Paper

on

Separate Discharge and Treatment of Urine, Faeces and Greywater Pilot Project

Dr.-Ing. A. Peter-Fröhlich, Dipl.-Ing. I. Kraume, Dr.-Ing. A. Lesouëf and Dr.-Ing. M. Oldenburg

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Separate Discharge and Treatment of Urine, Faeces and Greywater Pilot Project

A. Peter-Fröhlich[1], I. Kraume[1], A. Lesouëf[2] and M. Oldenburg[3]

[1]Berliner Wasserbetriebe, Wastewater Works, P.O. Box 021098, D 10122 Berlin; PH (+49)030-8644 1626; FAX (+49)030-8644 5077;
email: anton.peter-froehlich@bwb.de
[2]Vivendi Water, Wastewater Treatment Department, Paris, France;
email: andre.lesouef@generale-des-eaux.net
[3]Otterwasser GmbH, Lübeck, Germany;
email: oldenburg@otterwasser.de

Abstract

Berliner Wasserbetriebe has started a pilot project about new sanitation concepts in conjunction with Vivendi Water in the framework of the Kompetenzzentrum Wasser Berlin. In order to define the experiments for testing new, sustainable sanitation concepts a pre-study has been done. This study includes a cost comparison between two new sanitation concepts with gravity and vacuum separation toilets and the conventional system. It could be demonstrated that the new sanitation concepts may have cost advantages depending on the situation. This was a further motivation starting a pilot project in Berlin/Brandenburg testing the above mentioned toilet systems under realistic conditions. The operation of the gravity separation toilets concept will start in the summer 2003.

Introduction

World-wide serious problems with water in relation to quantity and quality are recognized as a challenge for the next decades. These problems can not only be solved by maintaining the existing drinking and wastewater techniques and concepts which are in use in industrialised countries.

Thus new techniques and concepts for drinking water preparation and supply and wastewater discharge and treatment should be additionally developed. This more sustainable approach should consider the reuse of treated water as well as the recycling of the nutrients if possible. Furthermore the energy consumption for wastewater discharge and treatment should be minimised. Such techniques and concepts are already available and in use, but further developments and validations are still necessary.

These are the reasons why Berliner Wasserbetriebe (BWB) and Vivendi Water (VW) launched this research-project in the framework of the Kompetenzzentrum Wasser Berlin (KWB).

The main goal of this project is the development of new sustainable sanitation concepts which have significant advantages according to ecological as well as to economical aspects compared to the conventional systems (end-of-pipe-system), which are mainly used in industrialised countries.

The new sanitation concepts should represent a relevant solution for
- remote areas, where the connection to a central system (e.g. big pipe networks) wouldn't be technically or economically feasible,
- rapidly growing suburbs in developing countries,
- countries with scarce water resources and
- it should be a contribution to the sustainable development with the recycling of nutrients and water.

Methods

The project is divided into two phases (***Phase I***, pre-study and ***Phase II***, pilot project). ***Phase I***, a theoretical approach, has been finished at the end of 2001.
- **A literature based project review**, patent reviews and a collection of informations about the various projects were made. Furthermore existing projects with separate treatment in Germany, Denmark and Sweden have been visited. These informations and detailed economic investigations have been the prerequisite for continuing the project.
- **Cost comparisons between a conventional and two new sanitation concepts** for an intended new housing estate in the federal state Brandenburg near Berlin have been made. The housing estate should be realised stepwise from 672 up to 5,000 inhabitants within the next 10 years. For the economic calculation three different sanitation concepts have been compared for different cost levels:
    - **Conventional sanitation concept:** Conventional flush-water toilets with stop bottom, one sewer system, normal gravity sewer system for the area, pumping station with transport sewer to the existing sewer network, system operated by the public supplier.
    - **Separation sanitation concept (gravity, composting of faeces):** Gravity separation toilets with separate outlets for urine and faeces, collection and storage of the urine, transport to the farmer nearby and utilisation in agriculture, faeces transported by a gravity sewer system, aerobic treatment in a compost separator, utilisation of the compost in the horticulture on the area, transport of greywater in gravity sewer system, treatment in a constructed wetland, transport to the receiving water.
    - **Separation sanitation concept (vacuum, digestion of faeces):** Vacuum separation toilets, gravity urine transport, storage of the urine, transport to the farmer nearby and utilisation in agriculture, faeces transported by a vacuum sewer system, common treatment with ground bio waste in a biogas plant, biogas utilisation by the equipment of the energy concept, transport of the digested sludge to the farmer nearby and utilisation in the agriculture, transport of greywater in gravity sewer system, treatment in a constructed wetland, transport to the receiving water.

