Greywater treatment in apartment building in Austria

Pilot system built in water rich Austria to reduce potable water consumption

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Abstract with summary of technical data

In an apartment house with 9 apartments and a total of 14 inhabitants a separate greywater collection system, treatment and distribution plumbing was implemented as part of a comprehensive water scheme also comprising water saving, rainwater harvesting, on-site treatment of water and reuse for toilet flushing, landscape irrigation and groundwater recharge. The greywater is treated in a Pontos SBR, which includes UV disinfection and a storage tank. The treated water has a good quality for its intended purpose of toilet flushing. Compared with nationwide average supply and treatment volumes per day the scheme allows to save approximately 65 litres of potable water and around 40 litres of wastewater per capita and day.

Description

A dilapidated complex of farm buildings, comprising the farm house, the stable, a barn and other annexes was to be refurbished and transformed into apartments. The farm lies in Pöllau in Styria in the South-East of Austria, a hilly region with a mild climate and a relatively even rainfall distribution with an average rainfall of 800 mm per year, average monthly rainfall varying between 31 mm in January and 126 mm in July (at Graz).

The concept used for the refurbishment of the apartment house (Pöllau 18, Figure 1) aims at overall sustainability. This concept comprises construction materials and construction physics aspects, energy for heating and water. The concept extends to the surroundings of the house with the plan to convert a vineyard to biological farming. Three buildings comprise 9 apartments, with 14 inhabitants at the end of the monitoring period, a function room for events, a common wine cellar and office space.

As far as possible materials from the previously existing buildings, especially bricks, were reused. The old structures were rebuilt with adapted techniques, including the vaulted ceiling of the function room. Thorough insulation and special windows adapted to the traditional architecture but with triple glazing ensure low energy demand and high quality of living conditions.

The energy supply relies on 100 % renewable sources with a 42 kW (60 m²) solar collector and a 50 kW wood chip boiler for space and water heating. Local farmers provide the wood chips. Energy contained in greywater is also recycled into the space heating system. A 17 m² photovoltaic system is generating part of the electric power needed. As far as possible the energy supply is CO_2 neutral. Heat is distributed to the building complex

Figure 1: The building

from the central heating room via a 2-conduit network and decentralised heat transfer stations in the apartments and other heat consumers.

Despite the relative water richness auf the region and Austria in general the owner also wanted a sustainable water concept for the complex, partly to match the sustainable energy concept, but also to reduce dependency on centralised supply infrastructure and operation cost to a possible minimum.

Water is supplied from three sources, the village water mains, rainwater from the roofs and recycled greywater from the bathrooms. The wastewater treatment comprises a septic tank followed by a constructed wetland, which treats the wastewater on site for infiltration into the ground or, at a later stage, possibly irrigation.

Thus an example of a comprehensively ecological housing estate was created, combining local traditions and modern solutions and making use of a range of available techniques in contrast to usually one single solution relying on centralised systems only.

Water system

The potable water supply comes from the communal water mains. Due to the high location of the house the water is distributed with a booster pump.

Potable water supply is supplemented by a rainwater harvesting system collecting water from 580 m² of roof surface with a total storage volume of 42 m³. The rainwater is used for laundry, a fire fighting reserve, landscaping and irrigation of a wine yard. For laundry two common highly efficient washing machines are provided, where the water is externally heated from the central heating system through a heat transfer station for each washing machine. The fire fighting reserve was necessary as the apartment buildings are located at the end of a branch of the water mains, which is not able to supply a sufficient flow for fire fighting. The overflow of the tanks fills a pond where it is infiltrated into the ground.

