Case study of sustainable sanitation projects

Ecological Settlement in Allermöhe Hamburg, Germany

Fig. 1: Project location

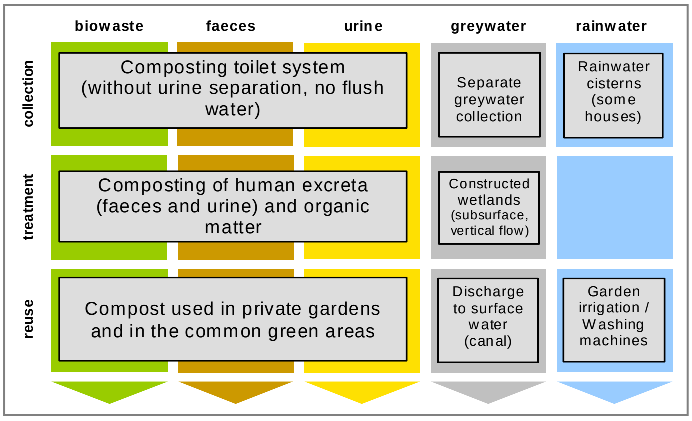

Fig. 2: Applied sanitation components in this project

1 General data

Type of project:
Residential settlement in urban area (full-scale)

Project period:
Start of planning: 1983
Construction period: 1985-2002 (in stages)
Start of operation: 1986 (in stages)

Project scale:
36 single-family houses, around 140 inhabitants

Address of project location:
Fanny-Lewald-Ring 32-92b
21035 Hamburg, Germany

Planning institution:
Berger Biotechnik GmbH (composting toilet systems)
AWA-Ingenieure (constructed wetland)

Executing institution:
Ökologisches Leben Allermöhe e.V. (a club of individuals)

Supporting institutions:
Government of the city of Hamburg
German Federal Ministry of Transport, Building and Housing
Hamburg Environmental Authorities

2 Objectives and motivation of the project

The project was planned to be a model settlement with high resource and energy efficiency through both the building and landscape architecture and by using appropriate ecological technology components. This included:

- Compact buildings, planned according to current state of the art for ecological architecture.
- Designs adjusted to the locations' environmental conditions.
- Ecological closed-loop processes via on-site wastewater treatment and therefore independence from a sewage system.
- High degree of involvement of the users in the planning, design, implementation and maintenance processes.

Fig. 3: Houses in middle court yard, constructed in 1986 (source: Berger Biotechnik).

3 Location and conditions

The ecological settlement is part of the new district Neu-Allermöhe, where 3,800 residential units were built between 1982 and 1994. It is a very green area with relatively low buildings (all less than 4 floors), 15 km southeast of Hamburg city centre. The eco-settlement in Neu-Allermöhe-Ost (New-Allermöhe-East) consists of 36 single-family houses with approx. 140 inhabitants aged from 0 to 99 years.

All inhabitants are owners of their houses and none of the houses are rented out. The two-storey twin and terraced houses differ in architecture to avoid uniformity. They are arranged around three small court yards: north, middle and south. The area of Allermöhe has many small canals. The entire area of the settlement has a high groundwater table.

Fig 4: Map of the settlement in 2006 with three court yards and constructed wetland ("PKA" in German). Source: Ökologisches Leben Allermöhe e.V.

4 Project history

This settlement is among the first ecological settlements in Germany with the initial stages of conceptual design starting in the 1970s. In 1983, the government of the city of Hamburg became involved in the planning. Together with several public authorities and the future users, an architecture competition on "ecological construction" was organised and the ecological and technical standards for the construction were determined. The construction period started in 1985, and one year later the first inhabitants moved in. The last residential houses were completed in 2002. In 2007, a community house was built in the southern court yard to put into practice the community spirit of the settlement as it was initially planned in the project conception.

Fig 5: Houses with green roof in northern courtyard, constructed in 1990/91 (source: Berger Biotechnik).

5 Technologies applied

Composting toilet systems:
Each household has a composting toilet system which consists of one or two toilet pedestals and a composting container in the basement to treat the human excreta (faeces and urine), toilet paper and organic kitchen waste (see Fig. 6, left and middle). Garden waste may also be composted in the composting container. Some households have an additional composter in the garden for kitchen waste and organic waste from gardening.

The toilet systems include the following models (all without urine diversion):

- 31 Berger Terra Nova composting toilet systems
- 5 Clivus Multrum composting toilet systems (1 American model and 4 Swedish models)

For further information see Section 6.

