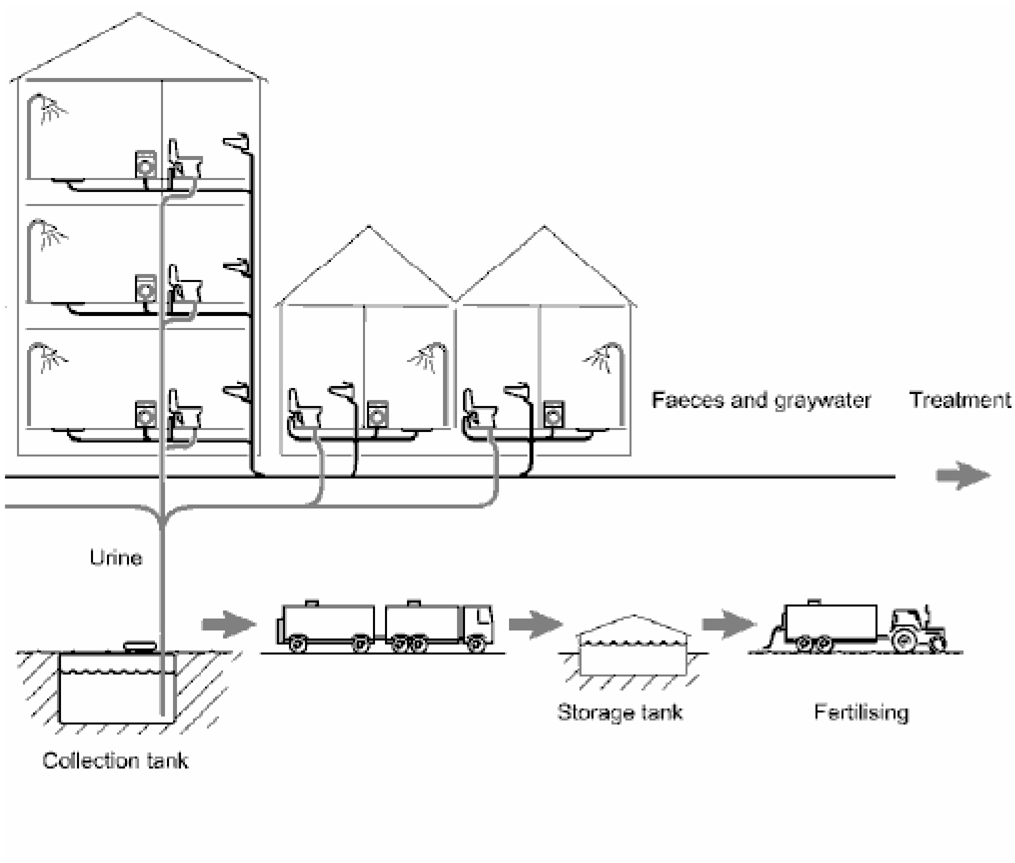
“Evaluated Source Separating Wastewater Management Systems (SSWMS)”

A research into the performance of Source Separating WMS in the Netherlands and Sweden, and the drivers and barriers that were crucial for their implementation.



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PREFACE

As part of the masters Environmental Technology I perform a thesis on Decentralised Sanitation And Reuse (DESAR) for the Urban Environmental Management (UAM) group of the Wageningen University. The thesis is part of a large study on the evaluation of several aspects on the SSWMS. I hope that my study can contribute to the further optimisation of the comparison of SSWMS with the conventional WMS. And that more SSWMS are implemented over the world.

In this research many actors were open for answers and helped me in gathering knowledge. Without these people, and there are too many to name them by person, this research was not possible. With some of them I had a very pleasant time, nice dinners and good conversations. I would like to thank all of you that contributed to this research. I hope that some of you can benefit from this study.

Finally I would like to thank my supervisors, Adriaan and Okke, for the possibility to perform this study and perform research in Sweden; and for their assistance in my research.

I wish you a pleasant reading,

Wouter van Betuw

SUMMARY

Recently new concepts for domestic WMS are developed, the so called Source Separating WMS (SSWMS). In several countries new neighbourhoods are designed with several types of SSWMS. The philosophy of SSWMS is a source related approach, at household (hh) level, by separating black water (toilet water) and grey water (shower-, washing-, and bath water). Also separation by urine collection, brown water (only feces and toilet water) and grey water are known.

This study focuses on a) Performance - the comparative performance (technical and financial) of the SSWMS with the reference WMS, and b) Technology choice - the drivers and barriers that lead to establishment of the SSWMS;

Ad a) the performance includes four criteria: compliance with primary functions, sub functions, user-perspective and environment. Each criterion has several quantifiable indicators. The indicators are standardized to fit all sanitation situations in the world.

Ad b) little is known about the rationale of the realization of these systems. Several actors involved in the design of the new neighbourhood enforce the realization. The actors are grouped as governmental organizations, project developer, and the future inhabitants.

The studied sites are in the Netherlands: ‘Het groene dak’ situated in Utrecht and ‘Polderdrift’ in Arnhem, and in Sweden: ‘Ekoporten’ situated in Norrköping, ‘Understenshöjden’ in Stockholm, ‘Gebers’ in Stockholm, Skogaberg in Göteborg.

The main research questions are:

1) What is the performance of the implemented SSWMS based on the criteria in the Netherlands and Sweden compared to the reference WMS.

2) What are the main drivers and barriers for the implementation of a SSWMS in the Netherlands and Sweden.

Table 1 presents the performance assessment of the sites compared to the conventional WMS.

Table 1

Criteria	**Indicator**	**Groene dak**	**Polder drift**	**Eko por ten**	**Skoga Berg**	**Under stens höjden**	**Gebers**
Primary functions	Health protection	-	-	0	0	0	-
	Protection of surface water	0	+	-	+	+	+
Sub functions	Rainwater management	+	+	+	+	+	+
	Drainage management	+	+	0	0	0	0
User perspective	Costs	-	-	-	-	+	+
	Invisibility / comfort	0	0	+	+	0	-
	Robustness	-	-	-	-	-	-
Environment	Resource use	+	+	+	+	+	+
	Emissions	0	+	+/-	+	+	+

The main drivers and barriers were different in the Netherlands and Sweden. One difference is the objective of water reuse. In most cases the Swedish tenants were not interested in the water-use. Yet a large part of their operational costs are defined by the water-use. Another difference is the recycling of nutrients that is actively addressed by all Swedish actors and is implemented in the new policy on WMS. In the Netherlands the nutrients are not very interesting.

In both countries health risks are important. Some health risks may be related to the lack of management and maintenance. Since the prevention of health risks is part of the primary functions they should be minimized. In Sweden is the protection of surface water, mainly the fragile lakes, very important. Therefore a local treatment plant may be a risk (by failure) for this quality. All actors address the high costs as an important barrier. Yet the distribution of costs and benefits is very diffuse over several actors. The discount on the water-board fee is part of this diffusion. The value of the SSWMS is for the water-boards in the Netherlands hard to define, because they have no interest/idea. In Sweden in some cases a discount is given, yet the proportion of the discount is not defined clearly. The last barriers is that in most urban areas already a conventional WMS is present, and several actors value the system on its reliability and cost effectiveness.

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1 INTRODUCTION

1.1 Research background

The domestic wastewater in the Netherlands is mostly, 98% (Mels, 2004a), treated before discharge on surface water by a wastewater management system (WMS). The wastewater is conventionally managed by means of transport by sewerage systems and treatment in a Wastewater Treatment Plant (WTP). This WMS is considered to be the conventional system. In very isolated areas septic tanks are common for individual households.

The primary functions of a WMS are: protection of public health by means of safe transport and treatment of human waste; and protection of surface water and environment by preventing discharges of hazardous compounds. Also the discharge of rainwater and groundwater is accomplished by the system. The conventional WMS undergoes several problems (Mels, 2004a):

- the sewerage needs renovation and expansion that results in high costs;
- there is direct pollution of surface water with untreated wastewater due to low capacity of sewerage and WTP to treat intensive rainfall;
- upcoming new EU standards on effluent quality of the WTP, therefore expensive tertiary treatment steps need to be installed;
- there is waste production of polluted sludge, it contains to much heavy metals, that has to be incinerated;

Recently new concepts for domestic WMS are developed, the so called Source Separating WMS (SSWMS). In several countries new neighbourhoods are designed with several types of SSWMS. The philosophy of SSWMS is a source related approach, at household (hh) level, by separating black water (toilet water) and grey water (shower-, washing-, and bath water). Also separation by urine collection, brown water (only feces and toilet water) and grey water are known. Compared to the conventional WMS the black water can be treated in a concentrated form (no grey water dilution) that increases treatment efficiency and makes reuse of nutrients possible. The grey water can be treated by means of reetbed filters, activated sludge or other technologies. These treatment methods make it possible to clean the wastewater at local level and the conventional WMS becomes unnecessary.

There are several types of SSWMS realized in the Netherlands and Sweden. These WMS are divided in clusters based on their separation.

- In the Netherlands the separation is between grey and black water. The grey water is treated locally yet the black water is still treated in conventional way.
- In Sweden the systems include separation of urine, brown, and grey water. The urine is reused by local farmers, or in other ways. The brown water is composted or digested with biogas production. And the grey water is treated locally or in conventional way.

This research is related to a stock taking research (STR) (Mels, 2004b) of these realized SSWMS. The STR's objective was to gather experiences of SSWMS to increase their establishment in the Netherlands. The STR describes the technical functions, the history, and the organization of the implementation of the WMS. This study focuses on a) Performance - the comparative performance (technical and financial) of the SSWMS with the reference WMS, and b) Technology choice - the drivers and barriers that lead to establishment of the SSWMS;

Ad a) the performance includes four criteria: compliance with primary functions, sub functions, user-perspective and environment. Each criterion has several quantifiable indicators. The indicators are standardized to fit all sanitation situations in the world.

Ad b) little is known about the rationale of the realization of these systems. Several actors involved in the design of the new neighbourhood enforce the realization. The actors are grouped as governmental organizations, project developer, and the future inhabitants. The research will include the realised sites and also some non-realised sites.

1.2 Research objective

The research objective is to assess the performance of SSWMS in the Netherlands and Sweden by comparison with the conventional WMS in the Netherlands; and defining their drivers and barriers in decision-making by evaluating established and failed SSWMS.

1.3 Main research questions

1) What is the performance of the implemented SSWMS based on the criteria in the Netherlands and Sweden compared to the reference WMS.

2) What are the main drivers and barriers for the implementation of a SSWMS in the Netherlands and Sweden.

1.3 Sub-research questions

Reference system:

1a.What is the average conventional WMS in the Netherlands?

1b.What is the average performance of the conventional WMS in the Netherlands?

1c. Which actors are involved in the decision-making process?

1d. What are the drivers and barriers of the conventional WMS?

SSWMS sites:

2a. What types of SSWMS sites are implemented?

2b. What sites are interesting for the research based on the clustering?

2c. In what criteria does the performance of the clustered SSWMS sites significantly differs from the conventional WMS in the Netherlands?

2e. Which actors are involved in the decision-making process?

2f. What are the drivers and barriers in the decision-making process to establish the SSWMS system?

1.4 Index

The next chapter presents the background of this study, the characterization of the wastewater and involved legislation. Thereafter the research method describes the strategy and method used. Then the reference systems, as well as two not implemented SSWMS are described. Chapter 5 and 6 present the SSWMS in the Netherlands and Sweden. Subsequently in the discussion the bottlenecks in this study are shown. Thereafter a conclusion on the main research questions and several recommendations are given. Finally a list with the definition of concepts is given.

2 WASTEWATER CHARACTERIZATION AND LEGISLATION

2.1 Introduction

This chapter portrays the characterization of the domestic wastewater to gain insight in the fundaments of the WMS. A distinction is made between the grey-, black-, urine, brown and rainwater. From this distinction new WMS can be developed. Subsequently the legislation regarding wastewater transport and treatment in the Netherlands, Sweden, and of the European Union is addressed. The legislation is part of the preconditions of the systems.

2.2 Sources of wastewater

Domestic wastewater arises from several habits that are water consuming. The water used for these purposes is mainly drink water. This drink water contains high quality standards based on protection of the public health. The amount of water used is based on three factors: the penetration of water consuming equipment, the actual use of persons, and the capacity of the water consuming equipment. In 2004 is in the Netherlands the average amount 123.8 L/p.d (Table 2). The water price is different at each water supply company, yet the average is € 1.02/m^3 (Geudens, 2005). In Sweden average amount is 200 L/p.d with a price of € 1.37/m^3. The Swedish price includes the sewerage taxes, water-board fee and WTP investment costs.

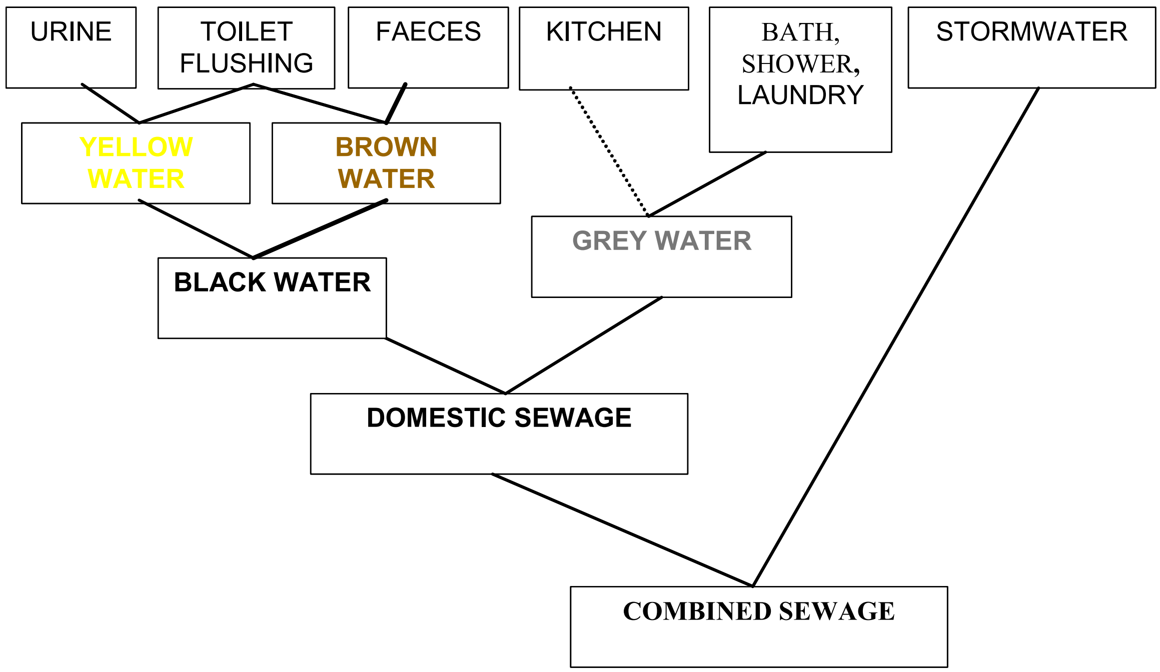
Table 2 Water consumption in the Netherlands in 2004 (Kanne, 2005)

Water consuming activity	Amount of water in (L/p.d)
Bath	2.8
Shower	43.7
Washbasin	5.1
Toiletflush	35.8
Washing clothes, by hand	1.5
Washing clothes, by machine	18.0
The diches, by hand	3.9
The diches, by machine	3.0
Food preparation	1.8
Koffee and thee	1.0
Water drinking	0.6
Other kitchen tap	6.4
Total	**123.8**

Due to the run off of hard surface areas in urban areas rainwater cannot directly infiltrate in the soil. Therefore it is normally discharged by the sewerage. In the Netherlands 75% of the sewerage is designed as a combined sewerage (Lemmen and Oomens, 2001). The amount of rainwater differs per region and time.