The comparison of these three sanitation concepts has been considered for four scenarios which are shown in Table 1.

Table 1. Scenarios for the cost comparison of the 3 different sanitation concepts

	Inhabitants	Water Operator *
Scenario 1	672	Local company
Scenario 2	5,000	Local company
Scenario 3	672	Berliner Wasserbetriebe
Scenario 4	5,000	Berliner Wasserbetriebe

* This determines the costs of the "conventional" system and the costs for drinking water in all scenarios

A decision based on an economic point of view should consider three aspects:

- Costs of the investment
- Costs of the reinvestment
- Operation costs

These costs have been considered and the following assumptions were made for the cost calculations:

- Lifetime of the project: 50 years
- Duration of the components depending on their lifetime. Reinvestment after the end of the lifetime.
- Real interest rate: 3.5 % per year
- Maintenance costs are calculated as a percentage rate of investment. Personal costs are taken in consideration separately.
- Operation costs divided into costs for
  - personal equipment
  - maintenance
  - water and wastewater
  - electricity
  - others equipment

The specific costs for water, wastewater, connection fees, energy and other costs are based on the informations of the local company or of the Berliner Wasserbetriebe. With these assumptions and informations the costs for the whole project period are calculated as total project costs. The total project costs (Projektkostenbarwert) are the sum of money which is necessary for financing the whole project (investment, operation, reinvestment; see Figure 1) for the assumed lifetime based on today's cost level.

The calculations have been realised with the German guideline “Dynamische Kostenvergleichsrechnung” (dynamic cost comparison calculation) published by the “Länderarbeitskreis Wasser LAWA”, a working group of all federal countries in Germany concerning water management) (LAWA, 1998). This method can also named as a lifecycle analysis.

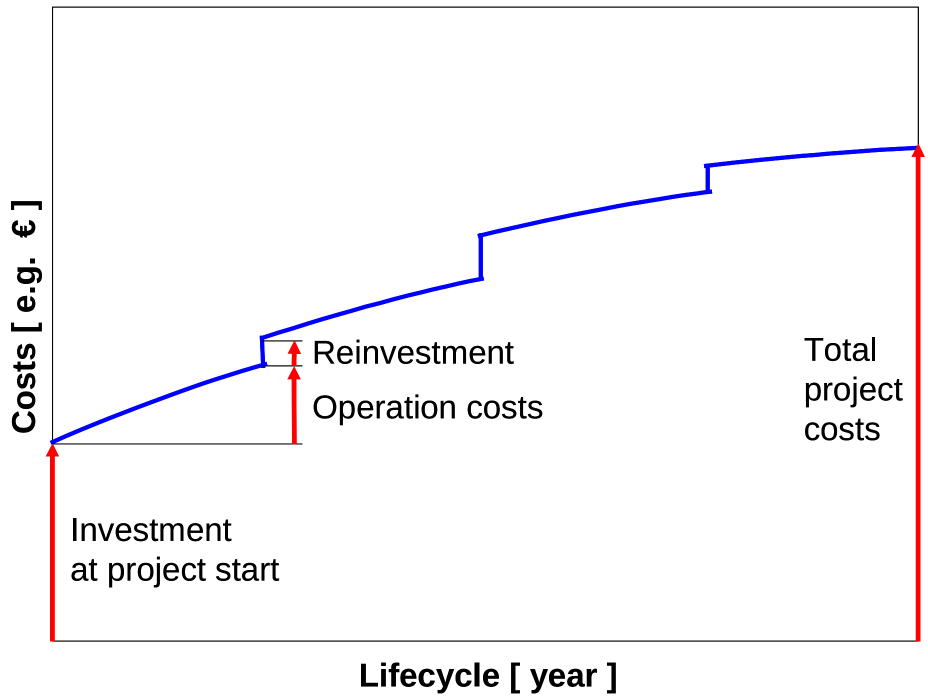

Figure 1. Demonstration of the total project costs (Projektkostenbarwert)