Constructed wetland system:
The greywater (wastewater from kitchens and bathrooms except from toilets) from all houses in the ecological settlement is led to a constructed wetland, located in the southern end of the settlement. Such a wetland is also called reed bed.

Rainwater harvesting:
9 of the 36 households collect the rainwater from their roofs in four underground cisterns with a capacity of 5-16m³.

Fig. 6: Berger Terra Nova composting toilet system with toilet pedestal (left) and composting container (middle). Separation chamber inside the bottom compartment for leachate (right). Source: A. Schöpe, 2009 (left) and Berger Biotechnik.

Fig. 7: Constructed wetland with reed in summer (left) and winter (right). Source: Ökologisches Leben Allermöhe e.V. (left) and A. Schöpe, 2009 (right).

6 Design information

Composting toilet system:
The architecture of the houses is adapted to the specific toilet designs. Each toilet is connected to one straight chute (downpipe) to the composting container in the basement (see Fig. 8). Up to 4 toilet pedestals can be connected to one composting container. Used toilet paper is thrown into the toilet and organic kitchen waste can be added as well. The containers have a chamber size of 1.5-3 m³ and are delivered with a starter bed consisting of 600 litres absorbing material (compost).

This waterless toilet system saves about 40 litres of water per capita per day compared to a conventional flush toilet (10 L per flush) which adds up to 2,044 m³ water savings per year for the whole settlement.

Current technical specifications and previous modifications of the toilets are:

- The toilet seat has a special oval design and offers enough security when being used by small children, so that they cannot fall down the chute (see Fig. 6, left).
- The toilet has a funnel-shaped plastic inlet for easy handling and cleaning of the toilet.
- The toilet lid has to close tightly to increase air draft and guarantee correct aeration of the composting container.
- A major part of the liquid (80-100%) added to the toilet in the form of urine/water is evaporated via the ventilation pipe[1].
- The ventilation pipe is insulated to increase air draft and avoid condensation.
- The fan in the ventilation pipe needs 29 Watt electrical power or less (fan power can be adjusted by a speed controller).
- Leachate in the container (resulting mainly from urine) can be collected in a separation chamber (see Fig. 6, right).
- A relatively wide chute diameter of 30 cm was chosen to reduce soiling of the pipes' inner surface .

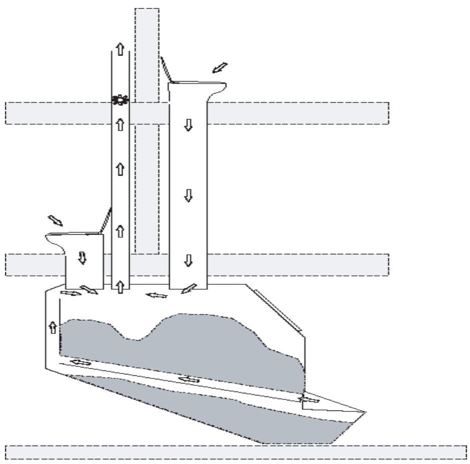

Fig. 8: Side view of a house with two toilets on two floors and one composting container in the basement, with removal compartment at bottom right (source: Berger Biotechnik).

Constructed wetland system for greywater treatment:
The constructed wetland has an area of 240 m² (currently 1.7 m² per person) and a capacity of 15 m³ per day. The actual inflow (in 2008) was 10-13 m³ per day (82 L per person per day[2]). The greywater pipes have a diameter of 100 mm. The filter material consists of sand with a depth of 1 m and is covered by gravel with a depth of 0.1 m.

Module A and B were built in 1988; Module C was built in 1992. The greywater from the houses first flows to an underground Imhoff tank[3] for grease removal. From there it is distributed in intervals to the three reed bed modules. All modules are planted with common reed plants (*Phragmites australis*) and are designed as vertical flow sub-surface constructed wetland.

The effluent from the reed beds is collected in a polishing pond and is led from there to the neighbouring surface water ("Annenfleet") (see Section 10 for further information on the effluent quality).

For effluent discharge into this canal, a permit issued under the water law of the Free and Hanseatic City of Hamburg was obtained. In case of process failure, the wetland has an emergency overflow to the municipal sewer.

