

Urine separation - Swedish experiences



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See also:
 Case Study "[Gebbers Housing project](#)" in the case study section of EcoEng-online

Abstract

Urine is the urban waste fraction containing the largest amounts of nutrients. It contains approximately 70% of the nitrogen and 50% of the phosphorus and potassium in all household waste and wastewater fractions. During the 1990-ies, urine separation has been thoroughly investigated in several research projects in Sweden. In these measurement between 50% and 85% of the urine has been source separated, depending on the motivation and dedication of the inhabitants.

The initial problems connected with the system, mainly stoppages in the toilet u-bend, have now largely been overcome and now the system functions without any large problems.

The urine is sanitised by enclosed storage and recommendations have been developed. The storage period recommended depends on which crops that are to be fertilised, storage conditions and type of system.

The fertilising effect of urine to cereals has for nitrogen been found to be close to that for chemical fertiliser (~ 90%) and for phosphorus to be equal to that for chemical fertiliser. The measured ammonia emissions after fertilisation to cereal crops has been 5% ± 5%. If the system is correctly designed, the ammonia emissions from collection, transport and storage are insignificant (<1%).

The environmental effects of urine separation have been investigated in several studies. They have all concluded that compared to a conventional sewage system, urine separation will recycle much more plant nutrients, especially nitrogen and will have lower water emissions of nutrients. Generally, urine separation has also been found to save energy. Urine separation has in all studies been found preferable to the conventional system from an environmental point of view.

Urine separation is now well documented and can be recommended for implementation under most conditions.

Introduction

Urine is the urban waste fraction containing the largest amounts of nutrients. It contains approximately 70% of the nitrogen and 50% of the phosphorus and potassium in all household waste and wastewater fractions, while the flow of urine is comparatively small (Figure 1).

This means that it is interesting to separate the urine at the source, i.e. the toilet. The urine separating toilets, were re-invented in Sweden in the 1980-ies, made the construction of urine separating systems possible. In these, the urine is source separated. The urine is then piped to collection tanks, stored and used as a fertiliser for agricultural and horticultural crops.

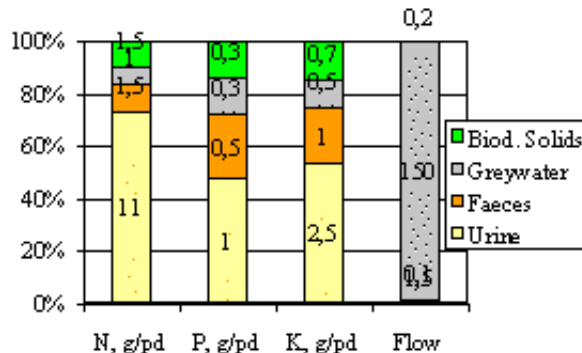


Figure 1. Distribution of nutrient flows, in grams per person and day (g/pd), and mass flow, in kg per person and day, of household waste and wastewater in Sweden (SEPA, 1995; Sonesson & Jönsson, 1996; Kärrman et al., 1999).

Research in Sweden

Urine separation received much interest from researcher in Sweden during the 1990-ies. There were

three important research groups. The largest group was centred in the Uppsala-Stockholm region and consisted of researcher from SLU (Swedish University of Agricultural Sciences), SMI (Swedish Institute for Infectious Disease Control), JTI (Swedish Institute for Agricultural and Environmental Engineering) and KTH (Royal Institute of Technology). Below the research centres are listed, which aspects that they mainly have been studying and the names of the most active researchers.

- SLU, SMI, JTI, KTH
 - Hygiene, function, i.e. degree of separation, functional problems, fertilising effects, resource usage, emissions, developing countries
 - *At SLU; H. Jönsson, B. Vinnerås, at SMI; C. Schönning (prev. Höglund), T.A. Stenström and at JTI A. Richert Stintzing*
- Luleå Technical University
 - Exergy analysis, storage, drying, nitrification
 - *D. Hellström, E. Johansson, J. Hanaeus*
- Gothenburg University
 - Algae growth, conc. (struvite, ion ex, freezing, etc)
 - *M. Adamsson, B.B. Lind, Z. Ban, S. Bydén*

In addition to these groups some individual researchers in other places have also been active.

To finance this research the housing and agricultural sectors have made the largest contributions. The water and wastewater sector has also made a large contribution, while the contributions by other sectors of society, for example the environmental sector, have been small. The most important financing bodies have been: BFR (Swedish Council for Building Research), SLF (Swedish Farmers Foundation for Agricultural Research), VA-FORSK (Swedish Municipalities Sewage Research Program), Swedish Board of Agriculture, Stockholm Water Inc., National Cooperation of HSB and Stockholmshem Inc.