Results

a) Literature survey and visits

The main results from the pre-study are:

- 17 new sanitation projects already exist in Western Europe (Table 2).
- The activities in relation to new sanitation concepts are increasing all over the world.
- The separation of urine, faeces and greywater based on the use of new toilet bowls, has proven to be feasible and accepted by the users (Johansson, 2001; Hellström and Thurdin, 1998; Swedenviro, 2001).

- Once urine is separated from the faeces, several configurations exist, differing between them by the collection and transport system chosen and the treatment of the three effluents (faeces, urine, greywater) (Otterpohl *et al.*, 1999).

Table 2. Existing new sanitation projects in Western Europe

No.	Project Name	Country	City	Project Start (year)	Toilet Installation	URL Project	Responsible Organisation
1	Hamburg-Allermöhe	Germany	Hamburg	1990	Composting toilet		
2	Hamburg-Braamwisch	Germany	Hamburg	1992	Composting toilet	www.oekologische-siedlung-braamwisch.de	Ökologische Siedlung Braamwisch e.V.
3	Kiel-Hassee	Germany	Kiel	1992	Composting toilet		Ökologische Siedlung Hassee
4	Öko-Technik-Park Hägewiesen	Germany	Hannover	1992	Solitar vacuum toilet	www.oeko-technik-park.de	BauBeCon AG mit Stadtwerke Hannover AG
5	As	Norway	As	1992	Drying toilet		
6	Ecological Village Björnsbyn	Sweden	Björnsby near Lulea	1994	Separation toilet		NLH (Norrbottens Läns Hushallningssällskap - the Agricultural Society of Norrbotten County)
7	Bielefeld Waldquelle	Germany	Bielefeld	1995	Composting toilet		
8	Palsternackan	Sweden	Stockholm	1995	Separation toilet		
9	Understenshöjden	Sweden	Stockholm	1995	Separation toilet		
10	Freiburg Vauban	Germany	Freiburg	1998	Vacuum toilet	www.vauban.de	
11	Gebers	Sweden	Skarpnäck	1998	Separation toilet (Drying toilet)	www.iees.ch/cs/cs_4.html	Fastighetsägare, BRF Konditorn, Gebersvägen 24, 128 65 Sköndal
12	Kiel-Vieburg	Germany	Kiel	1998	Composting toilet		
13	Hyldespäldet	Denmark	Kopenhagen	1999	Separation toilet		
14	Mön Museum	Denmark	Mön	1999	Separation toilet		
15	Wohnsiedlung Flintenbreite	Germany	Lübeck	1999	Vacuum toilet	www.flintenbreite.de	infranova GmbH & Co. KG, Flintenbreite 4, 23554 Lübeck
16	Lambertsmühle	Germany	Burscheid	2000	Separation toilet		Wupperverband
17	SolarCity Linz-Pichling	Austria	Linz	2001	Separation toilet		SBL Stadtbetriebe Linz

b) Cost comparison

The cost comparison between the conventional and new sanitation concepts shows that the new sanitation concepts have not only ecological advantages but can also have economical advantages (see below). The cost advantage is very depending on the specific conditions of the housing-estate. For the chosen example (see methods) cost advantages occur in the most cases of the new sanitation concepts which are shown in Figure 2 to Figure 5.

In the *Scenario 1* (Figure 2) only the sanitation concept with gravity separation toilets is significantly cheaper than the conventional system. With increasing inhabitants, shown in *Scenario 2* (Figure 3), both new sanitation concepts are cheaper compared to the conventional system after 3 and 9 years, respectively.