Figure 1 presents the different types of wastewater. The relative quantity of feces is 5 L/p.m, urine 50 L/p.m, toilet flush water 1000 L/p.m, grey water 2000 L/p.m and rainwater 1500-6000 L/p.m (Van Buuren, 2004).

Figure 1 Types of wastewater



2.3 Quality of the wastewater

The quality of the different types is diverse and defines the necessary treatment. Table 3 presents the daily loads to domestic wastewater (Van Buuren, 2004). The parameters mentioned are Chemical Oxygen Demand (COD), total nitrogen (N-total), total Phosphorus (P-total), and Fecal Colien (FC), respectively to indicate the oxygen consumption, eutrophication capacity (N and P), and indicating the amount of pathogens. The table shows that grey water contains only 30 % COD, 10 % N-total, less then 50% P-total, and 10% FC of the total domestic wastewater. These amounts are diluted in approximately 65-88 litre (Kanne, 2005 and Van Buuren, 2004) that makes it not very polluted. This makes simple treatment possible.

Table 3 Daily loads discharged to domestic wastewater

	COD (g/p.d)	N-total (g/p.d)	P-total (g/p.d)	Fecal Colien (n*/p.d)
Feces	44	2	0.85	1010
Urine	36	8	1.45	0
Black water**	80	10	2.3	1010
Grey water	34	1	1-2	109
Total***	**114**	**11**	**2-3**	**1.1*1010**

* n is the amount counted ** The blackwater is the cumulative of feces and urine *** The total value is cumulative of black and grey water

The black water is the combination of feces and urine. The amount is approximately 2 litre diluted with 32 – 35.8 litre flush water (Kanne, 2005 and Van Buuren, 2004). The feces contain a high concentration of pathogens and need to be disinfected before reuse. It can be composted or digested in biological treatment steps. The final sludge has a destination in land filling, incineration or reuse by farmers. The latter is due to the heavy metal concentration not applicable in the Netherlands. Of the black water the Urine contains approximately 45 % COD, 80 % N-total, 63 % P-total, and normally 0 % FC. The amount of pathogens can increase if the capita has kidney problems, i.e. a kidney infection. The amount of heavy metals is low (Palmquist and Jönsson, 2003). The separation of the urine is carried out at the toilet. After a disinfecting storage time it is reusable in agriculture as fertilizer. For cereals the N and P concentration is respectively 90 % and 100 % compared to a chemical fertilizer. The environmental effects of urine separation compared to a conventional sewerage system are: recycling of much more plant nutrients and therefore lower water emissions of nutrients, and energy saving due to less nitrogen removal in WTP and production of fertilizers. (Jönsson, 2001 and 2002)

The rainwater is managed by infiltration or by discharge on the sewerage. Table 4 portrays the rainwater quality. Before contact with any surface the quality is suitable for reuse. If it comes in contact with roofs it may be chemically of a good quality but biological unstable, i.e. it may contain FC and pathogens due to feces of birds. Reuse without any treatment, for instance for toilet flushing, leads to health risks higher than maximum acceptable (Senden, 2003a). The rainwater may take up pollutants of traffic and other human activities therefore treatment before discharge is necessary.

Table 4 Quality of rainwater without contact on any surface (Senden, 2003)

	Eenheid	Scheveningen		Zandvoort		Wijk aan Zee		Enschede	
		Gem.	Max.	Gem.	Max.	Gem.	Max.	Gem.	Max.
Temp	°C	10,3	23,3	9,1	21,5	10,7	19,2	8,6	18,6
SS	Mg/l	1,75	6,6	0,73	2	1,65	8	0,54	1,1
PH	-	5,94		5,06		5,72		6,54	
HCO_3	Mg/l	5,8	15	2,0	6	3,0	6	5,0	5,6
Ca	Mg/l	1,5	3	1,0	2,4	2,0	4	0,3	0,74
Mg	Mg/l	1,09	2,1	1,11	2,5	1,73	3,2	0,17	0,32
TH	Mmol/l	0,082		0,071		0,121		0,015	
IJzer	µg/l	32	70	19	40	46	90	14	70
Mangaan	µg/l	6	20	7	20	21	40	5	<10
EGV	µS/cm	115	335	79	160	104	181	25	40
NO_3	Mg/l	3,4	7,53	2,9	7,53	3,6	8,42	2,5	5,32
oPO_4	Mg/l	0,15	1,25	0,07	0,46	0,07	0,18	0,10	0,83
TPO_4	Mg/l	0,33	1,44	0,11	0,77	0,09	0,21	0,13	0,86
NH_4	Mg/l	1,10	2,99	1,08	3,87	0,99	2,03	1,72	3,35

2.4 Legislation in the Netherlands

In the Netherlands several legislations are involved regarding WMS. The legislation is made by the National government. The Housing Act states that according the 'Building Permission' each house should have a hygienic character. This means that the domestic wastewater needs to be collected by means of sewerage in order to prevent a dirty house. The Environmental Management Act states that the Local Government is responsible for the collection and transport.

The Pollution of Surface Waters Act established in 1970 and states that the discharge of domestic wastewater on surface water is only permitted in case of a Governmental License. The Water-board is treating it in a WTP and has this Governmental License. The Act focuses on the removal of pathogens, oxygen consuming waste (BOD and ammonium) and N and P. In 1991 European Union launched the Guideline Urban Wastewater (91/271/EEG). Table 5 presents the emission standards for new or existing plants.

Table 5 Emission standards in The Netherlands as of 2001

Parameter	Unit	Amount	Applies to
BOD	mg O_2/l	≤ 20	
N-Kjeldahl	mg N/l	≤ 20	
Suspended solids	mg TS/l	≤ 30	
Ptotal*	mg P/l	≤ 2	New plants + existing plants < 100,000 p.e.***
	mg P/l	≤ 1	New plants + existing plants > 100,000 p.e.
Ntotal*	mg N/l	≤ 15	New plants < 20,000 p.e.
	mg N/l	≤ 10 or 15**	New plants > 20,000 p.e.
	mg N/l	≤ 15	Existing plants < 20,000 p.e.
	mg N/l	≤ 10	Existing plants > 20,000 p.e.

* exceeding of these limits is possible under the condition that an average 75% elimination rate has been achieved within the area of a water board

** ≤ 10 mg N/l; unless phosphate is removed by simultaneous precipitation; in the latter case ≤ 15 mg N/l

*** p.e. = population equivalent

The sludge of the WTP is according the 'BOOM-besluit' to polluted for reuse in agriculture. Therefore it is incinerated at a centralized plant. The remaining ashes are used in construction activities. The treatment costs of the sludge are approximately 40 % of the total wastewater treatment costs. (Mels, *et. al*., 2004a)

In the Netherlands the main water source is drink water. Yet also 'household-water' is used that may contain a lower water quality. Article 4, first paragraph, of the 'Waterleidingbesluit' reveals that it may not contain micro-organism, parasites or substances in a concentration that might be harmful for the public health. The maximum applicable infection risk for pathogenic organism has a threshold value of one infection on 10,000 persons per year. From this perspective the Ministry of VROM concludes that the use of household-water may be risky. (Senden, 2003b)

2.5 Legislation in Sweden

In Sweden the Environmental Act regulates the discharge of the wastewater effluent. It contains no effluent demands for BOD, P, and SS. The effluent of WTPs at the sea is defined by EU legislation and considers for N-total the threshold value of 10, and 15 mg/L for respectively plants of <100,000 p.e. and >100,000 p.e. These values do not count for WTP north of Norrtälje. Above this city the temperature is in general so low that the biological nitrogen removal is reduced. (Website Swedish EPA)

It is advised by the LRF (farmers' organization) to not reuse the WTP sludge in agriculture. They question the effect of heavy metal, persistent organic pollutants, hormones, and medicines. The quality standards for the sludge that makes reuse for arable land applicable are depicted in table 6. Therefore most sewage sludge is land filled and incinerated.

Table 6 Metal content in DM sludge for arable land according the SNFS 1994:2 (Website Swedish EPA)

Metal	Amount in DM sludge (mg/kg)
Pb	40
Cd	0.4
Cu	40
Cr	60
Hg	0.3
Ni	30
Zn	100

2.6 Legislation in Europe

In 2006 / 2007 the effluent quality standards will be changed according the EU Water Framework Directive. In 2015 all WTP have to fulfill these new standards. The standards are depending on function(s) of the surface water at which the WTP discharges on. The exact standards still have to be defined. For some WTP the standards will equal the MTR (maximum tolerable risks) values for N-total < 2.2 mg/L, P-total < 0.15 mg/L, Copper 3.8 µg/L, and Zinc 40 µg/L. Finally an EU regulation state that human urine may not be used in ecological agriculture, yet in conventional agriculture (Jönsson, 2001).

3 RESEARCH METHODOLOGY

3.1 Introduction

In this chapter the research methodology is explained. First the research sites are clustered. Subsequently the performance assessment is presented. And finally the technology choice (drivers and barriers assessment) is described. In Appendix 1 the practical instruments of this strategy are given.

3.2 Research sites

The main focus of this research is not on all national WMS but on *urban areas* where a conventional WMS is normally applied. The water supply system is not taken into account, although in some sites this was part of the project. The reason for these preconditions is that the research would not fit in the available research time. It is advisable to assess those systems in further research as well.

The SSWMS involved in this research are selected from the STR. To gain an overview of the sites and their used technology they first are numbered and inserted in a database (the database has the extension '*Research sites.xls')*. Also the contact information of the actors of each site is inserted to outline and store the information. The database is designed to fit in more sites in the future. The database makes it easy to cluster the sites in the following concepts:

0. No separation of wastewater (reference WMS)
1. Partly separation of Urine and the rest (brown, grey, and rainwater)
2. Full separation of water:
    2a. Black, grey, and rainwater
    2b. Urine, brown, grey, and rainwater

Ad. 0) The reference system is the conventional WMS that contains no separation and is based on transportation by sewerage to the WTP. The rainwater is also discharged with this system. The sludge of this process is treated and finally incinerated, or land filled. The average of the conventional system in the Netherlands is representative to all conventional WMS in the Netherlands and Sweden.

Ad. 1 & 2) The rainwater and sludge transport and treatment are also taken into account. The selected SSWMS sites are based on research time, travel distance, and cluster.
In the Netherlands the sites are all in cluster 2a. The sites selected are:

(1) ‘Het groene dak’ situated in Utrecht;

(3) ‘Polderdrift’ situated in Arnhem.

In Sweden the four selected sites are:

(11) ‘Ekoporten’ situated in Norrköping that is in cluster 2b;

(12) ‘Understenshöjden’ in cluster 1 and situated in Stockholm;

(13) ‘Gebers’ in cluster 2b and situated in Stockholm;

(16) ‘Skogaberg, Göteborg’ in cluster 2a and situated in Göteborg.

3.3 Performance Assessment

The assessment of the performance contains a full description and evaluation of the implemented system. First the history and implemented technology are described, and then the performance by answering the questions in Appendix 1 paragraph 1.5. Subsequently the indicators of a system are inserted in the database. The database is standardized to compare all WMS around the world. Aspects of the database are: sort SSWMS, sort indicator compliance with the criteria

- primary functions
- sub-functions
- user perspective (costs, invisibility, and robustness), and
- environment (resource use and emissions).

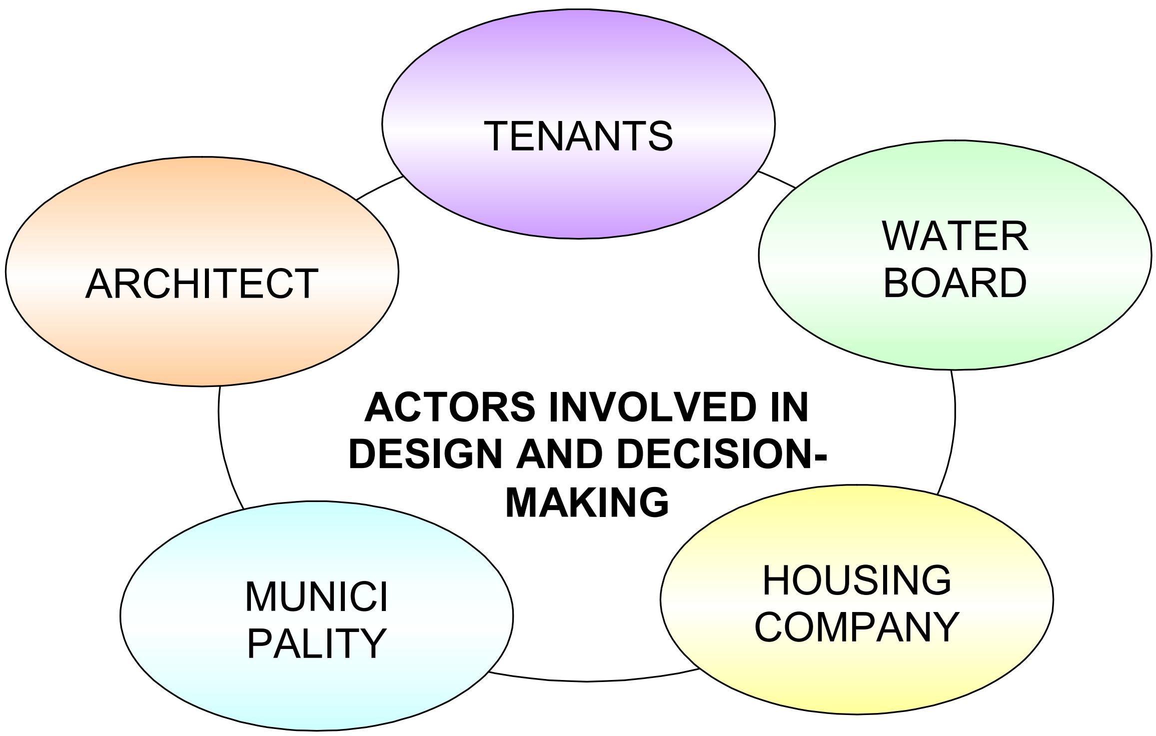
The environmental criterion is divided in resource consumption and emissions. The extra use of material is not included. The indicators are all calculated for a 2 persons’ household. The total costs consist of investment and operational costs. The annuity of the investment costs is calculated with an interest of 2.5 % and a lifetime of 25 years. The user-perspective is an average of the answers of the tenants. The systems indicators are compared with the reference WMS to assess the performance.