Additionally greywater from the bathrooms is collected separately and treated for reuse in a PONTOS Aquacycle 1500, a sequencing batch reactor (SBR) with a capacity of 1000 l/d. It comprises a two step biological treatment with bacteria growing on a fixed bed of foam cubes, a UV-lamp for disinfection of the treated greywater before storage, and a buffer tank with a volume of 600 litre. The treated greywater is used for toilet flushing. In case of greywater shortage the toilet flushing needs are first covered from the available rainwater before eventually switching to potable water if the rainwater is exhausted. Switching from one water source to another is done automatically. The energy contained in the greywater is recycled into the heating system via a cross flow stainless steel greywater heat exchanger with a total surface of 2,60 m² and a capacity of 28 l/min (ThermoCycle WGR 355, Forstner Speichertechnik GmbH), which is approximately equivalent to 4 showers. The heat exchanger is interposed in the main greywater collector.

Figure 2: PONTOS Aquacycle 1500, SBR greywater treatment

The blackwater and excess greywater are treated in a train comprising a 3-chamber septic tank of 7,5 m³, a vertical subsurface flow constructed wetland and a surface infiltration area. The constructed wetland has a length of 26,6, a width of 4,7 and a depth of 1,1 m. It is fed in batches from a feeding chamber located downstream of the septic tank and comprising a special “pipe valve” acting as a float and intermittent outlet device. No pumps or electronic devices are needed, which leads to a robust system and simple operation and maintenance. The treatment is designed for 25 population equivalents. This is the planned final population of the complex but was not reached during the monitoring period. The outlet of the plant has to comply with Austrian regulations for small plants (Table 1). It is planned to use the treated wastewater for fertigation of agricultural crops.

Table 1: Austrian effluent standards for small wastewater treatment plants (less than 50 people equivalent, 1.AEVkA, 1996).

Parameter	Limit
BSB_5 (mg O_2/l)	25
CSB (mg O_2/l)	90
TOC (mg /l)	30
NH_4-N (mg/l) [1]	10

Austria so far has no specific regulations concerning the implementation of greywater systems or quality criteria for greywater. There are however guidelines of professional bodies, which give some indications concerning the implementation, e.g. supply pipes and taps have to be clearly marked as supplying non-potable water. As for greywater quality, depending on the intended use, guidelines for specific types of water uses, e.g. for irrigation water, for bathing water, can serve as a rule for a minimum quality of the treated wastewater. Guidelines for the use of excreta and greywater in agriculture exist from the WHO (2006) but are not yet applied in Austria. Directive 2006/7/EC from the European Union "concerning the management of bathing water quality" is often referred to for the quality requirements of greywater used for domestic purposes. The "bathing water directive" provides quality criteria for prolonged full-body water contact.

In the present case the treated greywater is used for toilet flushing. It must not be assumed that toilet flushing leads to prolonged full-body water contact. It hardly leads to any water contact. Thus the requirements of Directive 2006/7/EC may not apply. Instead of protection of users from chemical or microbial hazards, the most important issues to take into consideration are technical durability of the greywater supply system, i.e. no unacceptable deposits in pipes, and sensorial aspects of the water and the toilet, e.g. turbidity, odour, colour of the water and possible deposits in the toilet bowl.

After completion of the first stage refurbishment of the buildings a monitoring of the water scheme was started. This comprised flow measurements to allow a water balance and water quality measurements of the various water flows including raw and treated greywater. The monitoring was partly constrained by the progressive moving in of inhabitants, the number reaching 14 only towards the end of the monitoring period. An extension of the monitoring is planned.

Cost

The following system costs are real costs of the implementation. The greywater treatment and the related plumbing added up to just below 11.000 Euro. The wastewater collection and treatment under the present configuration was built for 20.500 Euro (Table 2).

The costs of the rainwater harvesting are equivalent to those of the greywater system, even though there is no treatment included. However the reservoirs comprise the fire fighting volume. A detailed assessment of the cost for mains with a sufficient capacity for fire fighting was not made but the remoteness of the building suggests the cost would have been comparable. The rainwater harvesting system, which is comprising an infiltration pond, is also part of the drainage scheme, thus serving a third purpose besides providing extra water and storing the fire fighting reserve.

The costs for the standard plumbing are not available unfortunately. Therefore no comparison of the costs for overall plumbing to the additional greywater collection and distribution system can be made.

