Potentials for greywater treatment and reuse in rural areas

Elke Müllegger [1,2], Günter Langergraber [1,2], Helmut Jung [1,2], Markus Starkl [1], Johannes Laber [1]

[1] IWGA-SIG - Department for Sanitary Engineering and Water Pollution Control
BOKU - University of Natural Resources and Applied Life Sciences Vienna
Muthgasse 18, A-1190 Vienna, Austria
e-mail: elke.muellegger@boku.ac.at

[2] EcoSan Club (http://www.ecosan.at)
Neulerchenfelderstrasse 9/32, A-1160 Vienna, Austria
e-mail: ecosanclub@gmx.at

Keywords

Cost comparison, greywater treatment, reuse, single houshold solutions

Abstract

This paper compares various ways to deal with greywater (wastewater from sources others than the toilet: e.g. kitchens, bathrooms and laundry) especially for small-scale solutions – single households and small settlements. General considerations on the treatment of greywater will be discussed as well as the advantages and disadvantaged of various treatment technologies. Finally possibilities and limitations for discharge and reuse of the end-product – treated greywater – will be discussed including health hazards. The investment and operational costs calculated for different scenarios of wastewater treatment for a single household with and without greywater separation and/or treatment show a clear economic advantage of the scenarios with greywater separation compared to the collection and treatment of the total wastewater.

Introduction

The sustainability of conventional sanitation concepts (which consist of a sewerage system and a wastewater treatment plant – technical or natural treatment systems), compared to alternative solutions based on source control and separation of the wastewater's constituent parts, have been heavily discussed throughout the world in recent years. Major projects dealing with that question are e.g. Swedish Urban Water, Swiss Novaquartis, German Lambertsmühle and the Austrian project “Applied strategies towards sustainable sanitation” (Starkl & Haberl, 2003).

It is commonly known that the main fraction of the volume of domestic wastewater comes from sources others than the toilet (e.g. kitchens, bathrooms and laundry). The water quality of this so called greywater is very site-specific, varying in strength and composition. Generally it can be said that greywater contains only low fractions of organic matter, nutrients and additionally has a low microbial contamination (Laber & Haberl, 1999).

By thinking about concepts for the future a separate collection of blackwater (wastewater from toilets) and greywater is a logical consequence. Separation of urine and faeces leads up to a reduction of 90 % nitrogen as well as 80 % phosphorus in the remaining wastewater (Laber & Haberl, 1999). The remaining relative harmless greywater can be reused after an adequate treatment to safe valuable fresh water resources as well as to safe costs. Sustainable concepts and a change of the personal behaviour of the users can therefore lead to a more ecological sanitation.

Both the quantity and the quality of greywater can be controlled at the household level. Any strategy for managing greywater can be made easier by water conservation measures and attention to the soaps, cleansers and other household chemicals used. The amount of greywater generated can be significantly reduced through behavioural changes, good maintenance of pipe and water taps, and the use of water-saving devices. About 2/3 of the total wastewater volume can be assumed to be greywater (Laber & Haberl, 1999; Jefferson *et al*., 2001).

Compared to municipal wastewater greywater contains less nutrients. The BOD_5 : N : P ratio is about 100 : 20 : 5 for typical municipal wastewater and about 100 : 4 : 1 for greywater (Laber & Haberl, 1999). The optimal ratio for heterotrophic growth is 100 : 5 : 1. Therefore a biological treatment of greywater without addition of nutrients is possible. The microbiological contamination of greywater is typically about a factor 10 lower compared to municipal wastewater. However the concentrations for phosphorus, heavy metals, and xenobiotic organic pollutants are around the same level (Ledin *et al*., 2001).

Greywater treatment and reuse

A number of technologies have been applied for greywater treatment worldwide varying in both complexity and performance (Jefferson *et al*., 2001). These technologies range from systems for single households (e.g. using disinfected untreated greywater for toilet flushing), to physical treatment systems (e.g. sand filters or membranes), biological treatment options (e.g. rotating biological contactors and membrane bioreactors), and natural treatment systems (e.g. constructed wetlands and infiltration systems). The experience has shown that especially rotating biological contactors and constructed wetlands are suitable for greywater treatment including disinfection of the treated greywater when reuse is considered (Lange & Otterpohl, 2000).