The information is gathered by literature research and interviews with actors and tenants (5 households). The letter and survey for the households and actors are presented in Appendix 1. The households are selected with the method of random sampling. This amount can not give a generalization to the whole (SSWMS sites’) population, yet logical inference to the population is still possible.

3.4 Technology choice (Drivers and Barriers)

To gain insight in the decision-making of the design and implementation phase of the system several actors (stakeholders) involved are interviewed (figure 2). First an overview of the actors and their role and responsibility is presented. Subsequently an overview is made of their drivers and barriers in design, current and future situation. The time perspective is important to get insight in the development of their arguments. Also some experts are interviewed to gain knowledge on the barriers in not established SSWMS sites that failed during their decision-making.

Figure 2 Actors in design and decision-making



4 REFERENCE WASTEWATER MANAGEMENT SYSTEM

4.1 Introduction

This chapter presents the reference WMS systems in the Netherlands. Since the reference system in Sweden is quite similar in urban areas the system description may be used to compare all the SSWMS.

4.2 Reference WMS

Since the 1920s the authorities in the Netherlands are building sewerage systems. The objective was to remove all wastewater from the houses and protect the public health by preventing water-based epidemics (Mels *et. al.*, 2004a). To protect the surface water and drink water sources the sewage needed treatment in a wastewater treatment plant (WTP). The main objective was to remove oxygen consuming organic matter, nutrients (N and P), and pathogens. In 2001 15,732,214 inhabitants are connected to the centralized WMS (Rioned, 2002). Therefore approximately 7,866,107 households (2 p/hh).

4.2.1 Implemented Technology

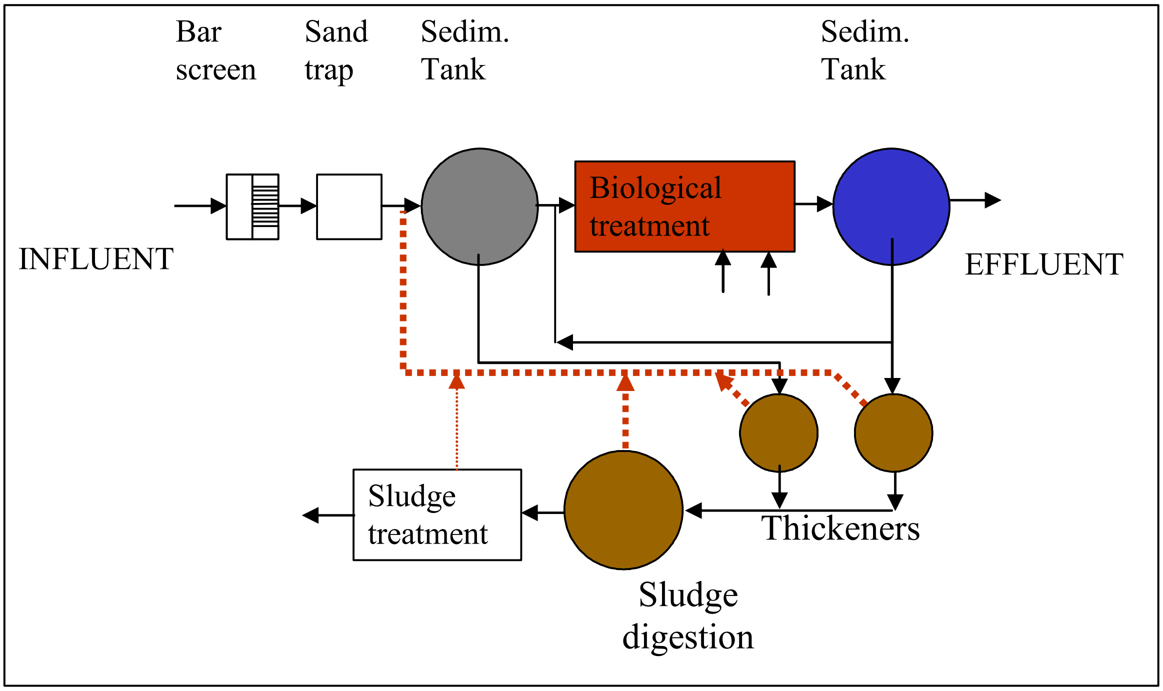
Rainwater

The rainwater may be collected separately with a rainwater sewerage or combined with the domestic sewage. The main problem of combined sewerage systems are the sewage overflows by intensive rain fall, and the dilution of the wastewater by rainwater. The separate collection prevents overflows of the domestic sewerage. In most cases discharges the rainwater sewerage directly on surface water. Therefore pollutants of roads and roofs end up in the surface water. Yet improved separated sewerages were build to discharge the (most polluted) first fraction to the domestic sewage system. The combined sewerage system is used as reference system.

Domestic sewage

There are 27 Water-boards in the Netherlands governing 393 WTPs treating 1,997-million m^3 wastewater in the year 2002-2003 (Stichting Rioned, 2002). Figure 3 presents a scheme of a conventional WTP in the Netherlands. In most WMS the combined sewage is treated by several steps: screening, sedimentation, biological treatment, sedimentation, and sludge treatment.

Figure 3 Conventional WTP (Van Buuren, 2004)



The effluent water is discharged on surface water. In 2002 was the average removal efficiency of all WTP for (Stichting Rioned, 2002):

- BOD 97 %
- P-total 79 %
- N-total 68 %
- Susp. Solids 94 %

The sludge is incinerated, land-filled, or reused in compost. In 2002 the yearly sludge production is 350 million kilo dry matter (VROM 2004).

Evaluation current system

The current system fulfils the functions of protection of the public health and surface water quality. However the system is not sustainable: it generates an enormous waste stream (sludge), does not recycle nutrients, and can overflow. Other drawbacks are that many parts of sewerage need renovation and the effluent qualities do not fulfill future quality standards. The amount of overflows in 2001 was 15,198, of which 443 form a risk for drinking cattle, and 267 form a risk for public health (Stichting Rioned, 2002).

5.2.2 Performance reference system

Primary functions

The chance for households to get in contact with the wastewater is present, yet low. The contact moments are the sewerage overflows. The chance for inhabitants to get access to the equipment is not present. The sewerage system and WTP are secured. The change of a calamity with the overflows is 15,198 times per year. The WMS protects surface water quality and the environment by means of prevention of discharges of oxygen demanding compounds and nutrients. The removal efficiency is described in the previous paragraph.

Sub functions

The WMS includes measures for rainwater management by means of collection and treatment in the WTP. The maximum rainwater intensity the system can store is unknown. The WMS include measures for removal of groundwater or drainage water due to sewerage system.

User-perspective

The user-perspective is divided in costs, invisibility and comfort, and robustness. The total costs of the conventional WMS are € 572/y (table 7).

Table 7 Investment and operational costs conventional WMS (Rioned, 2002)

Aspect	Cost (€/household)	Expected lifetime (year)	Costs (€/y)
sewerage system*	3500	25	237.5**
WTP*	875	25	
sewerage taxes			104***
water-board fee			139***
water supply			92
Total Costs			**572**

*(Mels *et. al.*, 2004a) **Annuity considering an interest of 2.5 % *** 2 p/hh

The invisibility and comfort is assumed by giving a score between 0 (very negative) and 4 (very positive). The toilet is a normal flush toilet. The SSWMS makes them not at all (0) feel environmental concerned / friendly. They will recommend the system to other households in other neighbourhoods without improvement (3). They think that the visible part of the WMS equipment in or near the houses is not disturbing (2). The WMS produces not at all (4) annoying noise levels. The WMS produces not at all (4) unpleasant odours. The WMS does not attract vermin at all (4).

The tenants do not have to perform maintenance. The maintenance on the sewerage system is carried out by the municipality and of the WTP by the water-board. The amount of maintenance

hours per household and year is unknown. The tenants face restrictions on products for flushing trough the toilet yet do not have a list of products. The robustness of the system is high. The general system failure is 15,198 / 7,866,107 = 0.0019 /hh.y. The indoor volume of the system is 0 m^3 (toilet not included). The outdoor surface is the summation of the pump station and WTP. The average area per household is unknown.

Environmental

The amount of energy used by the WMS is unknown. The amount of chemicals used is also unknown. The amount of water consumption is in general 93 m^3/hh. In Sweden this is much higher approximately 167.9 m^3 (Kranz, 2005). The amount of sludge produced by the WMS is 45 kg/hh.y. However this includes the sludge from industrial wastewater connected to the WMS. The volume of reusable water is 0 m^3/hh.y. The amount of nutrients recycled is nil. The water quality of the WMS fulfilled the effluent standards of 2001. The extend of compliance of the final water quality with futuristic EU quality standards (Water Framework Directive) is unknown.

5.2.3 Actors

The actors and their role in the design and decision-making are presented in table 8. The municipality and water-board are directly involved in the design of a new neighbourhood. They have to permit all the water management plans. The experience is that most municipalities and water-boards desire the conventional system. The architect, housing company, and project developer of the neighbourhood are the actors that should address what kind of WMS they desire.

Table 8 Actors in design and decision-making

	Description	**Role**
1	Municipality	Initiative and steering role in demands and design water aspect
2	Water-board	Treatment wastewater in WTP
3	Architect	Building Design
4	Housing company	Project manager rental houses
5	Project developer and constructor	Project manager owner-occupied houses and constructor

Responsibilities

In the Netherlands several governmental organizations are responsible for the WMS. These organizations are the National government, Local government and the Water-board. The national government designs legislation and policy and finances the WMS. The local government is responsible for design, installation and maintenance of the sewerage system. The water-board has the responsibility of the treatment. The tenants are responsible for the in-house equipment (toilet, pipes, etc.).

In Sweden water-boards do not exist, and the treatment is carried out by the municipality. Sometimes the municipality has divided the WMS in several departments or partly board out the services. Therefore all knowledge on water-quality, transport and treatment are integrated in one actor.

5.2.3 Drivers and barriers

Environmental Drivers and Barriers

The main environmental drivers are prevention of public health risks, rainwater floodings, high groundwater levels, and sewerage overflows (Mels, 2004a). Another driver is to protect the surface water by cost effective treatment according the effluent standards (Matsson, *pers. com.*). In Sweden the protection of lakes is very important because they are isolated and fragile for pollution. Therefore many WTP discharge the effluent on the sea. Another driver is to disconnect the rainwater as much as possible by rainwater sewerage (Warnshuis, *pers. com.*). The environmental barriers are health risks by sewerage overflows, production of sludge waste, no nutrients recycling therefore enrichment of surface water, and discharge of pathogenic organisms in surface water. Another barrier is the high water use and dilution of the waste fractions. Finally the uptake/infiltration off/in the groundwater is an environmental barrier, which could lead to groundwater pollution and drying out of the soil. (Mels, 2004a)

Economical Drivers and Barriers

The main economical driver is low costs for the households as a result of a centralized system. This refers to the scale of the system, by centralizing the WMS the amount of treatment plants, monitoring and maintenance activities, energy use, and calamities are reduced (Matsson, *pers. com.*). The sewerage system is due to its simplicity, gravity flows and pumping station, reliable; therefore maintenance activities and related costs are low (Bokesjö, *pers. com.*). The main economical barriers are high water use, nutrients depletion and diffuse costs. The households do not really care and take the payment of sewerage taxes and water-board fee as for granted (Hort, *pers. com.*).

Social Drivers and Barriers

The social drivers are the simplicity and reliability of the technology, no household disturbances (flush and forget principle), and is based on many experiences (Bokesjö, *pers. com.*). Another driver is the trust of the households in the governmental organization that they take care of the transport and treatment in a professional way. The social barrier is the alienation of the households with their wastewater and related problems.

4.3 Not implemented SSWMS

In two neighborhoods in the Netherlands SSWMS were planned. Yet due to the barriers in decision-making a conventional WMS was implemented. In Sweden the main implementation barriers are:

- protection of the inland lakes therefore minimize the risks of pollution by small treatment plants (Matsson, *pers. com.*)
- back-up connection to centralized treatment system in case of system failure. And this will further increase one main barrier: high installation costs. (Franzen, *pers. com.*)
- transport of the recycling products (de Blois, , *pers. com.*)

4.3.1 Stroomdal

The neighborhood Stroomdal is situated in Emmen. The neighborhood consists of approximately 200 private owned houses. The neighborhood was newly built, although the sewerage was already in place. The SSWMS proposal contained a black and grey water separation. The black water would be collected by vacuum toilets and sewerage, and finally digested. The grey water would be treated in the conventional WMS. The objective was to research the systems characteristics and nutrient recycling potential. (Zeeman and Heffer, *pers. com.*) In the design and decision-making many actors, except the tenants, were involved. Many actors had opposite thoughts and struggled with the drivers and barriers. The main barrier was the high investment costs of the system. Another barrier was that in the Netherlands no agricultural wish of recycling nutrients exists. (Zeeman and Heffer, *pers. com.*)

4.3.2 Rustenburg

The neighborhood Rustenburg is situated in Wageningen. The implementation of a SSWMS was planned in a flat of 20 apartments. The neighborhood was newly built. The SSWMS proposal contained a black and grey water separation. The black water would be collected by vacuum toilets and sewerage, and finally digested. The grey water would be treated in the conventional WMS. Also in this case the main barrier was the high investment costs of the system. Another barrier, for the architect, was that the vacuum toilets were only produced in a white color. The suggestion was that the tenants should have the possibility to choose the kind of color. (Zeeman, *pers. com.*)

5 SOURCE SEPARATED WMS IN THE NETHERLANDS

5.1 Introduction

This chapter presents the SSWMS in The Netherlands. Two neighborhoods named ‘Het Groene Dak’ and ‘Polderdrift’ in the cities Utrecht and Arnhem, respectively, were investigated. The source separation includes grey, black, and rainwater. These are eighter treated locally, in conventional way, infiltrated or stored.

5.2 Het Groene Dak

In 1989 the tenants association ‘Het Groene Dak’ initiated the design of an ecological neighborhood with a low environmental impact. The neighborhood was realized in 1993 in cooperation with several actors. The area consists of 66 houses, with two special clusters of five houses. Various sustainable building aspects were used, in these clusters a SSWWS. The two clusters are subject of this study. (website, Groene Dak)

5.2.1 Implemented Technology

The SSWMS includes separation of grey, black, and rainwater. The technical scheme and above view of the area are shown in appendix 2.