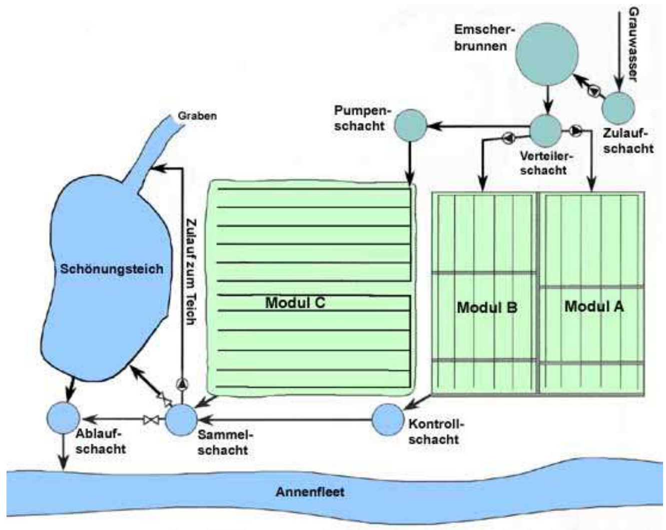

Fig. 9: Schematic of the constructed wetland (flow is from right to left, labels are in German). Source: Ökologisches Leben Allermöhe e.V. and AWA-Ingenieure.

7 Type of reuse

- The finished compost material from the composting container which is obtained after at least 2 years of composting in the container, is used as fertiliser in the household gardens and the common green area. About 40 L[4] of compost is produced per person per year.
- The leachate from composting can be diluted with water and used as liquid fertiliser during planting periods (see Section 10 for further information).
- The treated greywater (3,650 to 4,700 m³ per year) is discharged into the neighbouring channel and not reused.

8 Further project components

Further technical components of the ecological concept include:
- Rainwater from the area of the settlement and the roofs is collected in small basins and ditches (to infiltrate into the soil) or in cisterns to irrigate the green space. Some households also use the rainwater for their washing machines.
- 4 photovoltaic systems and 14 thermic solar heaters for warm water for some households. The photovoltaic modules cover a roof area of about 80 m² and produce a rated power of about 8 kW. The thermic solar heaters cover a roof area of about 81 m² and have about 400 litres storage capacity.

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[1] For comparison: Urine production of a family of three adults per year (if all urine is collected at home) is approx. 1.4 m³ (based on 1.3 L/person/day).
[2] For comparison: wastewater production (greywater plus toilet wastewater) of average German person is currently 120 L/person/day.
[3] An Imhoff tank is a settling tank with some anaerobic treatment (similar to a septic tank). The volume of this Imhoff tank is not known.
[4] 1 L of compost weighs about 650 g to 900 g, depending on the water content.

- Eco-friendly construction materials such as wood or grass for roofs (1/3 of the houses) or recycled material for highly efficient insulation.
- Innovative energy-conserving concepts for conservatories (as extension of a house).
- Passive houses (those houses constructed most recently): Very good insulation, including thermal windows, combined with a ventilation system with heat recovery to avoid heat losses and optimise heat gains.

9 Costs and economics

The German Federal Ministry of Transport, Building and Housing and the Hamburg Environmental Authorities supported the construction, operation and scientific monitoring of the composting toilet systems and the constructed wetland.

Composting toilet system:
Initial investment costs: During the construction period, the price of one complete Terra Nova system (standard) with 2 toilets was approx. EUR 3,700 (includes quantity discount for all houses constructed in 1986-1992). Special requests raised the price to EUR 4,000 to 4,500. The costs for delivery and installation were EUR 500. In 2009, the costs for one improved Terra Nova system, delivery and installation are approx. EUR 6,500.

Operation and maintenance costs: When necessary, moving parts like the ventilation fan have to be replaced after some years of use - at the earliest after 5 to 20 years with an annual periodic cleaning (price of one fan: EUR 190).

Constructed wetland:
Initial investment costs: The total costs for the constructed wetland were EUR 95,000 (treating greywater from 140 people). Nowadays, such a facility is less expensive because of more economical designs.

Operation and maintenance costs: External quality checks and sampling costs are about EUR 500 per year. Additonally, the sludge removal from the Imhoff tank costs EUR 250 each time (it is removed by an external company every two years, see Section 10). Pumps and moving parts have to be renewed from time to time.

It can be calculated that with this sanitation system, the eco-settlement saves about **EUR 18,000 per year** (equal to EUR 130 per person per year) based on:

- reduced water consumption (no toilet flushing, see point 1 below) and
- no wastewater fees (greywater treated and discharged locally instead of being discharged to the municipal sewer, see point 2 below) and
- relatively low O&M costs of the wetland (point 3 below).