Table 2: Investment cost of various components of the water system (excluding VAT)

Cost Information	Cost basis 2005
Rainwater harvesting system (tank, plumbing, pump)	€ 13.000
Greywater heat exchanger	Prototype
Greywater recycling system (SBR, plumbing)	€ 10.900
Constructed wetland for black water treatment	€ 20.500

In the present case the constructed wetland for the treatment of black water was built applying the standard Austrian dimensioning rule of 5 m² per person, without taking into consideration the reduced hydraulic and carbon load due to the greywater scheme. If the reduced hydraulic load were taken as the key dimensioning parameter the constructed wetland could have been built with 3 m² per person and would have cost an estimated 14.400 Euro.

Results

One target of the monitoring was to determine whether and to which extend water saving measures and greywater systems would contribute to water saving. A normal person in Austria uses 135 litres of potable water per day. About 120 litres of these become wastewater.

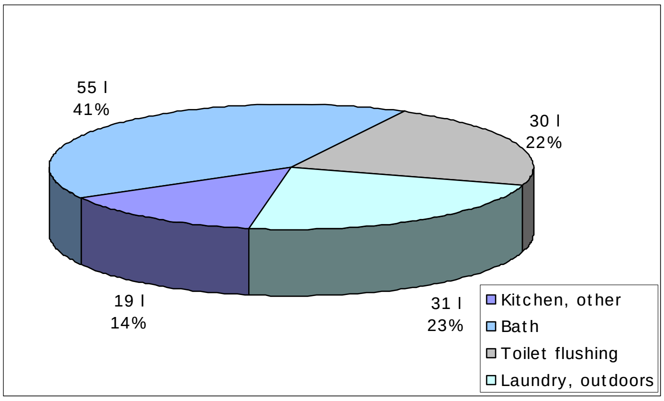

Figure 3: Average Austrian domestic water consumption per capita and day, for different consumption categories, total is 135 l/(c.d) (BMLFUW, 2009)

Figure 4: Water flows at Pöllau 18.

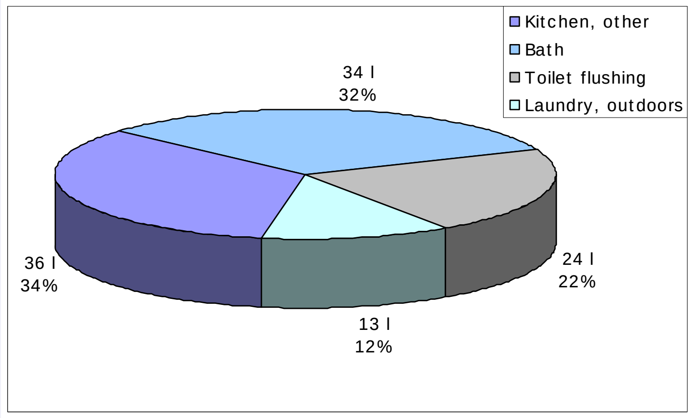

Figure 5: Water consumption at the apartment house Pöllau 18 per capita and day, for the same categories as in Figure 3, total is 107 l/(c.d)

An inhabitant at Pöllau 18 uses 107 litres of water per day. However 24 l of these are greywater and 13 are rainwater, so that only 70 l are potable water from the mains. That is almost down to half from the average figure or a yearly saving of about 24.000 litres for every person.

The respective consumptions in the category bathroom are 55 and 34 l/(c.d). This reduction by almost 40 % is probably due both to water saver fittings and a water conscious behaviour of the inhabitants. While the reduction also has an impact on the available volume of greywater, in the present case this has no consequences, as the volume of service water needed is less than the greywater collected. Additionally the next available water source is rainwater, where there is no shortage under the given circumstances.