Rainwater

The rainwater is disconnected in the whole area and reused, infiltrated in the ground, or stored in a retention pond. This is to prevent the drying out of the soil and overflows of the sewerage. Pipes collect the rainwater of the roofs in the neighborhood to the retention pond (about 50 m^2) in the central square. The central square is covered with infiltration material. The overflow of the pond is connected to the conventional WMS. Each year are the plants in the pond removed by the tenants (see figure 15 in appendix 2). Once the surrounding field flooded by clogging of the overflow pipe. In four clusters of 22 houses (including the two special clusters) reuse is arranged. The water is collected by the roof (265m^2) and stores tanks of 5 m^3 in two basements. In the tanks large particles from roof deposits settle. The tank is cleaned once in ten years (Post, *pers. com.)*. In dry periods suppletion of drink water is necessary to fulfill the demand. The water was used in four collective washing machines; however two are disconnected due to problems with smelly/dirty clothes (Reinboud, *pers. com.)*. It is also used in nine toilets. The drink water saving is approximately 25 L/p.d. (website groene dak)

The energy consumption of this recycling installation is 0.5 kWh/m^3 higher than the production and transportation energy of the water supply company, mainly due to placement of the washing machines on the attic (website groene dak). The reuse for toilet flushing and washing machine results in risks higher than the maximum acceptable infection-risks by biological pathogens (Senden, 2003a).

Grey water

The grey water treatment's design, management and maintenance are based on the IBA-regulations of 1991 (Witteveen+Bos, 1993). However the maintenance performed by Michél Post is based on experiences. Grey water of the two clusters it is collected and pre-treated in the basement. The pre-treatment consists of (see figure 13 in appendix 2):

- large particle filter (ø 35 mm) to prevent clogging of the pump, pipes and filtration bed. The sludge is removed every half year and composted. It is inspected each half year; yet the advice is each three months (Witteveen+Bos, 1993).
- Aerobic filter with a biofilm on carrier material to decrease BOD, COD, SS, N-total, and P-total. The aeration consists of natural ventilation by under-pressure. The aerobic filter is inspected each half year; yet the advice is once per month (Witteveen+Bos, 1993).
- Below the aerobic filter is a buffer/sedimentation tank to settle biomass and recirculated the water over the filter. It is inspected each half year; yet the advice is once per three months (Witteveen+Bos, 1993). The sludge (40 L/y) is removed once per year and composted or flushed trough the toilet. The final treatment of one cluster is carried out by a vertical infiltrating reedbed of 75 m^2 (12.5 m^2/p). The reedbed and biological activity in the ground take up the nutrients. After infiltration the water is transported to the retention pond. The final treatment of the other cluster is done by a vertical infiltrating greenhouse of 22 m^2 (1.8 m^2/p). The plants and biological activity in the ground take up the nutrients. After infiltration the water is transported to the retention pond.

In 1996 the water quality is measured by the Amsterdam University (Matthijs and Balke, 1997) and presented in table 29 in appendix 2. Both effluent qualities of the greenhouse and reedbed are fulfilling the Dutch quality standard IBA class III for local treatment. The table shows monthly averages during the period of March till May in 1996. The effluent concentration of E. Coli fulfills the discharge amount of <1000. This means that the grey water treatment system can operate well in good conditions.

Evaluation current system

Nowadays the reed surface decreased to approximately 10 m^2 visualized in figure 4. The tenants thought, by using very little water, the filter can decrease in size. The soil is never replaced or cleaned, which may lead to phosphorus accumulation. Also no water is transported to the retention pond any more, probably due to a leak in the watertight Ethylene-Propylene Rubber layer. The current performance is assumed insufficient. (Post, *pers. com.*). The ground in the greenhouse is replaced with soil with a low infiltration capacity by an unqualified firm. Also fewer plants are growing on the soil (figure 15 in appendix 2). Therefore a water layer is formed over the ground during operation. The current performance is assumed insufficient. The tenants consider shutting down the system (Post, *pers. com.*).

The current status and insufficient maintenance reduces treatment efficiency that may lead to contamination of the pond and surrounding soil and groundwater (infiltration). This may also increase health risks during contact moments with the effluent water, for instance during the emptying of the pond. The system is only monitored ones therefore the current status is unknown. Another problem is that the intended environmental benefits of source separation are not really realized. Because the retention pond has an overflow on the conventional WMS the system is not entirely disconnected. Only infiltration (in the ground under the pond) and evaporation results in less transport to the conventional WMS. A better source separating solution is the discharge of the overflow to rainwater sewerage or surface water.

Black water

The black water was first composted locally; however treated in a conventional WMS after many problems with smell, vermin and wrong composting processes. Currently the system consists of Gustavberg toilets with an average flush of 4.5 litres. The connection to the sewerage is done by a ‘flow-increaser’ for 4-5 houses combined. This reduced the connection costs to the local sewer (same price per connection of 4-5 houses as usual for one house). The benefits of the ‘semi’ disconnection of the grey water to the reduced discharge of wastewater are not measured. The tenants do not get a discount on the water-board fee. (website Groene Dak)

Figure 4 Current status of reedbed filter (visit 22-03-2005)

5.2.2 Performance SSWMS

Primary functions

The chance that tenants have contact with the wastewater is present. The maintenance of the retention pond results in direct contact. The recycled rainwater leads also to contact by toilet flushing and use of washing machine. The risks for public health are higher then maximum acceptable infection-risks by biological pathogens due to the recycling of rainwater for toilet flushing and washing machine use (Senden, 2003a). The chance that tenants have access to the equipment is present. The basement with the grey water pre-treatment and rainwater storage are not locked. The tenants have free access to the reedbed and greenhouse.

The chance of calamities is defined by the tenants' experiences. The change of a calamity with the pre-treatment is once in 15 years (Post, *pers. com.*). This occurs if a pump is not functioning that leads to flooding of the basement. There are no expected calamities from the reedbed. The chance of a calamity with the greenhouse is once in 10 years (Graaf, *pers. com.*). This occurs if the soil is saturated and the water is flooding in the garden.

In 1996 the WMS protected surface water quality and the environment by means of prevention of discharges of oxygen demanding compounds and nutrients. The current status is unknown and may lead to soil and groundwater contamination.

The treatment efficiency can not be compared with the conventional WMS because the system is still using the latter. However it is expected to be better than conventional due to less dilution of the black water with rain and grey water.

Sub functions

The WMS includes measures for rainwater management by reuse, infiltration and storage. The maximum rainwater intensity the tanks can store is 5 m^3 per eleven households in the two clusters. The amount water the pond can store is unknown. The WMS includes measures for removal of groundwater or drainage water by the rainwater collection system and the overflow to the conventional WMS.

User-perspective

Table 9 presents the total costs per year, € 628. The investment costs of the grey and rainwater systems are partly financed by the city Utrecht, water-supply company, and the national government.

Table 9 Investment and operational costs

Aspect	Amount of hh	Cost (€)	Cost (€/hh)	Expected lifetime*** (y)	Costs (€/y)
Grey water installation - pump	10	22,690* - 300	2,269	30 - 15	278#
Rainwater recycling - pump	22	30,630* - 300	1,393	50 - 15	
Inner garden and pond - ground + pipes - work - other	66	53,775* -40,387 - 7,261 - 6,126	815	50	
Gustavberg system connection	1	650**	650	50	
WTP			875		47#
Maintenance					50
Sewerage taxes					39.5
Water-board fee					139
Water-supply					74.3
Total cost					**628**

* (Website het groene dak) ** (Het Groene Dak, 1992) *** (Post, *pers. com.*) # considering an interest of 2.5 % and lifetime of 25 years

The invisibility and comfort is measured by asking three tenants of the reedbed cluster and five of the greenhouse cluster. They could give a score between 0 (very negative) and 4 (very positive). The average opinion of the households to the perspective questions is representative for the whole population. The toilet is a low flush (4.5 L) Gustavberg toilet. The SSWMS makes them very

often (3) feel environmental concerned / friendly. They can not recommend the system to other households in other neighbourhoods without improvement (2).
They think that the visible part of the WMS equipment in or near the houses is nice (3). The WMS produces not at all (4) annoying noise levels. The WMS produces a little bit (3) unpleasant odours. The WMS does not attract vermin at all (4). The tenants do not have to perform maintenance. Only one person takes care (8 h/year) of the plants in the greenhouse and thinks it is nice to do (3) (Graaf, *pers. com.*). They all face restrictions on products for maintenance or flushing trough the toilet and have a list of products.

The technical maintenance (16 h/y) is performed by an external person (Michél Post), hired by Portaal. He has to check and maintain the installations, and remove the sludge. However every year the tenants of the ‘Plant and Gardening Group’ need to remove the plants in the retention pond (figure 15 appendix 2.1). This is expected to take 16 hours per year. The greenhouse needs new plants and cleaning of the windows every year (Graaf, *pers. com.*).

The indoor volume of the system is the area of the rainwater storage tank and the pre-treatment installation. The volume, 10 m^3, is situated in the basement and has no direct influence on the living space of the tenants (Reinboud, and Post, *pers. com.*) The outdoor surface is the summation of the reedbed (75 m^2), greenhouse (22 m^2) and retention pond (50 m^2) divided by ten households is 14.7 m^2/hh. However the area of the conventional WMS is not included.

The robustness of the system is also an average opinion of the tenants. The problems they experienced are described below: The toilet has once in 5 years problems with flushing due to a biofilm on the toilet pipes. Cleaning and replacement of the pipes by a plumber solve this. In the rainwater storage tank the float may give problems and is replaced every 5 years. Sometimes the reedbed produces smells during clogging of the drainage pipes. Once in 10 years the drainage pipes in the greenhouse are clogged leading to smell and flooding. Flushing with high pressure and hot water solves this. The ground of the greenhouse loses the filtration capacity and needs to be replaced once in 10 years. The average system failure is 3 times in 5 year (Post, and Graaf, *pers. com.*).

Environmental

The amount of energy used by the grey and rainwater system is assumed to be 8 kWh/hh.y (Post, *pers. com.*). The energy use of the conventional WMS is unknown. There are no chemicals used by the grey and rainwater system. The amount of water consumption in the reedbed cluster is 32

m^3/hh. The amount of sludge produced by the grey and rainwater system is 8 kg/hh.y. The amount of the conventional WMS is unknown. The volume of reusable water is 18.25 m^3/hh.y. The amount of nutrients recycled is nil. The water quality of the grey water treatment fulfilled the standards of IBA class III in 1996, however the current status is unknown. The resulting effluent quality of the conventional WMS is unknown.

The final comparison with the conventional WMS is visualized in the table below. For each indicator a +, a 0, and a – is given for respectively the better, the same, and worse than in the conventional system.

Table 10 Performance comparison with conventional WMS based on criteria

Criteria	Indicator	Comparison
Primary functions	Health protection	-
	Protection of surface water	0
Sub functions	Rainwater management	+
	Drainage management	+
User perspective	Costs	-
	Invisibility / comfort	0
	Robustness	-
Environment	Resource use	+
	Emissions	0

5.2.3 Actors

Table 11 presents the actors and their role in the design and decision-making. They had a meeting approximately one time a month. The architect mentioned in the feasibility study the different options for the source separating technology, however his involvement in the decision-making was nil. The tenants association had a special ‘Water Group’ that developed the source-separating concept. The final decisions where made by the two project managers: ‘Woningstichting Juliana’ is responsible for the rental houses and ‘Geelen Bouwprojecten’ for the owner-occupied houses. ‘Woningstichting Juliana’ is taken over by ‘Portaal’; the latter was not cooperative in this research. (Post, Smeijer, and Reijinga, *pers. com.*)

The municipality Utrecht gave permission for the grey water system and the connection of the ‘flow-increaser’ system to the sewerage. They charged the tenants less connection fee to the sewerage. Yet Utrecht had no direct part in the decision-making. The involved departments are: ‘Dienst Volkshuisvesting’ to finance the feasibility study and expert’s advice, ‘City Building and Traffic’ was responsible to dispose the area and sewerage connection, and ‘Environment’ gave some advice and financed the grey water system. (SEVU, 1992)

Also some actors financed several aspects, due to intensive lobbying of the tenants association. The water supply company ‘Waterleidingmaatschappij Midden Nederland’ and ministry ‘VROM’ financed a part of the rainwater system. (SEVU, 1992)

Table 11 Actors in design and decision-making

	Description	Name	Role
1	Tenants association	‘Het Groene Dak’	Initiative and steering role in demands and design water aspect
2	Architect	‘BEAR Architecten’	Feasibility study and Building Design
3	Housing company	‘Woningstichting Juliana’	Project manager rental houses
4	Project developer* and constructor	‘Geelen Bouwprojekten B.V.’	Project manager owner-occupied houses and constructor

* This actor was not available to cooperate with the research

Responsibilities

The tenants are responsible for the in-house equipment (toilet, pipes, etc.). Portaal is responsible for the treatment and maintenance of the grey and rainwater system. The municipality has the responsibility of the conventional sewerage system after the ‘flow-increaser’. The ‘Water-board Vallei & Eem’ is responsible for the treatment of the black and pond overflow water. The tenants did not have to pay any fee when they had the composting toilets; however the Water-board currently charges the tenants the same as in a conventional WMS. (Post, and Smeijer, *pers. com.*)

5.2.3 Drivers and barriers

The drivers and barriers are divided in environmental, economical, and social aspects and are evaluated for the design, current, and future situation of the grey and rainwater system. They are addressed in table 30 in appendix 2.2 with corresponding numbers to the actors.

Environmental Drivers and Barriers

The main environmental drivers of the tenants association are the reduction of water use and wastewater discharges to the sewerage. They want to reduce the drying out of soil in their neighbourhood and in the area of the water supply pumping station. They want to prevent sewerage overflows and discharges of nutrients on surface water by the conventional WMS. The water use is reduced by approximately 40 % (Website groene dak). They also think the reedbed, greenhouse and pond are elements part of a nice neighbourhood to live in. The system increases the environmental behaviour of the tenants. The energy use of the pumps in the rainwater system is higher then the production and transportation energy in the water supply. Therefore the current and future environmental drivers are less then in the design phase. The main environmental drivers of ‘Woningstichting Juliana’ are the same as of the tenants.