The assumptions for this calculation are:

1. 40 L/person/day saved for toilet flushing, for 140 residents. Water and wastewater together is charged at about 4 EUR/m^3 in Hamburg. So the non-flush composting toilets save about EUR 8,176 per year.
2. The produced greywater does not attract a wastewater fee as it is not discharged to the municipal sewer (normally in Hamburg: 2.67 EUR/m^3 for wastewater discharged). So for the 11.5 m^3/d of greywater produced, this results in avoided wastewater fees of EUR 11,207 per year.
3. The annual cost for the constructed wetland charged by the Allermöhe club is 25 EUR/person/year (or a maximum of 100 EUR/household/year), and this is for sampling and analysis twice per year (for COD and BOD), sludge removal from the Imhoff tank (every second year) and putting money aside for repairs, replacements and re-investment. The total annual cost for the wetland is about 1,400 EUR/year.
4. The free labour provided by the volunteers of the settlement is not included in the cost estimate.

10 Operation and maintenance

All operation and maintenance activities are carried out by the residents themselves (or volunteers amongst the residents), which reduces costs and increases the feeling of ownership.

Composting toilet system:
Maintenance of the composting container is carried out by the residents themselves. Approx. 1 hour per month is required to level, mix and aerate the compost heap and to add organic matter from the kitchen and garden to improve its structure and avoid densification. Some residents use a compost thermometer to monitor the temperature in the composter.

Finished compost material is taken out of the removal compartment (located below the composting container with "potato box principle"[5], see Fig. 6, middle) every 1-2 years depending on the incoming quantity of faeces. If 40 litres of compost is produced per person per year, a family of four has to remove about 160 litres finished compost (16 buckets of 10 litres) per year. Direct access to the cellar from the garden is provided.

The quantity of leachate inside the container depends on drinking habits, temperature and liquid content in the added organic matter[6]. Surplus leachate is collected in a chamber next to the removal container (see Fig. 6, right). It has to be emptied with a pump or a small bucket from time to time. In some households in the eco-settlement no surplus leachate occurs.

Fig. 10: Compost heap inside the composting container of the toilet (left), greywater in Imhoff tank (middle) and final effluent from constructed wetland (right). Source: A. Schöpe, 2009.

Constructed wetland:
Every year in April, volunteers from the community jointly harvest the reeds[7] from the reed beds, clean the reed beds and flush all distribution pipes. The reed is composted at the common green area. Tanks, valves and pipes are checked again at the end of autumn. The Imhoff tank is cleaned twice a

[5] Moved by gravity and by muscle power (fork or aeration stick) along a 30°-slope into the removal compartment at the bottom of the container.
[6] This leachate is excess liquid (some urine which did not evaporate) which is not incorporated into the compost.
[7] The annual harvest is recommended, but not required.

year to avoid clogging and its settled sludge is removed once every two years by a removal company and then transferred to the local wastewater treatment plant (the settled sludge is removed even when the tank is less than 50% full with sludge to avoid sludge deposits in the pipes to the wetland).

The effluent quality of the constructed wetland is tested twice a year by the Hamburg Environmental Authorities. For example, a sample taken on 12 December 2008 had a COD (chemical oxygen demand) of 16 mg/L and BOD (Biochemical oxygen demand) of 4.5 mg/l. The pH value was 7.3. The legal limit for discharge to surface water is 80 mg/L COD and 20 mg/L BOD.

11 Practical experience and lessons learnt

General:

- User involvement in, and ownership of the technology is very high due to the common vision which was the basic idea of the eco-settlement.
- Ownership is higher when the inhabitants are owners of the houses (and not tenants), as is the case here.

Composting toilet systems:

- The compost compartment requires monthly attention by the users.
- The right level of temperature and humidity is essential for the compost organisms. Rule of thumb: when squeezing the compost by hand, no water should come out (otherwise it is too wet) nor should it fall to crumbly pieces (otherwise it is too dry).
- Sometimes the finished compost does not slip to the removal container and has to be pushed down. To facilitate access to the compost, containers can be modified: a third access hatch in the middle of the container can be added.
- The temperature in the compost container fluctuates, depending on the material added. Adding grass, for example, increases the temperature. On average, the temperature in the composter is only a little bit higher than the temperature in the cellar.
- Maintenance work and emptying of the compost container can be very demanding especially for elderly people.
- Composting of fruit waste may result in fly breeding. In most of the cases, the flies started breeding in the compost while fruit waste was stored in the kitchen. Fruit waste should be quickly added to the compost in the container or composted outside in a separate container.
- The cellar for the composting container has to be large enough to enable maintenance work and emptying of the container and to allow good ventilation. Removal of compost is easier when there is direct access via a door from the garden to the cellar.
- More compost is produced than what can be applied in the private gardens (size of gardens: 130 - 250 m²). Hence, the compost is also used for the common green area.
- The upper end of the ventilation pipe has to be high enough to ensure the emission of air without odour being noticed at ground level. It is recommended to run the fan continuously.
- Even though some households have changed ownership, the spirit of the eco-settlement is still alive. The settlement is not connected to the municipal sewer, which means that inhabitants cannot change their toilet system to a conventional system with flush toilets, even if they wanted to.