A mechanical pre-treatment is required when constructed wetlands are used as a main treatment stage. Using horizontal subsurface flow constructed wetlands a good removal efficiency for organic matter (> 90 %) and pathogens (up to a factor of 100) can be achieved. If nitrification is required only subsurface flow constructed wetlands with vertical flow and intermittent loading can be used. Compared to technical solutions (e.g. rotating biological contactor) constructed wetlands are relatively easy to maintain and operate resulting in low operating costs (however, low maintenance requirements does not mean no maintenance). In general natural treatment systems provide a more stable and robust than small-size technical systems. Disadvantages of natural treatment systems are that they require a larger area compared to technical systems and they can not be applied inside a house. For greywater treatment the specific area demand for constructed wetland is still a matter of discussion as well as the optimal design of the mechanical pre-treatment (Langergraber & Haberl, 2001).

If the treated greywater is discharged the same standards are applied as for treated municipal wastewater. In rural areas in Austria one major problem is that some receivers can fall dry temporarily. This fact has to be considered carefully when discharging effluents (Laber & Haberl, 1999).

The main risks when using greywater for groundwater recharge is contamination of the soil and the receiving groundwater body (Ledin *et al*., 2001). Using only treated greywater for recharge can reduce this risks.

Often the easiest way to recycle greywater is for plant irrigation. In many parts of the world where water is scarce, this is done as a matter of course. Greywater irrigation can be as simple as pouring it on garden areas by hand. Even where there are few gardens, greywater can be put to use, such as in the peri-urban areas in cities, where households routinely apply it on the road in front of their houses to keep dust down. However, recent studies confirm that there is a considerable amount of gardening practised in urban and peri-urban areas, so greywater irrigation is often feasible (Ersey *et al*., 1998).

For the use of treated greywater for toilet flushing only disinfected treated greywater can be used from a technical point of view (microbial growth in pipes and tanks) (Laber & Haberl, 1999).

Cost comparison of sanitation systems for a single household

Different systems of sanitation for a single household with and without greywater separation are discussed and their costs are compared (BMLFUW, 2003). The costs for wastewater treatment can be subdivided into investment and operational costs. To include the pay-back of the investments the investment costs are transformed into yearly costs (using an economical interest rate; 3.5 % are used in the examples given below). In the presented examples the assumed life-time of the treatment system (technical system, SBR (Sequencing batch reactor) in this case, and constructed wetland) is 20 years, for the sewer system a life-time of 40 years is assumed.

Table 2 compares the investment, operational, and yearly costs for different treatment scenarios. The costs were calculated using data typical for Austria. Operational costs include costs for energy, maintenance, sludge disposal, and analysis. However, costs depend on local circumstances and several, partly unquantifiable factors, thus the below given costs are different for different projects (c.f. Starkl *et al.,* 2002 and Ertl *et al.,* 2002).

Scenario		**1**	**2**	**3**	**4**	**5**	**6**	**7**
System		SBR	CW	CP	CP(BW)	CP(BW)	CP	US
Disposal of cesspit waste		-	-	WWTP	AU	WWTP	AU	AU
Separation Black-/Greywater		no	no	no	no	yes	yes	yes + US
Greywater treatment		-	-	-	-	CW	CW	CW
Investment costs								
Treatment unit	$EUR.PE^{-1}$	1'450	1'450	1'780	1'780	1'120	1'120	1'160
Sewer	$EUR.PE^{-1}$	350	350	230	230	410	410	290
Operational costs								
Treatment unit	$EUR.PE^{-1}.yr^{-1}$	240	170	370	230	160	130	90
Sewer	$EUR.PE^{-1}.yr^{-1}$	5	5	5	5	5	5	5
Yearly costs	$EUR.PE^{-1}.yr^{-1}$	**362**	**292**	**468**	**336**	**246**	**208**	**192**

Legend: SBR … Sequencing batch reactor; CW … Constructed wetland; CP(BW) … Cesspit (only for blackwater); WWTP … Wastewater treatment plant; AU … Agricultural use; US … Urine separation

Table 2: Comparison of investment, operational, and yearly costs for treatment alternatives for a single household with 5 PE (BMLFUW, 2003, modified).