‘Woningstichting Juliana’ was convinced by the advice of the ‘Water Group’ and had the same objectives. However they did not mention the protection of surface water. (Post and Smeijer, *pers. com.*)

In the design phase the tenants association had only one environmental barrier, the high material consumption. In the current and future situation the barriers are diverse. They consider health risks due to reuse of rainwater, flooding, and direct contact in the greenhouse, however nobody is reported ill. Also flooding risks of the basement and retention basin is a barrier. Also maintenance problems occur due to new technology. And high energy and material consumption due to respectively pumps and installation and extra pipe materials are assumed to be barriers. Woningstichting Juliana had as barriers maintenance, smell and odour problems. They had the responsibility to maintain the installation and face the risks of changes in rental people. (Post, and Smeijer, *pers. com.*)

Economical Drivers and Barriers

The main economical drivers of the tenants association in the design phase are low costs of water and energy consumption, sewerage taxes, and water-board fee. Another driver is the development of a new technology that might result in future benefits. The subsidisation of different actors in the technology made the realization possible. In the current and probably future situation only the savings in water consumption and sewerage taxes are realized. The savings are lower than the increased operational costs (due to maintenance and energy use). ‘Woningstichting Juliana’ expected the same economical benefits except for the decrease in water-board fee. (Post, Smeijer, *pers. com.*)

The main economical barriers are for both actors the very high installation and design costs compared to the conventional WMS. The higher costs are made due to more pipes, pumps, greenhouse and reedbed, and consultants. Both actors expected high operational costs due to replacement of installation parts, and maintenance. In the current situation the energy costs are high. All higher costs are arranged in the rents of the tenants. ‘Woningstichting Juliana’ does not implement the system in other neighbourhoods due to the high installation costs. For them another barrier is the risk that no other people want to rent it. (Post, Smeijer, *pers. com.*)

Social Drivers and Barriers

The social drivers in the design phase are for both actors an intensive contact between the neighbours, environmental friendly behaviour and a nice neighbourhood. These are respectively because of the joint management and design, existing ideas and philosophy, and the creation of an area with pond, reedbed, and greenhouse. In the current and future situation the installation does not increase the environmental behaviour of the tenants. (Post, Smeijer, *pers. com.*)

The tenants association assumed that a social barrier was the management and use of the system. They consider it as a difficult technology in design, current and also future phase. 'Woningstichting Juliana' thought as well that the management of the system is a barrier. They had to hire an expert to manage it. (Post, Smeijer, *pers. com.*)

5.3 Polderdrift

In 1991 the 'Housing Society Gelderland' ('Woningbouwvereniging Gelderland') organized different information events for new building projects. A concept was developed in which new tenants could participate in the urban and architectural design and other aspects of their future neighborhood. About 60 new tenants participated and came up with a plan for ecological and efficient ('op maat') living. In 1994 the 'Algemene Woningbouwvereniging Arnhem (AWBA)' took over the project.

The objective was to use lower qualities than drink water for toilet flushing, washing machine, washing the car, and spraying the garden. The architect company 'opMAAT' applied the national policy goals in the 'Vierde Nota Ruimtelijke Ordening' in the design. The neighborhood, with 40 houses, was realized in 1997. The AWBA is taken over by the company Portaal nowadays. (Stein and Luising, 2002) (Ruiven, *pers. com.*)

5.3.1 Implemented Technology

The SSWMS in the Polderdrift is based on separate collection of grey, black, and rainwater. The technical scheme and arial view of the system are shown in appendix 3. The design is based on different gradations: from private to public areas, a relief from low till high and wet and dry. (Bleuzé, 1995)

Rainwater

The rainwater is disconnected in the whole area; it is directly infiltrated or discharged in a retention area and pond (Bleuzé, 1995). The rainwater of the roofs is collected in two sedimentation tanks (2 x 35 m^3) under the technical building. The average amount of rainwater is 17 L/p.d that fulfills the demand of washing machines of 14 L/p.d (Bleuzé, 1995). If there is less drink water is supplied, and too much it will overflow to the retention pond. Two times a year a specialized company removes the rainwater sludge (Engelen, *pers. com.*). Last year no maintenance activities were performed (Ruiven, *pers. com.*).

The central square is covered with permeable material and has an infiltration area and pond. The purpose is to have a separated sewerage system to prevent overflows of the sewerage. Each year the tenants remove plants from the pond. (Ruiven, *pers. com.*)

The preconditions of the rainwater reuse are formed based on a research in Hamburg. The water should not cause health risks on, be color-less, and contain no solids that may damage the pumps and moving parts of the washing machine. The water has a low metal and lime concentration that can decrease the amount of washing powder. (Bleuzé, 1995)

Grey water

The grey water amount is due to water saving aspects approximately 72 L/p.d (Bleuzé, 1995). The local treatment consists of: fat removal, sedimentation, followed by a reedbed. The sedimentation tank has four compartments: three settling chambers of 3 m^3 and a pump shaft of 1 m^3 (Soons, 2003). The water quality after sedimentation is measured by the Wageningen University (table 32 in appendix 3.1) (Soons, 2003).

Four times per day the water flows in a vertical infiltrating reedbed (2.88 m^2/p). The reed and biological activity in the ground take up the nutrients. The expected effluent quality is given in table 31 in the appendix 3.1(Bahlo and Wach, 1992). After infiltration the water is filtered by a large particle filter and transported to the clean water distribution tank and reused for toilet flushing. The assumed amount is 20 L/p.d that fulfills the demand of toilet flushing (Bleuzé, 1995). The overflow of the reedbed and distribution tank is connected with the pond. The pond has an overflow to surface water. (Bleuzé, 1995)

The tenants' maintenance consists of cutting the reed and flushing the drainage pipes once a year. The manholes need regular inspections. Problems are reported to Portaal. Two times a year a specialized company removes the settled sludge (Engelen, *pers. com.*). The sludge quality is unknown (Engelen, *pers. com.*). The tenants pay a yearly advance fee of € 141 to Portaal for the maintenance (Koopmans, *pers. com.*). Depending on the maintenance activities they receive restitution.

Evaluation current system

The reuse of rain and grey water results in 57 % less water consumption (Pötz and Bleuzé, 1998). 85 % of the domestic wastewater discharge is reduced (Pötz and Bleuzé, 1998). The water reuse has risks higher than maximum acceptable (Senden, 2003). Recent research shows that the water quality (table 33 appendix 3.1) meets the household-water standards (C-mark, 2004). Yet the research did not include pathogens as Entero-viruses and Campylobacter. The analysis of these pathogens should be carried out 3 times/y and costs around € 5,000 per analysis (Medema, *pers. com.*). Yet there is no governmental legislation on these analyses.

The current status is not good; the sedimentation tanks was not cleaned last year, the water flows in the reedbed every hour (too much), and by over-saturation water floods the reedbed (Ruiven, *pers. com.*). This increases smell and health risks due to exposure of inhabitants to untreated grey water. After eight years the reedbed still has the same soil. This may lead to P saturation and reduced removal efficiency. The grey water treatment efficiency is unknown.

Black water

The black water is discharged on the conventional WMS of 'Water-board Rivierenland'. The effect of local treatment on the influent loads of the WTP is unknown. In the period 1997-2001 the tenants received a discount on the water-board fee of € 60/y. However since 2002 this discount does not longer exist, although the tenants are still trying to receive it (Derksen, *pers. com.*).

5.3.2 Performance SSWMS

Primary functions

The chance that tenants have contact with the wastewater is present if the reedbed is flooded and overflows to the pond. The maintenance activity on the reedbed results to direct contact. Also the water reuse results in contact by washing of clothes and toilet flushing. The report of C-mark concluded on the current measurements that no health risks are present. However this report is just a one moment conclusion and risks can occur in the future. The public health risks are higher than the maximum acceptable infection-risks by biological pathogens (RIVM, 1997 and Senden, 2003).

The chance that tenants have access to the equipment is present. The technical building is locked, although the tenants have free access to the reedbed, pond and manholes of the rain and grey water storage tanks. The chance of calamities is defined by the tenants' experiences. One calamity occurred in 8.5 years (Theunissen and Ruiven, *pers. com.*). Due to clogged drains of the reedbed grey water flooded the surrounding ground. Nowadays they clean the drains each year and no calamities are expected in the future.

An 85 % reduction of discharges of domestic wastewater is realized. The WMS protects surface water and environment by means of prevention of discharges of BOD and nutrients. The current status of operation is unknown. Because the SSWMS is still connected the treatment efficiency can not be compared with the conventional WMS. However a higher efficiency is expected by the reduction of wastewater and its dilution.

Sub functions

The WMS includes measures for rainwater management by rainwater storage and reuse. The maximum rainwater storage capacity is 70 m^3 per 40 houses. The amount the system can treat with the pond and infiltration area is enough to prevent flooding (Ruiven, *pers. com.*). The WMS includes measures for removal of ground- or drainage water by the rainwater collection system.

User-perspective

Table 12 depicts the investment and operational costs of the SSWMS, € 1011/y. The pumps are replaced in 2002 (expected once in 10 years) with a total cost of € 10,000 (Engelen, *pers. com.*). The tenants received during 1997-2001 a reduction on water-board fee of € 60/hh. However this reduction is not operative since 2002

Table 12 Investment and operational costs

Aspect	**Cost (€/hh)**	**Expected lifetime** (y)**	**cost (€/y)**
Grey water installation - pumps	4,333*	20 - 10	353#
Rainwater recycling - pumps - pipes - retention area	2,170*	50 - 10 - 20	
Sewerage connection	3500	25	238#
Conventional WTP	875	25	
Maintenance and energy			141***
Sewerage taxes			104
Water-board fee			139
Water supply			36
Total Cost			**1011**

* (Pötz and Bleuzé, 1998) ** (Engelen, *pers. com*) ***(Koopmans, *pers. com.*) # considering an interest of 2.5 % and lifetime of 25 years

The invisibility and comfort is measured by asking five tenants. The toilet is a conventional flush toilet. The SSWMS makes them sometimes (2) feel environmental concerned / friendly. They will recommend the system to other households in other neighbourhoods (3). They think that the visible part of the WMS equipment in or near the houses is nice (3). The WMS produces not at all (4) annoying noise levels. The WMS produces a little bit (3) unpleasant odours. The WMS does not attract vermin at all (4). They have to perform the maintenance activities mentioned before by themselves approximately 8 h/year and they think it is nice to do (3). They all face restrictions on products for maintenance or flushing trough the toilet and have a list of products. The technical maintenance (8 h/year) is performed by an external company. They remove the sludge of the grease separator and sedimentation tanks.

The indoor volume of the system is not more than conventional. The outdoor surface is the summation of the reetbed (230 m^2), infiltration-retention area approximately 100 m^2 and a pond approximately 100 m^2 and area of technical building and underground tanks of approximately 100 m^2 (Bleuzé, 1995) divided by 40 households resulting in 13.25 m^2/hh. However the area of the conventional WMS is not included.

The robustness of the system is also an average opinion of the tenants and Portaal. During 8.5 years four of the five tenants experienced problems with the WMS and these are described below: The toilet was polluted by brown precipitation of the grey water once. The cause was heavy rain on the reedbed that took up large particles and oversaturated the final filters. Cleaning and replacement of the large particle filter solved it. The rainwater was not transported two times due to connection problems. This was solved by replacement of the pipes by Portaal. The black water sewer clogged four times, Portaal solved this. The external company dried-out and broke the grey water pumps. Portaal replaced the pumps yet on the initiative of the tenants. The reedbed produces smells during all days in intervals on several months. This occurs due to the wrong pump frequency of the grey water pumps to the reedbed. Still Portaal does not solve this. The total system failure is approximately seven times in 8.5 years. A more general problem is the languid management of Portaal, during problems. (Ruiven, *pers. com.*).

Environmental

The amount of energy used by the grey and rainwater system is unknown but expected to be higher than conventional. There are no chemicals used by the grey and rainwater system. The water consumption is approximately 50 m^3/hh (Bleuzé, 1995). The amount of sludge produced by the grey and rainwater system is assessed to be 12.5 kg/hh.y (Ruiven, *pers. com.*). The amount of the conventional WMS is unknown. The volume of reusable water is 25 m^3/hh.y (Bleuzé, 1995). The amount of nutrients recycled is nil. The water quality of the grey water treatment fulfilled the standards of reuse; however the current status is unknown. The resulting effluent quality of the conventional WMS is unknown.

The final comparison with the conventional WMS is visualized in the table below. For each indicator a +, a 0, and a – is given for respectively the better, the same, and worse than in the conventional system.

Table 13 Comparison with conventional WMS based on criteria

Criteria	Indicator	Comparison
Primary functions	Health protection	-
	Protection of surface water	+
Sub functions	Rainwater management	+
	Drainage management	+
User perspective	Costs	-
	Invisibility / comfort	0
	Robustness	-
Environment	Resource use	+
	Emissions	+

5.3.3 Actors

The actors and their role in the design and decision-making are presented in table 14. They had a meeting approximately one time a month. The final decisions where made by Portaal the owner. (Ruiven and Engelen, *pers. com.*) The municipality Arnhem permitted to the local grey water treatment and the black water connection to the conventional WMS. The rainwater is not allowed to be discharged on the conventional WMS (Brouwer, 1996). However Arnhem had no direct part in the decision-making, they only set the demands and preconditions that are based on permits.

Table 14 Actors in design and decision-making

	Description	Name	Role
1	Tenant respondent	Ad van Ruiven	Participative role in design water aspect
2	Architect	opMAAT	Building Design
3	Housing company*	Portaal	Current manager /owner houses
4	Municipality	Gemeente Arnhem	Preconditions and demands
5	Housing company**	AWBA	Project manager houses

* This actor was not involved in the design phase.
** This actor does no longer exist therefore the current housing company Portaal was interviewed.

Responsibility

Portaal is responsible for the treatment of the grey and rainwater system (Engelen, *pers. com.*). The tenants are responsible for the in-house equipment (toilet, pipes, etc.), the reedbed and pond maintenance, inspection of the rain and grey water tanks, and alert technical problems (Ruiven, *pers. com.*). The municipality Arnhem has the responsibility over the conventional sewerage system after a certain connection/inspection point (Warnshuis, *pers. com.*). The 'Water-board Rivierenland' is responsible for the treatment of the black water.

5.3.4 Drivers and barriers

The drivers and barriers are divided in environmental, economical, and social aspects and are evaluated for the design, current, and future situation of the grey water and rainwater separation. They are addressed in table 34 in appendix 3.2 with corresponding numbers to the actors.

Environmental Drivers and Barriers

During the design phase the main environmental drivers of the tenants were reduction of water use and reduction of wastewater discharges to the conventional WMS. The obtained reduction amount 57 % and 85 %, respectively (Pötz and Bleuzé, 1998). One aim prevention of rainwater overflows, although the protection of surface and groundwater were no drivers. They also consider the reedbed and pond as elements that contribute to a nice neighbourhood to live in. The tenants give the same arguments in the current and future situation as during the design phase. (Ruiven, *pers. com.*)

The drivers of the tenants municipality are partially the same as those of the. They also considered the protection of surface and groundwater as important. For the current and future situation they consider water saving and prevention of drying out of soil as environmental drivers (Warnshuis, *pers. com.*). The main environmental drivers for Portaal are the same as of the tenants. They also have drivers as the protection of surface and groundwater, and a micro biotope created by means of the pond, infiltration area and reedbed. (Engelen, *pers. com.*)

During the design phase the tenants had no environmental barriers. In the current and future situation barriers arise. They experience health risks by reuse of rain and grey water, however nobody is reported ill. Also flooding of toilet (occurred by clogging and breaking of pipes), maintenance problems, high-energy use (due to pumps), and smell and odour problems (from the reedbed) are barriers. (Ruiven, *pers. com.*) The municipality has in the three phases the same barriers: flooding risks, use of chemicals (more cleaning chemicals), and maintenance problems (Warnshuis, *pers. com.*). For the current and future situation Portaal has as barriers: health risks for the tenants (Portaal is responsible), use of extra chemicals (due to cleaning), maintenance problems, and a higher energy use (due to pumps). Portaal does not implement the system in other neighbourhoods due to the potential health risks. (Engelen, *pers. com.*).