Results

The results presented below are mainly based the research done by the group centred around SLU and SMI. The results presented below are presented in more detail by Jönsson et al (2000), Höglund (2001), Jönsson et al. (1997), Jönsson et al. (1999) and Johansson et. al. (2001), Lindgren (1999) and Vinnerås (2001).

Hygiene

The hygienic research carried out is described in an article by [Mats Johansson and Miriam Nykvist](#) in this newsletter, therefore the results are here given extremely short. Pathogens were found to die off during storage and recommendations have been developed for how the urine should be sanitised via storage before being used as a fertiliser. The storage period recommended depends on which crops that are to be fertilised, storage conditions and type of system (small or large system).

Toilet - function and degree of separation

The function of the toilet and the degree of separation have been studied in measurements in five different housing districts with all together 315 inhabitants (Table 1). Most of the measurements have lasted around 30 consecutive days. The apartments in most of the districts were rented, but the eco-village Understenshöjden was tenant owned. The inhabitants in Understenshöjden had decided themselves that they wanted a urine separating sewage system in the eco-village. In the other districts, the house owner had installed urine separation without asking the tenants.

Thus, the inhabitants of Understenshöjden were much more informed, motivated and dedicated than the inhabitants in the other districts. The tenants in Miljöhuset, on they other hand, knew very little about urine separation and why they had urine separating toilets. One reason for this is that they on average moved much more frequently than in the other houses. As is seen in Table 1 the motivation and dedication by the inhabitants have a profound impact on the percentage of urine actually being source separated.

	Understen- höjden	Palster-nackan	Hushagen	Ekoporten	Miljöhuset
Inhabitants	160	50	8	35	62
Toilet	BB Dn	BB Dn	WM DS	BB Dn	BB Dn
Apartment type	Tenant owned eco-village	Rented	Rented	Rented	Rented
Urine-N collected, %	78	59	65	>62	46
Urine-P collected, %	74	61	>65	62	>40
Urine-K collected, %	95	70	58	87	49

Table 1. Investigated housing districts, and the calculated percentage of source separated nutrients in each district. In some measurements some phosphorus or nitrogen was probably lost in the collection and handling of the probes. Thus, these numbers are minimum figures and in the table they are given in italics. BB Dn: Dubletten, BB Innovation & co.. WM DS: DS, Wost Man

The conclusions from these measurements are:

- Motivation, information and feedback are important for the amount of urine actually being source separated!
 - Normally 60-90% of the urine produced is source separated.
- Avoid metals in the system. Urine is very corrosive and at excretion the concentrations of heavy metals are very low. Metals in the system cause contamination, which is easy to detect.
- The nutrient content of the source separated urine, mixed with 1-2 parts of flush water, expressed as the N:P:K ratios in % is approximately 0.3:0.03:0.1.
- If the inhabitants are at home 16 h/day the systems should be dimensioned for a flow of:
 - 1,5 litre/person, day (550 litre/person/year) if the toilet Dubbletten by BB Innovation & Co Inc. is used, and
 - 2,5 l/pd (910 l/person/year) if the toilet DS by Wost Man Ecology Inc. is used.
 - The amount of flush water saved by a urine separating system depends on the motivation. Savings of 80% are possible, but so far only up to 50% have been measured.

The function of the toilets were studied in two questionnaires, one in 1997 to 96 households and one following up in 1999 to 73 households. The two toilets studied were Dubbletten and DS. The most important problem found was that stoppages normally appeared in the u-bend of the toilet after a short time. These stoppages were a big problem, since the users did not know how to clear them.

Studies of the stoppages showed that 76% of them mainly consisted of precipitation, mainly calcium and magnesium ammonium phosphates, forming on hairs and fibres. These stoppages could easily be cleared with a mechanical snake or with caustic soda.

The remaining 24% of the stoppages consisted of precipitation on the pipe wall, which could efficiently be cleared with caustic soda. From talking to users, now when they know how to clear the stoppages, they say that the stoppages are not a problem any more. Like stoppages in the u-bend of the shower, they appear once or a few times a year and are easy to clear.

Some users also complained about inadequate flushing of the urine bowl and of odours. However, these problems were small, and the toilet manufacturers have been trying to deal with them, so they might not exist on new installations.