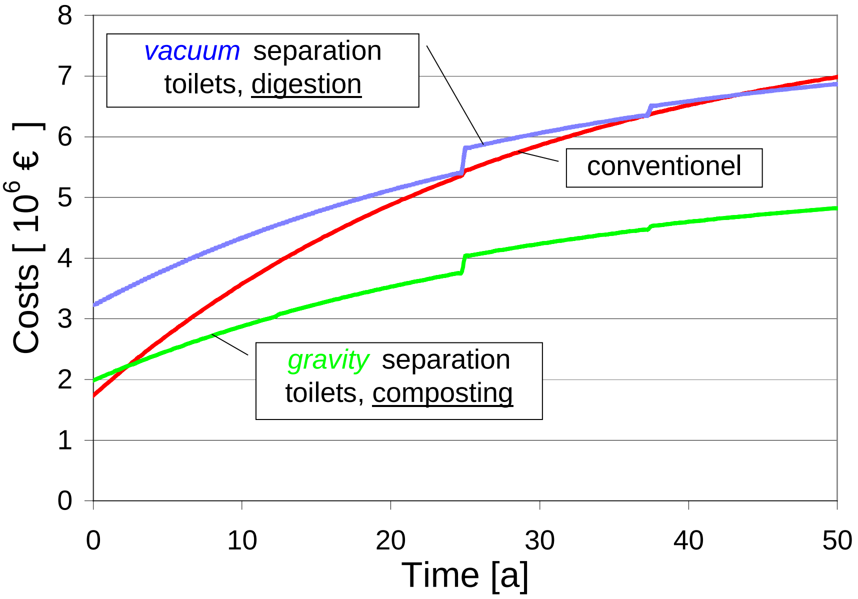

Figure 2. Total project costs for the conventional and the new sanitation concepts (*672* inhabitants); cost basis: *local company*

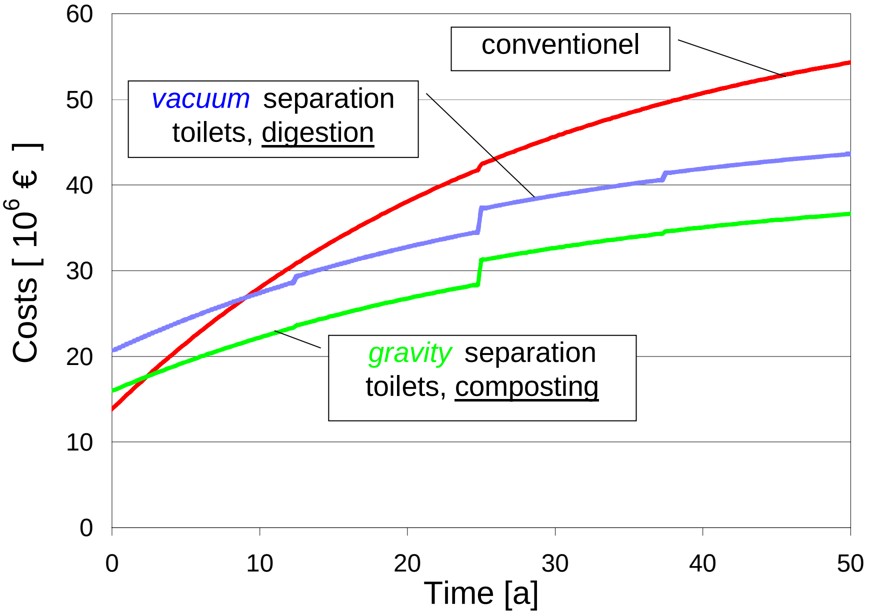

Figure 3. Total project costs for the conventional and the new sanitation concepts (*5,000* inhabitants); cost basis: *local company*

The results from *Scenario 3* (Figure 4) demonstrate only a benefit of the new sanitation concept with gravity separation toilets compared to the conventional system right from the project start. In the *Scenario 4* (Figure 5), which represents the enlarged settlement, both new sanitation concepts are cheaper than the conventional system during the whole operation time.