Economical Drivers and Barriers

The main economical drivers of the tenants in the design phase are low design costs and low water-board fee. Another driver is the development of a new technology that might result in future benefits. In the current and probably in the future situation the savings in water consumption is realized. However, the design costs were high and the water-board fee reduction is not given since 2002. (Ruiven, *pers. com.*) The municipality has the reduction of water consumption costs and development of a new technology as drivers in all phases (Warnshuis, *pers. com.*). Portaal expected the same economical benefits except as the municipality in all phases (Engelen, *pers. com.*).

The main economical barriers for all actors are the very high installation and design costs compared to the conventional WMS. The higher costs are made due to more pipes, pumps, reedbed, and consultants. Also they all expected high operational costs due to replacement of installation parts, and maintenance activities of tenants and Portaal. Also the energy costs are expected to be high by the tenants. The higher operational costs are arranged in a special rent for the tenants. Portaal does not implement the system in other neighbourhoods due to the high installation and operational costs.

Social Drivers and Barriers

The social drivers in the design phase are for all actors an intensive contact with the neighbours, environmental friendly behaviour and a nice neighbourhood. These are respectively because of the joint management and design, existing ideas and philosophy, and the creation of an area with pond, infiltration area, and reedbed. In the current and future situation the intensive contact of the tenants has declined. (Ruiven, Warnshuis, and Engelen, *pers. com.*)

In the design phase the tenants had no social barrier, currently the smell and odour problems of the reedbed are a barrier. In design, current, and future phase the municipality has health risks, acceptation of new tenants, and risks for housing equipment, and a difficult technology of the system as barriers. In current and future phase Portaal thinks that health risks and acceptation of new tenants of the system is a barrier. (Ruiven, Warnshuis, and Engelen, *pers. com.*)

6 SOURCE SEPARATED WMS IN SWEDEN

6.1 Introduction

This chapter describes the studied SSWMS in Sweden. Of each case the implemented technology, performance, actors, and drivers and barriers are described.

6.2 Ekoporten

In 1967 the local government of Norrköping constructed the apartment's complexes in the neighborhood Hageby. During the late eighties the neighborhood experienced social problems and the quality of the complexes became physically poor. The governmental housing company "Hyresbostäder I Norrköping AB" reconstructed the apartments in 1995. The last building to renovate (1996) was the Ekoporten house consisting of 18 apartments. The housing company rebuild the house according the latest environmental friendly technology. The implemented technology is based on the themes energy, in-door climate, ventilation, and water & wastewater. The latter is discussed in this study. The company's objective was to gain experiences for future reconstructions, an environmental marketing's image, and a positive symbol for the neighbourhood. In 2004 the housing company 'Markarydsbostäder' took over the building. Currently approximately 35 tenants live in Ekoporten. They are proud to live in the Ekoporten house and are environmentally educated.

6.2.1 Implemented Technology

The SSWMS in Ekoporten is based on separate collection of urine (yellow), grey, brown, and rainwater. The water consumption in the households is in (1996-1997) approximately 44 % lower than normal (Bokström, 2002). The quality of the water-streams is depicted in table 35 in appendix 4.1. The technical scheme and aria view of the system are shown in appendix 4.1. The design is based on resource- saving and recycling living.

Rainwater

The rainwater is partly used in a fountain and infiltrated in the ground, and partly discharged on the conventional sewerage. It is infiltrated in the areas where no hard surface is present. However rainwater is not a priority in this building. (Jonzon, *pers. com.*)

Grey water

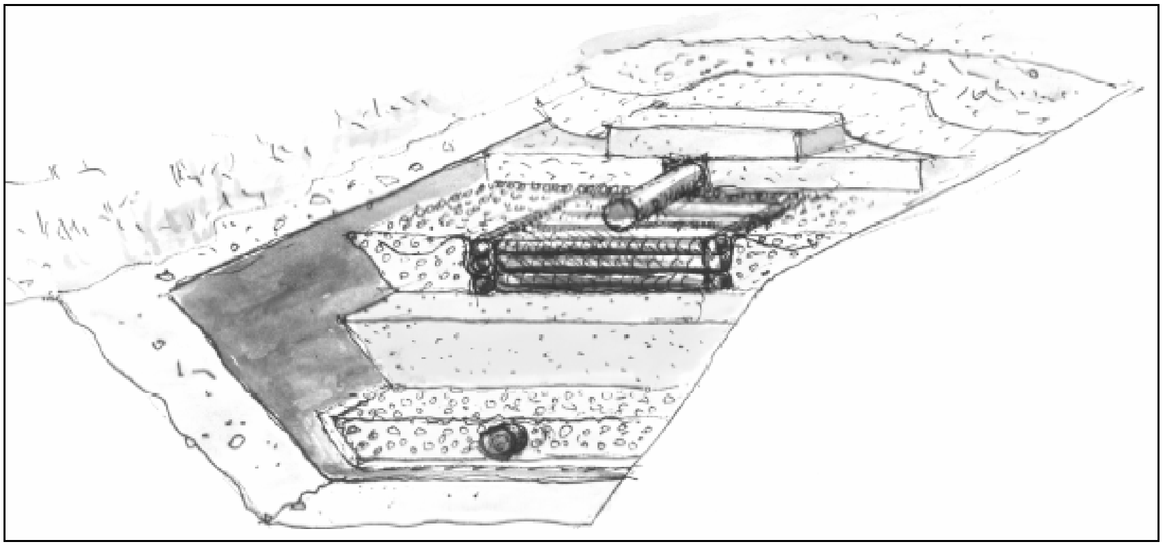
Originally the grey water and feces flush water are treated locally. The feces flush water is gathered from the black water by an Aquatron centrifugal solids/liquid separator. The amount of grey water is approximately 104 L/p.d. Due to water saving aspects (taps and shower) this is 30 % less than the Swedish norm (150 L/p.d). The amount of feces flush water is approximately 29 L/p.d. (Vinnerås, 2001)

The treatment is performed by means of a three-chamber-sedimentation tank, UV-filter, segmentation tank, and thereafter a horizontally infiltration reedbed. In 1999 are the UV-filter and horizontally infiltration reedbed replaced by a vertically infiltration reedbed (InFiltra). The reason was a poor functioning UV-filter (because the water had a high suspended solids concentration) and therefore high amounts of bacteria indicator organism in the effluent. Also the possible direct contact with the greywater in the horizontally infiltration reedbed was a risk for exposed people. (Gustafsson, 2005) The three-chamber-sedimentation tank has a total volume of 11 m^3, with a retention time of approximately 2.3 days. In this tank particles settle and a sludge waste is created. The amount of sludge is approximately 980 kg/y. Two times per year this sludge is removed and treated by the WTP 'Slottshagens' (Norrköping). (Karlsson, 2002)

From the sedimentation tanks the water passes a segmentation tank from which it is pumped over the two parallel segmented reedbeds (figure 5). The total reedbed area is 270 m^2 approximately 7.7 m^2/p. The plants and bacteria in the sand carry out the biological conversion of organic matter (BOD), N and P. The sand also filters suspended solids and has a disinfecting property for pathogens. The removal efficiency of the reedbed is shown in table 36 appendix 4.1 it depicts no significant difference in winter and summer. Subsequently the effluent is discharged into the small creek Ljura.

The maintenance consists of cutting the reed and flushing the drainage pipes twice a year. This is carried out by the installation manager Peter Jonzon. He also inspects the total system one day a week. The soil of the reedbed needs to be replaced after 10 years. (Jonzon, *pers. com.*)

Figure 5 InFiltra kompaktfilter (Gustafsson, 2005)



Urine

The installed Dubletten toilet makes separation of urine and feces possible (figure 6). The toilet consists of two compartments, and two flush possibilities for feces and urine. The urine needs a flush of 0.2 litres and the feces 4 litres. With the same amount of flushes the toilet saves 25 % water compared to a conventional Swedish toilet (Vinnerås, 2001). The quality of the urine is depicted in table 35. The urine and flush water mixture's amount is approximately 1.3 L/p.d (Vinnerås, 2001). The percentages of nutrients compared to the complete wastewater stream present in the urine are for N 62 %, P 62%, and K 87 % (Jönsson, 2001).

Figure 6 Dubletten toilet at Ekoporten (Visit Ekoporten, 2005)

The urine pipes are of copper and contain angles of 90°. The mixture is collected in two 15 m^3 tanks and one 30 m^3 tank stored under the ground. If 85 % of one 15 m^3 tank is filled an alarm will sound. Then the manager has to connect the 'new' urine to the other 15 m^3. In the 30 m^3 all the collected urine of the full tanks can be stored. The urine has to be stored for at least 6 months for disinfection of pathogens.

Before 2002 the urine was transported to the WTP 'Slottshagen'. Since 2002 the urine is transported to two local farmers and discharged on their land. The transport is paid by the housing company.

One farmer (Till Åke Karlsson) is interviewed on his perception; however he has not yet received the urine. The farmer would like to contribute to the environment, and is informed about the recycling advantages. The farmer will mix the human urine with cow urine, and spray it on grassland on which cows are living. He will receive 15 m^3/y and can fertilize one time 3 hectare (he has 28 hectare of land). The farmer will save 1800 kg of fertilizer and therefore approximately € 950. The farmer has no idea about the urine quality and is skeptical on the hormone and medicine concentrations. He expects a low risks for the cows, and even lower for his customers. He even thinks that he will get more customers due to the environmental friendly image. (T. Karlsson, *pers. com.*)

Brown water

The brown water undergoes a centrifugal liquid/solid separation in the Aquatron. The amount of separated solids varied between 1.4 and 6 L/p.d. The solids were combined with the organic household waste (vegetables etc.) and an addition of wooden pellets. The amount of pellets added is approximately 1000 kg/y (Jonzon, *pers. com.*). The solids are grinded in a rotor and stored in a shed to compost for six months. Thereafter it is used in the tenants' garden and surrounding field.

The amount of compost is 0.23 kg/p.d (Vinnerås, 2001), approximately 6 m^3/y. The amount of indicator bacteria in the compost is during 1997-1999 very low. The contact with the compost has no higher risks than contact with normal soil (Karlsson, 2002). The amount of N, P, and K in the compost is shown in table 37 in appendix 4.1.

Evaluation current system

The current status of the grey water treatment system is ok. However the removal efficiency is decreasing due to saturation of the soil. In 2002 the reedbed discharges a daily average of 15.3 g P-total and 76 g N-total on the Ljura. When the grey water was treated in the central WTP Slottshagen the discharge was approximately 1 g P-total and 40 g N-total. Therefore it is advised by Miljöinvest to connect the grey water to the central WMS. (Karlsson, 2003)

The current status of the urine system is ok. The urine system experienced some small problems. The main problem is clogging of the collection pipe. The clogging emerges by magnesium and calcium phosphates precipitation especially in the horizontal parts of the pipe and in the angles of 90°. Because the diameter of the pipe is low complete stoppages emerge. The tenants flush the toilet more often to remove the sediments. They also clean flush the toilet with soda. The other problem was that till 2002 no farmer was found that reused the urine.

This addresses the uncertainty of the reusability of the urine. The current status of the brown water/ composting system is ok

6.2.2 Performance SSWMS

Primary functions

The chance that tenants have contact with the wastewater is not present. The risks of recycling the compost (Karlsson, 2002) or urine (Höglund, 2001) are also low. The chance that tenants have access to the mechanical equipment is present. The technical building is locked, although the tenants have free access to the reedbed.

The chance of calamities is defined by the tenants' experiences. Only once in nine years two tenants experienced a calamity with the urine system (Kindstrand and Aberg, *pers. com.*). Due to clogged drains they could not flush the urine away. Nowadays they clean the drains and flush more often and no calamities are expected from the pipes anymore.

The WMS protects surface water quality and the environment by means of prevention of discharges of oxygen demanding compounds and nutrients. The current status shows that the amount (in gram per day) of N and P discharged by the reedbed are higher then in the centralised WTP. The amount of discharged P will increase in the future because the soil becomes saturated. The reuse of urine and compost reduces the amount of nutrients and organic matter discharged.

Sub functions

The WMS includes measures for rainwater management by rainwater use and infiltration. The maximum rainwater storage capacity is unknown. The WMS does not include measures for removal of ground or drainage water because that is unnecessary.

User-perspective

Table 15 depicts the investment and operational costs of the SSWMS. The investment costs of the system are twice as high as for a conventional system (Bokström, 2002) and were financed by the Swedish national government. The reedbed is replaced in 1999 with a total cost of € 15,000 (Jonzon, *pers. com.*). The yearly operational costs are included in the rent, yet the tenants do not pay a higher rent than normal. The tenants do not receive a discount on the water supply price

Table 15 Investment and operational costs

Aspect	**Cost (€)**	**Cost (€/hh)**	**Expected lifetime (y)**	**Cost (€/y)**
Complete installation - reedbed - composting device - urine	320000 - 15000 - 10000	17.800	50 - 10 - 10 - 50	966#
water supply & treatment				112
Monitoring and maintenance	7700			428
Total cost				**1506**

considering an interest of 2.5 % and lifetime of 25 years

The invisibility and comfort is measured by asking five tenants. The toilet is a 'Dubletten' flush toilet. The SSWMS makes them always (4) feel environmental concerned / friendly. They will recommend the system to other households in other neighbourhoods (3). They think that the visible part of the WMS equipment in or near the houses is not disturbing (2). The WMS produces not at all (4) annoying noise levels. The WMS produces a little bit (3) unpleasant odours. The WMS does not attract vermin at all (4). They do not have to perform maintenance activities. This is done by Peter Jonzon approximately 1 day/week and he finds it is nice to do (3). They all face restrictions on products for maintenance or flushing trough the toilet and have a list of products.

The indoor volume of the compost room is 2.7 m^3/hh. The outdoor surface is the summation of the reedbed and urine tanks 18 m^2/hh. The robustness of the system is also an average opinion of the tenants and Peter Jonzon. Two tenants experienced problems with clogged urine pipes 1 time per year. Jonzon reports that due to heavy rains in the autumn the reedbed floods 2 times/y, the Aquatron is clogged once in 5 years, and the drum is flooding once in 2 years. The total system failure is approximately 3.7 times/y. However these problems are solved by the tenants and Jonzon. A more general problem is smell of the urine toilet that all tenants experience.