The following recommendations were derived from the studies:

- The flow from the urine bowl should not be hindered by anything (hairs and fibres should be flushed away by the water when cleaning the toilet).
- It should be possible to use a mechanical snake to clear the urine u-bend.
- The urine u-bend should be easy to access and disassemble (which probably will not be needed, but just in case).
- The urine bowl should suit also men urinating while standing up, otherwise the percentage of urine actually separated will drop.
- The toilet should be comfortable and easy to use (try it before purchase)
- The flush of the urine bowl should be effective and use little water (≤ 0.1 l/urination).
- The toilet or system should contain no metal in contact with the urine mixture.
- The toilet should be easy to clean.

Pipes and tanks

Measurements and observations by video and naked eye of pipes and tanks have resulted in the following results and recommendations:

- Installations must be water tight (pipes should be welded or similar). Ground water leaking in was the most frequent problem found!
- Horizontal pipes should have a slope of at least 1% and a diameter of >75 mm (preferably 110 mm), because sludge continuously precipitates from the urine mixture. The sludge is easy to flush away.
- The pipes should have good opportunities for inspection and cleaning.
- The system should not be ventilated. If it is correctly constructed the total ammonia emission from collection, transport and storage is <1%.
- The tanks should be filled from the bottom and have the man hole close to the incoming pipe.

Fig. 2: Mechanical snake used for cleaning urine separating toilets



Fertilising effect

The fertilising effect of source separated urine has been investigated in two pot experiments, a three year field experiment and a one year field demonstration.

Source separated human urine is a well balanced complete fertiliser and its nutrients are readily available to plants. The nitrogen effect was found to be close to that for chemical fertiliser (~ 90%). It varied between 70% and more than 100% between different years. The phosphorus effect was equal to that for chemical fertiliser.

In the experiments, the ammonia emission after spreading varied between less than 1% and 10%. It averaged around 5%. No toxic effects have been observed in these or other experiments with cereals. The urine has been spread on the soil or in the growing crop. However, the nitrogen in stored urine is mainly found as ammonia and it is well known that some crops easily burn if ammonia is applied on the plants themselves.

The concentrations of heavy metals in source separated urine are very low. For example the Cd/P ratio was around 2 mg Cd per kg of P. In spite of this, the European Union (EU) only allows the use of source separated urine in conventional farming, but not in organic farming. It is very important that urine in the future also will be allowed in organic farming.

Emissions and resource usage

The computer package ORWARE was used to model and simulate the urine separating sewage system of Palsternackan, where the faecal water (faeces, paper and flush water) and greywater were treated in the central sewage treatment plant in Stockholm. The calculated environmental effects and resource usage of this system were compared to those calculated for a conventional sewage system, using conventional toilets and treating all wastewater, including the urine, in the central treatment plant. In both systems 50% of the generated sewage sludge was assumed to be spread on arable land and 50% was assumed to be landfilled.

Urine separation decreased the emissions of nitrogen and phosphorus to water by 55% and 33%, respectively. A large fraction of the plant nutrients were recycled, instead of being led to the treatment plant. Thus, the urine separating system, compared to the conventional system, recycled 27 times more plant available nitrogen, 35% more phosphorus and 25 times more potassium.

The levels of heavy metals were very low in the urine. Mercury, cadmium and lead were all below their detection limits, 0.0004, 0.0013 and 0.027 mg/l respectively. These values corresponded to: < 1 mg Hg/kg P, <4 mg Cd/kg P and <89 mg Pb/kg P. In the measurements at Ekoporten, performed after this ORWARE study, the detection limit for cadmium was lowered and it was found that the Cd/P ratio was 2 mg Cd/kg P. Thus, urine is a very clean fertiliser.

Energy, 24 MJ/person and year, was required for transporting the urine mixture 33 km with a truck and trailer to a farm and for spreading it as a fertiliser. However, the decreased nutrient load on the sewage system meant that 31 MJ/person and year were saved in the sewage system. In addition, the source separated urine replaced mineral fertilisers, which would have required 75 MJ/person and year to produce. Thus, urine separation saved in total 82 MJ/person and year. A sensitivity analysis showed that the urine mixture could be transported 220 km by truck and trailer before the urine separating system used as much energy as the conventional one.

Urine separation has also been investigated in a number of other environmental systems analyses using the methods life cycle assessment and mass flow analysis. These studies have been using a variety of data and assumptions. Considering the environmental impacts and the use of natural resources, they have all concluded that urine separation is preferable to the conventional sewage system (Bengtsson et al., 1997; Bjuggren et al., 1998; Kärrman et al., 1999; Kärrman & Jönsson, 2001; Jernlid & Karlsson, 1997; Tidåker & Jönsson, 2001; Tillman et al., 1997). Therefore, the conclusion that the sewage system is improved if it is supplemented with urine separation seems robust. It seems to hold under most conditions and assumptions. Urine separation improves the sewage system more, when the reduction achieved in the sewage treatment is low.

