration cities - Inventory of agricultural demand in Accra / Demand and distribution of ecosan fertilizers in Beijing's Agriculture, 018530 - SWITCH, Sustainable Water Management in the City of the Future, Integrated Project -Global Change and Ecosystems - within the sixth framework program (2002-2006), D 4.1.5

Tettenborn, F. in preparation. Aspects of a system for separate urine collection and treatment - selected techniques, potential implementation in an urban context. Hamburg, Germany.

von Muench, E. and Winker, M., 2009. Technology review. Urine diversion components, Report German Development Cooperation, Eschborn, Germany. URL: http://www.gtz.de/en/dokumente/gtz2009-en-technology-review-urine-diversion.pdf.

Winker, M., Paris, S., Heynemann, J. and Montag, D., 2010. Phosphorrückgewinnung aus Urin mittels Struvitfällung in einem Frankfurter Bürogebäude. Fbr-wasserspiegel 16, 3–4.