Environmental

The amount of energy used by the grey and rainwater system is unknown. There are no chemicals used by the grey and rainwater system. The water consumption is approximately 82 m^3/hh. The amount of sludge produced by the grey water system is approximately 28 kg/hh.y, the amount of compost is 333 kg/y, and the amount of urine is 833 kg/y (Vinnerås, 2001).

The amount of nutrients recycled is for N, P, and K respectively 61500, 7900, 23300 kg (Vinnerås, 2001). The effluent water quality is lower than of conventional WMS.

The final comparison with the conventional WMS is visualized in the table below. For each indicator a +, a 0, and a – is given for respectively the better, the same, and worse than in the conventional system.

Table 16 Comparison with conventional WMS based on criteria

Criteria	Indicator	Comparison
Primary functions	Health protection	0
	Protection of surface water	-
Sub functions	Rainwater management	+
	Drainage management	0
User perspective	Costs	-
	Invisibility / comfort	+
	Robustness	-
Environment	Resource use	+
	Emissions	+/-

6.2.3 Actors

The actors and their role in the design and decision-making are presented in table 17. The design is carried out by the housing company "Hyresbostäder" however they did not want to cooperate in this research. The final decisions where made by the housing company. The new owner is "Markarydsbostäder" that gives a current and future perspective. The local government "Norrköping Kommun" demanded a control program to monitor the different streams 4 times per year, and that a special manager is appointed to maintain the system. They also demand that a connection to the centralized sewerage was necessary in case problems occurred. However "Norrköping Kommun" had no direct part in the decision-making, they only set the demands and preconditions based on permits.

Table 17 Actors in design and decision-making

	Description	Name	Role
1	Tenant respondent*	Lind	No participative role
2	Consultant*	Miljöinvest	Analysing watersystem
3	Housing company*	Markarydsbostäder AB	Current manager /owner houses
4	Municipality*	Norrköping Kommun	Preconditions and demands
5	Housing company**	Hyresbostäder I NRAB	Project manager design houses

* These actors were not involved in the design phase.
** This actor is no longer involved in the current situation.

Responsibility

Markarydsbostäder is responsible for the complete SSWMS (Käkelä, *pers. com.*). The tenants are responsible for the in-house equipment (toilet, pipes, etc.).

6.2.4 Drivers and barriers

The drivers and barriers are divided in environmental, economical, and social aspects and are evaluated for the design, current, and future situation of the urine, brown, grey, and rainwater separation. They are addressed in table 38 in appendix 4.2 with corresponding numbers to the actors. The municipality, consultant, tenant and housing company did not take part in the design phase.

Environmental Drivers and Barriers

In the current and future phase the main environmental drivers of the tenants were reduction of water use, recycling of nutrients, and a nice neighbourhood. Especially the reuse of urine and compost is important for the tenants (Lind, *pers. com.*) The drivers of the municipality are recycling of nutrients, and related reduction of water emissions with high nutrients concentration. They also considered the protection of surface and groundwater as important. (Franzen, *pers. com.*). The main environmental drivers for Markarydsbostäder are the same as of the tenants. They also have drivers as the protection of surface water and a nice environmental behaviour feeling (Käkelä, *pers. com.*). The housing company can also receive an environmental friendly image with the building. The drivers of the consultant are recycling of nutrients, and nice neighbourhood and environmental behaviour feeling (Karlsson, *pers. com.*).

The environmental barriers of the tenants are only the maintenance problems. The municipality has as barriers: health risks and maintenance problems (Franzen, *pers. com.*). For the current and future situation Markarydsbostäder has as barriers: health risks for the tenants and maintenance problems (Käkelä, *pers. com.*). However the health risks are negligible. For the current situation Miljöinvest has as barriers: maintenance problems, higher energy use, and higher emissions (Karlsson, *pers. com.*). In the future he expects that when the grey water is connected to the central sewerage the emissions are significantly lower.

Economical Drivers and Barriers

The main economical drivers of the tenants in the current and future phase are low water supply costs and the development of a new technology that might result in future benefits. The municipality has no interest in the costs. Markarydsbostäder considers the economical benefits to be lower taxes for waste and the development of a new technology. The consultant considers a low water-board fee and the development of a new technology as economical drivers. The main economical barriers for all actors (except municipality) are the very high installation and maintenance costs.

Social Drivers and Barriers

The social drivers in the current and future phase are for all actors environmental friendly behaviour and a nice neighbourhood. These are respectively because of the recycling, and the creation of a nice house and reedbed. The tenants, housing company, and consultant also consider a higher intensive contact between the neighbours. This because the discussion and learning of the system and reuse of the compost. They are all very proud to live in the building!

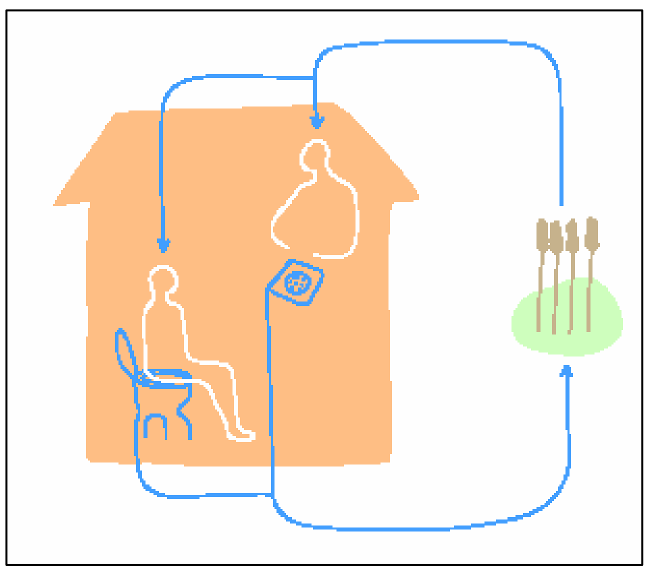
In the current and future phase the tenants and consultant had no social barrier the smell and odour problems of the urine are a barrier yet accepted. In current and future phase the municipality and housing company have health risks and a difficult technology of the system as barriers.

6.3 Skogaberg

In 2001 the social housing company “Egnahemsbolaget” and the construction / architect company “Sweco FNNS’ addressed the integration of a black water system in the planned neighborhood Skogaberg. The local governmental “Department of Sustainable Water and Waste Management” was found to be the responsible actor for the system, since they take care of the conventional WMS of Göteborg city. The building of the neighborhood started in 2002 and will consist of 17 apartments (in flats), 6 special apartments, and 110 houses therefore 133 households (de Blois, 2004).

The main reason for the black water system is closing the ecocycle of plant nutrients. Since the Federation of Swedish Farmers (LRF) strongly addressed their apprehension in reuse of sewage sludge in agriculture, the recycling of plant nutrients discharged by households almost ended. The main obstacles for reuse are the heavy metal content and risks of not easily degradable organic compounds present in the sewage sludge. In Sweden therefore most sewage sludge is digested and composted. (Karlsson, 2005)

Figure 7 Schematic symbol project Skogaberg



Yet the phosphorous resource in artificial fertilizers is finite, therefore the LRF’s perspective is to reuse the nutrients excreted by households in the future. The desired sewage sludge is nutrient rich and contains low concentrations of heavy metals and organic compounds. To obtain this sludge the experiment in Skogaberg was started. (Karlsson, 2005)

6.3.1 Implemented Technology

The SSWMS in Skogaberg is based on separate collection of black, grey, and rainwater. The collection and treatment of organic kitchen waste is also integrated in the black water system. The design is based on the recycling of nutrients. To avoid the accumulation of copper in the sludge the water supply pipes in the neighborhood are free of copper. The black water treatment is still in a pilot phase in which several technology is tested (Aarsrud, *pers. com.*).

Rainwater

The rainwater is disconnected from the central sewerage system. The water runs off by gravity and finally infiltrates in the ground. A rainwater sewerage was unnecessary because of the inclination conditions and infiltration area. The disconnection aims to minimize the amount of water discharged to the centralized WMS 'Rya'. However rainwater is not a priority in this neighborhood. (Aarsrud, *pers. com*)

Grey water

The grey water is collected separately and discharged to the conventional sewerage. The sewage transport in the neighborhood is based on gravity. The treatment is done by the centralized WMS 'Rya'. The water effluent from 'Rya' is discharged in the 'Göta älv' and finally ends up in the sea. The sewage sludge is mostly composted and finally incinerated. (Aarsrud, *pers. com*)

Black water

The black water is collected together with the organic kitchen waste. The toilet uses a 3 or 6 Litre flush (Torjusen, 2002). The black water is separated because of its nutrient content. In the kitchen are two sinks present. The organic kitchen waste is grinded by a disposer (figure 8) below one sink, and the grey water is collected by the other sink. The grinded organic waste is transported by vacuum to the black water pipe. This pipe transports the waste by gravity to the local black water treatment plant. (Karlsson, 2005)

Figure 8 Disposar

The normal amount of the black water mixture would be approximately 16 m^3/d (de Blois, 2004). The measured quality is depicted in table 39 in appendix 5.1. Two treatment systems will be tested: 1) drum-screening, dosing anti-scalant, and reversed osmosis, and 2) sedimentation enhanced with chemical precipitation. The objective of these systems is to concentrate the nutrients in a dry substance that makes transport energy/costs low (Karlsson, *pers. com.*).

Subsequently the dry matter is transported to an external biogas facility at which also the organic kitchen waste of Göteborg's restaurants will be digested. The digestion plant is centralized to minimize risks with gas and smell. Thereafter it may be used in agriculture as fertilizer. The remaining water of the black water treatment system might be used for irrigation of the nearby golf court. (Karlsson, 2005) Yet the treatment is still in pilot phase and the water and waste are discharged to the centralized sewerage. Currently (April 2005) are the drum-screening and reversed osmosis in tested. There are no written results yet. The centralized biogas facility does not exist yet. (Aarsrud and Karlsson, *pers. com.*)

6.3.2 Performance SSWMS

Primary functions

The chance that tenants have contact with the wastewater is not present. The risks are equal compared to a conventional WMS. The system is designed to minimize health risks and problems by using ordinary pipe systems. The chance that tenants have access to the mechanical equipment is not present. The chance of calamities is defined by the tenants' experiences. There were no calamities reported by the tenants.

The WMS protects surface water quality and the environment by means of prevention of discharges of oxygen demanding compounds and nutrients. The objective is to reuse the nutrients by 80 %. This will reduce the amount of nutrients discharged on surface water. However it is still unknown what results will be obtained.

Sub functions

The WMS includes measures for rainwater management by rainwater infiltration. The maximum rainwater storage capacity is unknown. The WMS does not include measures for removal of groundwater or drainage water because that is unnecessary.

User-perspective

Table 18 depicts the investment and operational costs of the SSWMS, € 710/y. The investment costs of the treatment plant, conventional sewerage system, and the research were paid by the local government 'Department of Sustainable Water and Waste Management' (96 %), and the construction company (4 %) (Karlsson, *pers. com.*). The costs of the sedimentation with precipitation technology are unknown. The costs of the centralized digestion plant and transport costs are unknown. The cost benefits in agriculture are unknown.

The tenants do not pay a higher rent or taxes than normal. They only paid € 1900 (included in the house price) more than in a conventional system. The tenants do not receive a discount on the water supply price.

Table 18 Investment and operational costs

Aspect	Cost (€)	Cost (€/hh)	Expected lifetime (y)	Cost (€/y)
- Disposar and - double sewerage	254000	1900	- 25 - 50	510[#]
Treatment plant - membranes	570000 - 106000	4300	25 - 5	
Conventional sewerage system	211000	1600	50	
Research and sampling	211000	1600	-	
Water-supply				200
Total cost				**710**

considering an interest of 2.5 % and lifetime of 25 years

The invisibility and comfort is measured by asking five tenants. The toilet is a normal flush toilet. The SSWMS makes them very often (3) feel environmental concerned / friendly. They separate the organic kitchen waste now completely, while they experienced some obstacles to separate in the conventional bin system. They will recommend the system to other households in other neighbourhoods (3). They consider the disposer as luxury equipment, because they do not have to take the garbage out, clean the 'old' dirty bin, and have much less smell and flies problems. They think that the visible part of the WMS equipment in or near the houses is not disturbing (2).

The WMS produces not at all (4) annoying noise levels. The disposer makes a sound when it is used, yet this is already considered as normal. The WMS produces not at all (4) unpleasant odours. The tenants compared the smell of the disposer with the conventional separation of the organic kitchen waste as extraordinary better. The WMS does not attract vermin at all (4). One tenant experienced a visit of flies in the disposer several times in the summer. Yet the tenant related this to low cleaning activities. Most tenants experienced many vermin problems with the conventional organic kitchen waste system.

They do not have to perform maintenance activities; only add some oil drops in the disposer when it is unused for some time. The maintenance activities on the black water system, including the treatment system, will be carried out by one man for 40 hours a week (Karlsson. *pers. com.*).

The first two years the “Water and Sewers Work” will inspect the sewerage pipes in the neighbourhood (Karlsson. *pers. com.*). The tenants face restrictions on products for maintenance or flushing trough the toilet and have a list of products.

The indoor volume of the system is 0.2 m^3/hh for the disposer. However the conventional separation bin would also take some place. The outdoor surface is the area of the local treatment plant and is 0.75 m^2/hh.

The robustness of the system is also an average opinion of the tenants. Four out of five tenants experienced problems with the disposer. Two tenants had a clogged disposer by potato peels, fish bones or lime shelves. This occurred two times per year; however they cleaned the disposer with flush water. One tenant experienced leakage of the disposer two times a year, which is still not solved. One tenant has a dysfunctional disposer. One time in the first year two out of five tenants experienced a problem with the sewerage system. The sewerage pipe was clogged, and they could not use the toilet for a while. However the clogged pipe was cleaned by the “Water and Sewers Work”.

Environmental

The amount of energy used by the grey and rainwater system is unknown. There are chemicals (anti-scalants) used in the black water system. The amount of chemicals is still unknown. The water consumption is approximately 145 m^3/hh. The objective is to minimize the use of artificial fertilizers, therefore protection of the phosphorus resources. The amount of sludge produced by the black water system is unknown. The amount of nutrients recycled is unknown. The water quality of the discharged effluent is higher compared to a conventional WMS.

The final comparison with the conventional WMS is visualized in the table below. . For each indicator a +, a 0, and a – is given for respectively the better, the same, and worse than in the conventional system.

Table 19 Comparison with conventional WMS based on criteria

Criteria	Indicator	Comparison
Primary functions	Health protection	0
	Protection of surface water	+
Sub functions	Rainwater management	+
	Drainage management	0
User perspective	Costs	-
	Invisibility / comfort	+
	Robustness	-
Environment	Resource use	+
	Emissions	+

6.3.3 Actors

The actors and their role in the design and decision-making are presented in table 20. The design is carried out by the housing company ‘Egnahemsbolaget’ and construction company / architect ‘Sweco FNNS’. The latter was taken over by the Göteborg municipality ‘Department of Sustainable Water and Waste Management’ (‘Kretslopp Department’). The final decisions where made by the housing company and the Kretslopp Department. The houses are owned by the tenants and housing company. The new owner of the full scale treatment plant and sewerage system will be the Water and Sewers Work (VA-Verket).