Using a constructed wetland for treatment of the total wastewater (2) shows lower yearly costs compared to the conventional technical treatment system (1). When all the wastewater is collected in a cesspit the yearly costs of the scenario with agricultural use of the cesspit waste (4) are only about 75 % of the yearly costs when disposing the waste to a wastewater treatment plant (3). However, all scenarios with source separation (5-7) show the lowest operational and yearly costs. Separating toilet water from greywater leads to a tremendous reduction of the volume that has to be collected and therefore the operational and therefore also the yearly costs drop drastically. Urine separation (7) shows the lowest costs and additionally closes water and nutrient cycles on a local scale and is therefore a promising system towards a more ecological sound sanitation. The costs show a clear economic advantage of the scenarios with greywater separation compared to the collection and treatment of the total wastewater.

Conclusions

Greywater comprises about 70 % of the volume but only 40 % of the BOD_5 and less than 10 % of the nitrogen load of municipal wastewater. The BOD_5 : N : P ratio of about 100 : 4 : 1 enables a biological treatment of greywater without addition of nutrients. Rotating biological contactor and constructed wetlands are best suited for greywater treatment. When greywater is reused the hygienic aspects have to be considered.

For small wastewater treatment plants especially the operational costs are essential. For the given assumptions it was shown that for single households source control solutions with separation of at least blackwater and greywater have lower costs compared to solutions where the different types of wastewater are mixed and therefore a large volume has to be treated. Besides the cost advantages these systems also close water and nutrient cycles on a local sale and are therefore a more ecological sound way for sanitation

References

BMLFUW (2003): Kosten-Nutzen-Überlegungen zur Gewässerschutzpolitik in Österreich mit besonderer Berücksichtigung des ländlichen Raumes (Cost-benefit analysis of water pollution control in Austria with a special focus on rural areas). *Schriftenreihe des BMLFUW* (in press), Vienna, Austria [*in German*].

Ertl T, Bogensberger M, Starkl M, Habich J, Haberl R, Murnig F & Sleytr K (2002): An analysis of costs for operation and maintenance of sewerage systems in Austria. In: University of Bradford (Ed.): Proceedings of the International Conference on Sewer Operation and Maintenance (CD), 26-28 November 2002, Bradford, UK.

Esrey S, Gough J, Rapaport D, Sawyer R, Simpson-Hèbert M, Vargas J, and Winblad U (1998): Ecological sanitation. SIDA, Stockholm, ISBN 91 586 76 12 0.

Jefferson B, Judd S & Diaper C (2001): Treatment methods for greywater. In: Lens P, Zeeman G & Lettinga G (eds.): Decentralised Sanitation and Reuse: Concepts, systems and implementation. IWA Publishing. London, UK; pp.334-353.

Laber J & Haberl R (1999): Teilstrombehandlung häuslicher Abwässer mit dem Schwerpunkt der Grauwasserbehandlung in Pflanzenkläranlagen (Treatment of separate streams of domestic wastewater with a special focus on greywater treatment using constructed wetlands); Report, IWGA-SIG, BOKU, Vienna [*in German*].

Lange J & Otterpohl R (2000): Abwasser. Handbuch zu einer zukunftsfähigen Wasserwirtschaft. (Wastewater – Manual for sustainable water management). *2nd edition.* MALLBETON-Verlag, Donaueschingen-Pfohren, Germany [*in German*].

Langergraber G & Haberl R (2001): Constructed wetlands for water treatment; Minerva Biotecnologica 13(2), 123-134.

Ledin A, Eriksson E & Henze M (2001): Aspects of groundwater recharge using grey wastewater. In: Lens P, Zeeman G & Lettinga G (eds.): Decentralised Sanitation and Reuse: Concepts, systems and implementation. IWA Publishing. London, UK; pp.354-370.

Starkl M & Haberl R (2003). The SUSSAN Project: Strategies towards sustainable sanitation – presentation of an Austrian applied research project. Poster presentation at the 1st IWA Conference on Sustainable Sanitation, 07-11 April 2003, Lübeck, Germany (this conference).

Starkl M, Ertl T & Haberl R (2002): Experiences with benchmarking of sewerage systems with a special focus on investment costs. In: University of Bradford (Ed.): Proceedings of the International Conference on Sewer Operation and Maintenance (CD), 26-28 November 2002, Bradford, UK.