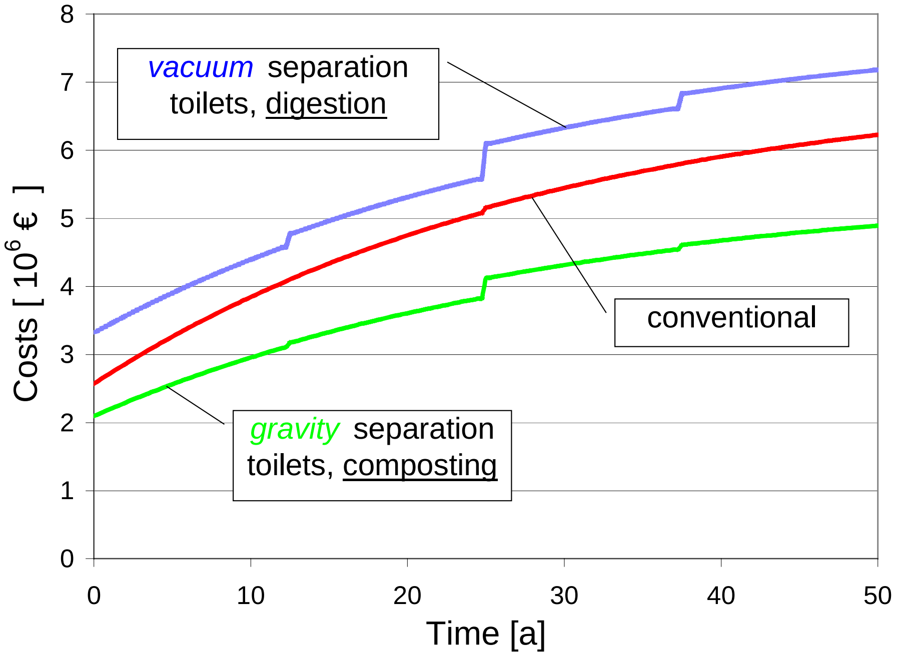

Figure 4. Total project costs for the conventional and the new sanitation concepts (*672* inhabitants); cost basis: *Berliner Wasserbetriebe*

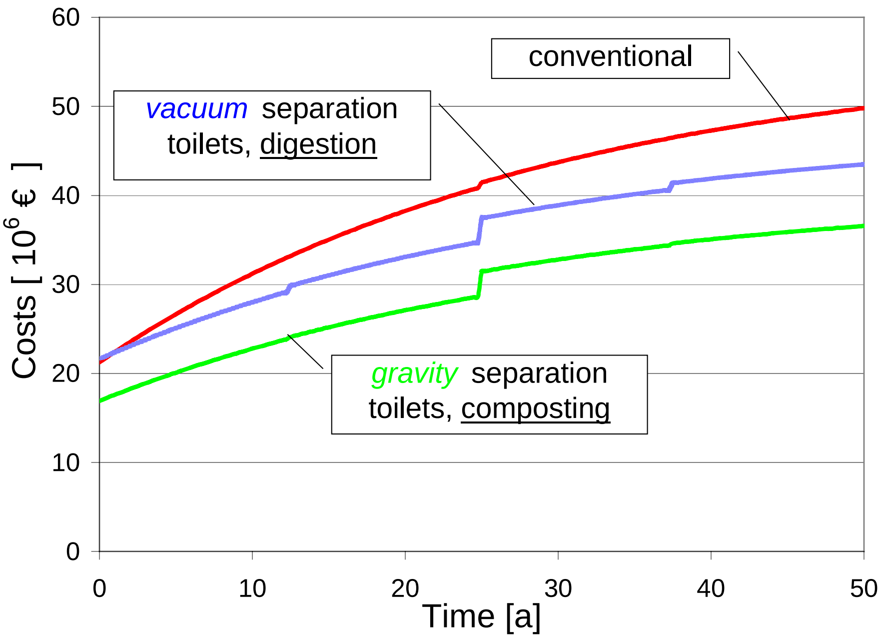

Figure 5. Total project costs for the conventional and the new sanitation concepts (*5,000* inhabitants); cost basis: *Berliner Wasserbetriebe*

The cost comparison between the two new sanitation concepts and the conventional system for the four chosen scenarios show in general that the advantages for the new sanitation concepts are increasing with the size of the settlement.