If this were not the case, e.g. due to further service water uses, it would have been possible to add the laundry runoff to the greywater. (Figure 4)

Somehow astonishing is the comparative consumption in the "kitchen and other" category. This category is formed because at Pöllau 18 its water consumption is computed from the total potable demand minus the greywater produced in the bathroom. This amount of water should cover the demand at the kitchen and cleaning plus any other use of water from the mains, which should be rather limited. Yet the consumption is 36 litres per capita and day compared to 19 litres for Austrian average. The reason for this discrepancy cannot be explained with the available data and will have to be investigated in a further monitoring phase.

The amount of wastewater leaving the building is also down to 76 litres per capita and day, from the average 120, which corresponds to a 37 % reduction. (Figure 5)

Quality data for the raw greywater are given in Table 3. With a COD of just above 70 the raw greywater is rather less polluted than literature states for greywater from shower and bath (Eriksson et al., 2002). The COD/BOD_5 ratio of around 1.25 suggests the greywater is easily biodegradable. This is confirmed by the good

Table 3: Raw greywater quality (Sample size =8; n.d. = not detectable)

	Average	Median	Standard deviation	Max	Min
COD (mg O_2/l)	72.4	75.0	34.4	118.0	10.4
BOD_5 (mg O_2/l)	58.3	53.5	32.5	105.0	17.0
NH_4-N (mg/l)	2.4	1.3	2.8	6.9	<0.5
N_{tot} (mg/l)	10.6	5.3	15.7	49.0	1.1
P_{tot} (mg/l)	0.7	0.6	0.3	1.2	<0.5
E. coli (CFU/100 ml)	6.3E+06	0.33E+06	12E+06	35E+06	n.d.

Table 4: Service water quality (Sample size =11; n.d. = not detectable, [1]in 8 samples)

	Average	Median	Standard deviation	Max	Min
COD (mg O_2/l)	13.2	12.4	8.3	40.9	9.2
BOD_5 (mg O_2/l)	2.7	1.9	3.0	12.0	1.1
NH_4-N (mg/l)	<0.5	<0.5		1.1	<0.5
N_{tot} (mg/l)	3.2	2.8	1.2	5.8	1.7
P_{tot} (mg/l)	0.4	0.4	0.2	0.7	0.2
E. coli (CFU/100 ml)	145	n.d .[1]	308	1000	n.d.

elimination of carbon as shown in Table4. The nutrient content is particularly low in this greywater. This may not always be the case, e.g. if there are babies or if the households use any detergent with some phosphorus.

The already low concentration of nitrogen is further reduced from 10 to 3 mg/l in average. Almost all ammonium is denitrified or at least oxidised. The treated service water looks clean, colourless and has no particular odour.

This SBR greywater treatment leads to water, which is well suited for purposes but direct consumption, e.g. toilet flushing, in the household. The water and wastewater savings are substantial and could help reduce the pressure on water resources especially in water scarce regions. In future implementations of such systems the cost of the greywater scheme could be partly offset by the corresponding savings made on the wastewater treatment. Any savings go automatically to the developer in the case of decentralised wastewater schemes implemented by the developer himself. In other cases this may not be achievable. If water saving measures or greywater systems are implemented upstream of centralised sewerage and wastewater treatment schemes appropriate tariffs or subsidies will be needed to transfer at least part of the overall economic advantage to the developer.

The investment costs are higher for the more complex scheme, than if a water mains connexion and a constructed wetland for wastewater treatment were implemented. However, in future such systems a more detailed knowledge of the wastewater produced will allow to reduce the size of the wastewater treatment and thus reduce the cost accordingly, thus reducing the gap between the two schemes while still maintaining the level of sustainability and autonomy.

Further investigations have to be made concerning the possible size reduction of constructed wetlands, or any wastewater treatment for that matter, in case of a greywater scheme treating part of the wastewater flow. For this purpose more data are needed concerning the hydraulic and organic load reduction at the inlet to the wastewater treatment due to the greywater scheme. This should lead to the critical parameter for the dimensioning of the wastewater treatment.

While domestic water demand has a very high priority, the potential of on-site recycling to guarantee a sufficient water supply should not be neglected. The saved water remains available for other purposes in potable water quality.

Acknowledgements

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