References

- Bengtsson, M., Lundin, M., Molander, S. 1997. Life cycle assessment of wastewater systems — Case studies of conventional treatment, urine sorting and liquid composting in three Swedish municipalities. Rapport 1997:9. Technical Environmental Planning, Chalmers Technical University, Gothenburg, Sweden
- Bjuggren, C., Björklund, A., Dalemo, M., Oostra, H., Nybrant, T., Sonesson, U. 1998. Systemanalys av avfallshantering i Stockholm — slutrapport. AFR-Report 215, AFN, Naturvårdsverket.
- Höglund, C. 2001. Evaluation of microbial health risks associated with the reuse of source-separated human urine. PhD thesis, Department of Water and Environmental Microbiology, Swedish Institute for Infectious Disease Control (SMI). Stockholm, Sweden.
- Jernlid, A-S., Karlsson, K. 1997. Väta toalettssystem - driftstudier och utvärdering med livscykelanalys i Södra Valsängs ekoby. Examensarbete 1997:6, VA-teknik, Chalmers tekniska högskola. Göteborg.
- Johansson, M., Jönsson, H., Höglund, C., Richert Stintzing, A. & Rodhe, L. 2001. Urine separation — closing the nutrient cycle (English version of report originally published in Swedish). Stockholm Water Company. Stockholm., Sweden.
- Jönsson, H., Stenström, T.A., Svensson, J. & Sundin, A. 1997. Source separated urine - Nutrient and heavy metal content, water saving and faecal contamination. *Water Science and Technology*35(9):145-152.
- Jönsson, H., Vinnerås, B., Höglund, C. & Stenström, T.-A. 1999. Source separation of urin (Teilströmerfassung von Urin). *Wasser & Boden* 51(11):21-25.
- Jönsson, H., Vinnerås, B., Höglund, C., Stenström, T.A., Dalhammar, G. & Kirchmann, H. 2000. Källsorterad humanurin i kretslopp (Recycling source separated human urine). In Swedish, English summary. VA-FORSK Report 2000•1. VA-FORSK/VAV. Stockholm, Sweden..
- Kärrman, E., Jönsson, H., Grubberger, C., Dalemo, M. & Sonesson, U. 1999. Miljösystemanalys av hushållens avlopp och organiska avfall — syntes av hanteringssystem undersökta inom FoU-programmet "Organiskt avfall som växtnäingsresurs" (Environmental systems analysis of wastewater and solid organic household waste from households — synthesis of handling systems studied in the R&D programme "Organic waste as a plant nutrient resource"). VA-FORSK Report 1999•15.
- Kärrman, E., Jönsson, H., Grubberger, C., Dalemo, M., Sonesson, U., Stenström, T.A. 1999. Miljösystemanalys av hushållens avlopp och organiska avfall — syntes av hanteringssystem undersökta inom FoU-programmet "Organiskt avfall som växtnäingsresurs". VA-FORSK Rapport 1999-15. VAV AB,

- Stockholm.
- Lindgren, M. 1999. Urinsorterande toaletter — rensning av stopp samt uppsamling och attityder. (Urine separating toilets - clearing of stoppages and collection and attitudes). Departemental Note 99:05, Department of Agricultural Engineering, SLU. Uppsala.
 - SEPA, 1995. Vad innehåller avlopp från hushåll? (What does wastewater from households contain?). Report 4425, Swedish Environment Protection Agency, Stockholm, Sweden. (In Swedish)
 - Sonesson, U., Jönsson, H. 1996. Urban biodegradable waste amount and composition - Case study Uppsala. Report 201, Department of Agricultural Engineering, SLU. Uppsala, Sweden.
 - Tidåker, P. & Jönsson, H. 2001. Life cycle assessment of source-separated urine as fertiliser in wheat production — initial results. Proceedings of International Conference on LCA in Foods, Gothenburg, Sweden, 26-27 April. ISSN-0280-9737, SIK-Dokument 143, SIK. Gothenburg, Sweden.
 - Tillman, A-M., Svingby, M., Lundström, H. 1996. Livscykelanalys av alternativa avloppssystem i Bergsjön och Göteborg — Delrapport från ECO-GUIDE-projektet. Rapport 1996:1. Avdelningen för teknisk miljöplanering. Chalmers tekniska högskola, Göteborg.
 - Vinnerås, B. 2001. Faecal separation and urine diversion for nutrient management of household biodegradable waste and wastewater. Licentiate thesis, Report 244, Department of Agricultural Engineering, SLU. Uppsala, Sweden.
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