The results from this cost comparison were an additional motivation for the start of a pilot project testing

- gravity separation toilets and
- vacuum separation toilets

in conjunction with different treatment configurations. The pilot project started in the year 2002 (***Phase II***). The new sanitation concepts will be tested in existing buildings (office building and apartment house) of the Stahnsdorf WWTP owned an operated by the Berliner Wasserbetriebe. The realisation of the new sanitation concept in the office building takes place in the frame of a general restoration of this building. For the apartment house a stepwise realisation of a new sanitation concept is intended.

The general process scheme for the new sanitation concepts in the office building and in the apartment house can be seen in Figure 6.

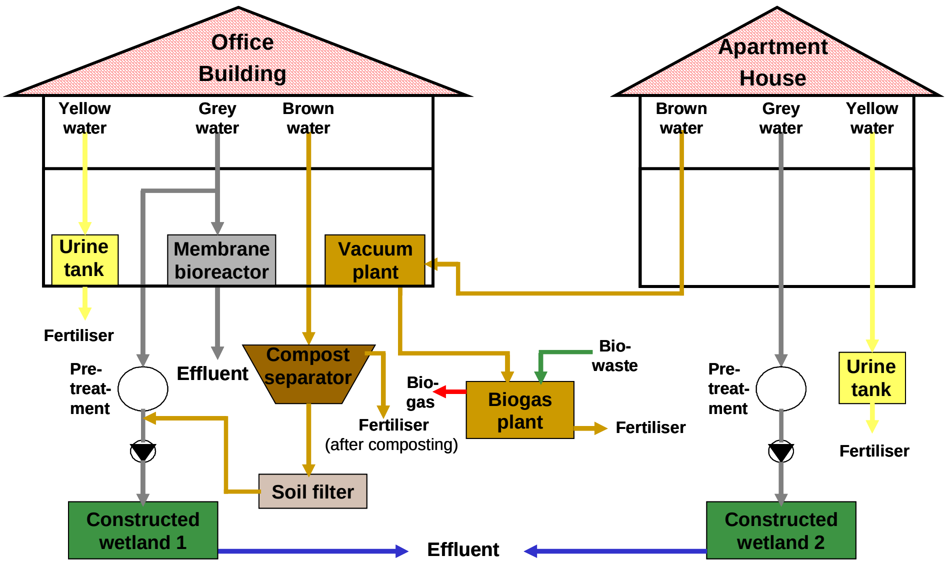

Figure 6. New sanitation concepts with *gravity* separation toilets in the office building and with *vacuum* separation toilets in the apartment house of the WWTP Stahnsdorf

In the new sanitation concept for the office building gravity separation toilets (10 toilets) will be used. In the men toilets five waterless urinals are foreseen additionally. The type of the toilet is shown in Figure 7.

With this type of toilet dilution of urine (yellow water), which reinforces the formation of “urine stones” (precipitation of Ca^{+}, Mg^{+}, PO_4^{3}, mainly into struvite, hydroxyapatite and calcite; Udert *et al.*, 2002), can be prevented due to a moveable plug (see description in Figure 7). Hence formation of “urine stone” is reduced which should prevent blockages in the urine pipes. Furthermore the volume of urine will not be increased by flush water. This is a further advantage for the urine treatment and handling.