Constructed wetland:

- When operation started in 1986, only little operational experience with constructed wetlands was available in Germany, which resulted in several of the legal requirements being overly cautious.
- Due to these legal requirements, the reed bed modules A and B were built with an expensive concrete lining. Experience showed that a waterproof plastic liner is sufficient and this was used in module C.
- The Imhoff tank for pre-treatment and grease collection could have been built much smaller.
- Soil subsidence required reconstruction of pipes for greywater distribution twice.
- To avoid clogging of the pipes to the wetland, settled sludge in the Imhoff tank is removed every two years. The level of settled sludge is measured with a long stick because it cannot be seen; experience is needed for that.
- The effluent quality from the reed beds does not vary between summer and winter unlike for other constructed wetlands.
- The group of volunteers (residents) maintaining the constructed wetland now has a sound know-how. This guarantees flawless operation of the system.

12 Sustainability assessment and long-term impacts

A basic assessment (Table 1) was carried out to indicate in which of the five sustainability criteria for sanitation (according to the SuSanA Vision Document 1) this project has its strengths and which aspects were not emphasized (weaknesses).

Table 1: Qualitative indication of sustainability of system. A cross in the respective column shows assessment of the relative sustainability of project (+ means: strong point of project; o means: average strength for this aspect and – means: no emphasis on this aspect for this project).

	collection and transport			treatment			transport and reuse		
Sustainability criteria:	+	o	-	+	o	-	+	o	-
• health and hygiene		X		X			X		
• environmental and natural resources	X			X			X		
• technology and operation		X			X			X	
• finance and economics	X			X			X		
• sociocultural and institutional	X			X			X		

Sustainability criteria for sanitation:

Health and hygiene include the risk of exposure to pathogens and hazardous substances and improvement of livelihood achieved by the application of a certain sanitation system.

Environment and natural resources involve the resources needed in the project as well as the degree of recycling and reuse practiced and the effects of these.

Technology and operation relate to the functionality and ease of constructing, operating and monitoring the entire system as well as its robustness and adaptability to existing systems.

Financial and economic issues include the capacity of households and communities to cover the costs for sanitation as well as the benefit, e.g. from fertilizer and the external impact on the economy.

Socio-cultural and institutional aspects refer to the socio-cultural acceptance and appropriateness of the system, perceptions, gender issues and compliance with legal and institutional frameworks.

For details on these criteria, please see the SuSanA Vision document "Towards more sustainable solutions" (www.susana.org).

Regarding long-term impacts of the project, the following can be concluded:

1. Residents living in this settlement have a smaller “footprint” with regards to water and energy use compared to the average German resident. They also make their own soil conditioner (compost).
2. The ecological settlement Allermöhe-East is a good example for a settlement using a sustainable sanitation system for more than **23 years**. Inhabitants do not only use sustainable sanitation, they are aware of the importance of sustainable solutions and also save water and energy. The settlement is a reference project with a long history which can inspire its many national and international visitors to copy the approach.

13 Available documents and references

- Information on the eco-settlement is available on the club's homepage: http://www.oeko-siedlung-allermoehe.de/ (in German).
- Additional information on the composting toilet system: http://www.berger-biotechnik.de (in German, English and French).
- A book on composting toilet systems: Berger, W. and Lorenz-Ladener, C. (2008) Kompost-Toiletten. Sanitärtechnik ohne Wasser. Verlag ökobuch (in German). Partial preview: http://www2.gtz.de/Dokumente/oe44/ecosan/de-kompost-toiletten-ohne-wasser-2008.pdf
- A booklet on sustainable settlements in Hamburg: http://www.hamburg.de/contentblob/135030/data/zukunftsfaehig-nachhaltig-oekologisch.pdf (in German).

14 Institutions, organisations and contact persons

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SuSanA 2009
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