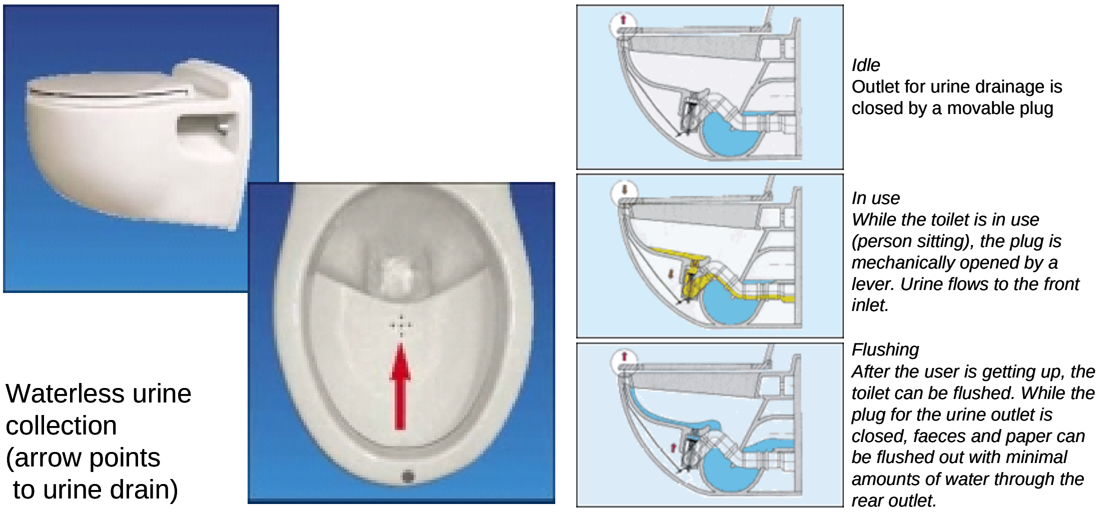

Figure 7. Gravity separation toilet (Roediger-No Mix Toilet; Roediger, 2001)

The faeces (brown water) will be drained and composted. The filtrate from the compost separator will be treated with a soil filter before mixing it with greywater. The greywater passes a septic tank before the treatment in a constructed wetland. In parallel to the constructed wetland a membrane bioreactor will also be tested for the greywater treatment. The urine will be stored in tanks. Different methods will be tested for the handling and treatment of the urine before using it as fertiliser. The methods may be adjusting different pH-values during the storage of the urine, extraction of the nutrients etc.

For the new sanitation concept for the apartment house (15 flats) vacuum separation toilets are taken into consideration. This type of toilet is under development. In this concept the urine and the greywater are discharged transported by gravity and the faeces by a vacuum system. Each flow is also treated separately. The urine will be treated as mentioned above. The faeces will be digested together with ground bio waste. The digested sludge is also a fertiliser, e.g. for farmlands. The biogas can be used either in gas cookers or in a combined heat and power unit (CHPU). This topic will not be tested in this project. The greywater passes like in one case of the office building a septic tank before the treatment in a constructed wetland.

Since the dish washing powders has a high content of phosphate (often more than 30 %) and dishwashing machines are more and more common, for both concepts, a phosphate precipitation could also be necessary for the greywater treatment.

The treated greywater can be used e.g. for irrigation in general. In this project the effluent of the membrane bioreactor will be investigated for the different options of utilization as water on a lower quality level than drinking water.

These two sanitation concepts are technical options belonging to the new approach, others are possible, e.g. composting of the faeces together with bio waste in cases if production of biogas is not wished.

The kind of greywater treatment for both new sanitation concepts will differ depending from the special situation. For large settlements an activated sludge tank etc. could be a more appropriate solution than a constructed wetland. But the size of an activated sludge tank for greywater treatment can be much smaller as for municipal wastewater treatment due to the far lower load of COD, Nitrogen etc. (Otterpohl, 2001).

Conclusion

The results from the pre-study of this project enhanced the motivation for realising a pilot project testing gravity and vacuum separation toilets.

Although the cost comparison showed higher costs for the new vacuum sanitation concept compared to the gravity sanitation concept and although the operation is likely to be less simple, it may be an appropriate solution especially in cases with water shortages. The flush water consumption will be about 6 l/(p•d) compared to about 15 l/(p•d) for the gravity separation toilet or about 25 – 40 l/(p•d) for the conventional toilet with stop bottom.

Important objects of this pilot project (***Phase II***) are:

- Increasing of the knowledge of design, installation and costs of new sanitation techniques based on separation technologies
- Experience of the operation of new sanitation concepts by investigation of the various modules of the separation concept in different conditions

In accordance to the schedule of this pilot project the start of the operation of the gravity concept in the office building is planned for summer this year (2003).

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