Table 20 Actors in design and decision-making

	Description	Name	Role
1	Consultant	H2OLAND	Analysing and process design black water system
2	Housing company	Egnahemsbolaget	Current manager houses
3	Architect*	Sweco FNNS	Design neighborhood
4	Department of Sustainable Water and Waste Management (municipality)	Kretslopp department	Project manager and investor
5	Water and Sewers Work (municipality)	Va-Verket	Building sewerage system and 2 years of inspection
6	Sewerage and treatment department (municipality)	Gryaab	Advise on technology, and permission for organic kitchen waste in sewerage

* The architect is not longer working at the construction company. This actor is no longer involved in the current situation.

Responsibility

The housing company (Gustavsson, *pers. com.*) and the Department of Sustainable Water and Waste Management (Aarsrud and Karlsson, *pers. com.*) are responsible for the final decisions in the design.

The Department of Sustainable Water and Waste Management is responsible for the complete SSWMS (Karlsson, *pers. com.*). When the installation operates in full scale mode the Water and Sewers Work will be responsible (Bokesjö, *pers. com.*). The tenants are responsible for the in-house equipment (toilet, pipes, etc.). The Water and Sewers Work is responsible for the sewerage pipe system.

6.3.4 Drivers and barriers

The drivers and barriers are divided in environmental, economical, and social aspects and are evaluated for the design, current, and future situation of the black water system. They are addressed in table 40 in appendix 5.2 with corresponding numbers to the actors. The tenants did not take part in the decision making.

Environmental Drivers and Barriers

All actors address the recycling of nutrients as main environmental driver in all the phases. The project is based on this environmental driver. The consultant (de Blois, *pers. com.*), housing company (Gustavsson, *pers. com.*), Department of Sustainable Water and Waste Management (Aarsrud and Karlsson, *pers. com.*), and architect (Aleby, *pers. com.*) also address a nice neighborhood as environmental driver in all phases. The architect also included the use of environmental friendly materials and minimizing the demolition of the surrounding area as environmental driver in all phases. The architect and housing company have a nice environmental behaviour feeling as driver in all phases. The 'VA-Verket' (Bokesjö, *pers. com.*) and 'Gryaab' (Mattsson, *pers. com.*) address the reduction of waste water emissions and overflows as environmental driver.

The consultant has as environmental barriers: health risks, flooding risks, use of chemicals, maintenance problems, high energy use and calamity risk due to acid doses in almost all phases. The housing company has as environmental barriers: maintenance problems in design phase, and higher water consumption in all phases. The architect has as environmental barriers: maintenance problems in design phase, and risks of recycling the sludge in agriculture in all phases. The Kretslopp Department has as environmental barriers: chemical use, higher energy use, and maintenance problems in almost all phases. VA-Verket has as environmental barriers: health risks, flooding risks, use of chemicals, maintenance problems, risks of medicine and hormones in agriculture, high energy use, no space in ground for two sewerage systems, and resources use in all phases. Gryaab has as environmental barriers: flooding risks, use of chemicals, maintenance problems, and high energy use in all phases.

Economical Drivers and Barriers

The main economical driver of all actors in all phases is the development of a new technology that might result in future benefits. The consultant has as economical driver a low water board fee and low sewerage taxes in the future. Gryaab has as economical driver a lower garbage costs in all phases.

The main economical barriers for all actors are the very high installation and maintenance costs. VA-Verket also has the high energy costs and not possible upscaling of the system as economical barrier in all phases. 'Gryaab' has the high energy costs, high sewerage taxes, high water-board fee, use of ground space, and not possible upscaling of the system as economical barrier in all phases

Social Drivers and Barriers

The consultant has as social drivers: a higher intensive contact between the neighbours, environmental friendly behaviour, and a nice neighbourhood in all phases. The housing company has as social drivers: a higher intensive contact between the neighbours, environmental friendly behaviour, a nice neighbourhood, and a good contribution for the whole community in all phases. The architect has as social drivers: environmental friendly behaviour and a nice neighbourhood in all phases. The Kretslopp department has as social drivers: environmental friendly behaviour, a nice neighbourhood, and same system as in conventional in all phases. VA-Verket has as social driver the luxury of the disposer in all phases. Gryaab has as social drivers: a higher intensive contact between the neighbours, the luxury of the disposer, and a nice neighbourhood in all phases

The consultant and housing company have as social barrier the risks for housing equipment. The architect has as social barrier the not visible environmental behaviour. The Kretslopp Department has as social barrier the conventional thinking of several actors. VA-Verket has as social barriers the difficulty of the technology and health risks. Gryaab has as social barriers the difficulty of the technology and sewerage blockage.

6.4 Understenshöjden

In 1990 the tenants association ‘EBBA’ (Ecological Development in Björkhagen) was formed to initiate a project on ecological living. They cooperate with the housing companies ‘HSB’ (the National Association of Tenants' Savings and Building Societies) and ‘SMÅA’ (Småföretagarnas Arbetslöshetskassa) that are familiar with individual house building project. HSB and SMÅA are the project developers. The tenants initiated several ecological themes of which one was a completely disconnected SSWMS. To ensure that prospective home owners played an active role in the project an innovative plan was designed. The members had to work ten hours each month in the design or building of the village or pay € 32 instead (website Fujita research). They combined the self-building concept with user participation in the design process and the use of environmentally friendly materials and technology. In the area Björkhagen in Stockholm 44 houses were constructed. In 1995 the tenants (160) owned the houses and could move in. (HSB, 1997)

6.4.1 Implemented Technology

The SSWMS in Understenshöjden is initially based on separate collection of urine (yellow), grey, brown, and rainwater. The local treatment of the grey and brown water is after a control program closed. Currently these streams are transported to the centralized WMS Hendriksdals in Stockholm. The water saving utilities consists of the taps and toilet. The water saving capacity of the urine separation toilet is depending on ones habits approximately 5 – 40 L/p.d (Johansson and Nykvist, 2001). The system’s scheme and above aria view are shown in appendix 6.1. The design is based on resource- saving and recycling (nutrients) living.

Rainwater

The rainwater is disconnected from the sewerage system. It is collected in a rain barrel and reused for plants, or led to a pond and ditch system from which it infiltrates in the ground. The pond and ditch have a total area of 360 m^3. The assumed infiltration capacity is according the permeability 100-200 m^3/year. (HSB, 1994)

Grey and Brown water

The grey and brown water are transported to the centralized WMS ‘Hendriksdals’ in Stockholm. The brown water is flushed with 4 litres. The amount is 17 m^3/day, respectively 100-110 L/p.d. (Verna Ecology).

Urine

The houses have a urine separating ('Dubletten') toilet (figure 6). The urine contains approximately 70 % N and 50 % of P and K of all household waste and wastewater (Jönsson, 2002). Approximately 82 % of the urine is source separated (Jönsson, 2002). The urine quality is depicted in table 41 in appendix 6.1. The amount is approximately 0.2 m^3/d (1.25 L/p.d), respectively 160-180 m^3/year. It is flushed with 0.2 litres of water and runs by gravity to two large tanks of 40 m^3 in the underground of the surroundings. The urine pipes are made of Polypropylene and have a diameter of 110 mm. When the first tank is full the other is connected.

The urine is transported once a year to a farmer at Lake Bornsjön (in Salem). There it is stored for six months (to disinfect it from pathogens) at in a 3 x 150 m^3 tank. In spring the farmer fertilizes cereal crops from the urine. The transport over 33 km requires 44 MJ/p.y (Jönsson, 2002). However the energy savings are for the central WMS and fertilizing production respectively 32 MJ/p.y and 75 MJ/p.y (Jönsson, 2002). According to Jönsson the emissions of N and P to water decreased by 55 % and 33 %, respectively (Jönsson, 2002).

6.5.2 Performance SSWMS

Primary functions

The chance that tenants have contact with the wastewater is not present. The risks of recycling the urine are low (Höglund, 2001). The chance that tenants have access to the mechanical equipment is not present. The chance of calamities is according to Sederlund (*pers. com.*) very low. However he worries the chance of children falling in the urine tank, although it is locked.

The WMS protects surface water and environment by means of prevention of discharges of oxygen demanding compounds and nutrients. Due to the collection of 82 % of the urine approximately 57 % N, 41 % P, 41 % K, and 25 % COD are separated and reused.

Sub functions

The WMS includes measures for rainwater management by collection in rain-bins, ponds and infiltration. The maximum rainwater storage capacity is 360 m^3. The rainwater is reused for spraying the plants in the garden. The WMS does not include measures for removal of groundwater or drainage water because that is unnecessary.

User-perspective

Table 21 depicts the investment and operational costs of the SSWMS, € 512/y. The urine transport costs are paid by the tenants, approximately € 1690. (Sederlund, *pers. com.*) The tenants get a discount of 8.3 % on the water price (Schultz, *pers. com.*). Once in 5-10 years the pipes and tanks are cleaned by an external company for € 36/hh.

Table 21 Investment and operational costs

Aspect	Cost (€)	Cost (€/hh)	Expected lifetime (y)	Cost (€/y)
Urine separating toilet - porcelain - wooden seat	33924	 - 654 - 126	 - 30 -13	41.8[#]
Urine pipes & tanks	Unknown	Unknown	30	40*
Black and grey water	4375			237.5**
Urine transport	1690			38.5
Water supply				147
Maintenance				7
Total cost				**512**

*assumed, ** Dutch price for connection and treatment, # considering an interest of 2.5 % and lifetime of 25 years

The invisibility and comfort is measured by asking four tenants. The toilet is a 'Dubletten' toilet. The SSWMS makes them always (4) feel environmental concerned / friendly. They all address the importance of the reuse of the nutrients in agriculture. They will recommend the system to other households in other neighbourhoods (3). They think that the visible part of the WMS equipment in or near the houses is nice (3). However one tenant mentioned that the other people should learn from their experiences to overcome the difficulties (Sederlund, *pers. com.*). The WMS produces not at all (4) annoying noise levels. The WMS produces sometimes (2) unpleasant odours. The odours appear especially when the urine pipes are clogged (Schutz, *pers. com.*). The WMS does not attract vermin at all (4).

Figure 9 Mechanical snake

The tenants' maintenance activities consist of flushing the toilet with hot water and soda, and clean the pipes with a mechanical snake (figure 9). The average time is approximately 32 h/y. Once in 5-10 years an external company cleans the complete pipe system and urine tanks (Sederlund, *pers. com.*). They all do not care to perform maintenance (2) because it is part of the system. All households reported experiences with clogging of the urine pipe approximately 2 times/y.

The Agricultural Sciences department of the Uppsala University reported that 76 % of the stoppages mainly consist of (calcium and magnesium ammonium phosphates) precipitation, formed on hairs and fibres. The remaining 24 % consists of precipitation on the pipe wall (Jönsson, 2001).

The tenants face restrictions on products for maintenance or flushing trough the toilet, although they do not have a list of products. The indoor volume of the system is not higher than normal. The outdoor surface is area of the urine tanks is approximately 0.46 m^2/hh (the farmer's urine tanks not included).

Environmental

The amount of energy saved by the urine reuse and a distance to the farmer of 33 km is 35 kWh/hh.y (Jönsson, 2002). Caustic soda is used for cleaning yet the amount is unknown. The water consumption is approximately 140 m^3/hh. The amount of feces sludge produced is unknown. The amount of nutrients recycled is 1.6 kg N/p.y and 0.15 kg P/p.y, enough to fertilize 160 m^2 at 100 kg N per hectare (10 000 m^2) (Jönsson, 2001). The water quality of the discharged effluent is higher compared to a conventional WMS.

The final comparison with the conventional WMS is visualized in the table below. For each indicator a +, a 0, and a – is given for respectively the better, the same, and worse than in the conventional system.

Table 22 Comparison with conventional WMS based on criteria

Criteria	Indicator	Comparison
Primary functions	Health protection	0
	Protection of surface water	+
Sub functions	Rainwater management	+
	Drainage management	0
User perspective	Costs	0
	Invisibility / comfort	+
	Robustness	-
Environment	Resource use	+
	Emissions	+

6.5.3 Actors

The actors and their role in the design and decision-making are presented in table 23. The initiative and ideas are founded by the tenants' organisation EBBA (Sederlund, *pers. com.*). The housing company 'HSB' financed and managed the project (Westin, *pers. com.*). The final decisions where made by the tenants and the housing company.

The municipality Stockholm permitted the SSWMS (Lundin, *pers. com.*). The water-board 'Stockholm Vatten' advised on the technology (Hellström, *pers. com.*). Also a consultant company 'VERNA Ecology' (Johansson, *pers. com.*) was involved in the design and research of the current status.

Table 23 Actors in design and decision-making

	Description	Name	Role
1	Tenant organization	EBBA	Initiator, ideas,
2	Housing company	HSB Stockholm	Project developer and manager
3	Municipality	Stockholm city	Preconditions and demands
4	Water-board	Stockholm Vatten	Advice water system
5	Consultant	Verna Ecology	Advise in design phase and research on current status

Responsibility

The tenants are responsible for over the individual pipes of the water system and the urine collection. 'Stockholm Vatten' is responsible for the brown and grey water transport and treatment.

6.5.4 Drivers and barriers

The drivers and barriers are divided in environmental, economical, and social aspects and are evaluated for the design, current, and future situation of the urine and rainwater separation. They are addressed in table 42 in appendix 6.2 with corresponding numbers to the actors. The municipality does not take part in the design and future phase (Lundin, *pers. com.*).

Environmental Drivers and Barriers

The main environmental driver for all actors in all phases is the recycling of nutrients. The tenants address water saving, reduction of water emissions, recycling of nutrients, protection of surface water for overflows, reduction of energy use, nice neighborhood, and nice environmental behaviour feeling as environmental drivers in all phases. The housing company considered the same in the design phase, however in the current and future phase not the reduction of water emissions, protection of surface water for overflows and reduction of energy use. The housing company relates this to the connection of the brown and grey water to the conventional WMS. The municipality addressed reduction of water emissions, the recycling of nutrients, protection of surface water for overflows, nice neighborhood, and nice environmental behaviour feeling as environmental drivers. The water-board had reduction of water emissions, the recycling of nutrients, protection of surface water for overflows, nice neighborhood, and nice environmental behaviour feeling as environmental drivers.

The consultant had water saving, reduction of water emissions, the recycling of nutrients, protection of surface water for overflows, no use of chemicals, nice neighborhood, and nice environmental behaviour feeling as environmental drivers

All actors consider maintenance problems in all phases as environmental barrier, however the water-board considers them only the design phase. The housing company considers health risks in the current and future phase as environmental barrier. The water-board considers chemical use and smell in almost all phases as environmental barrier.

Economical Drivers and Barriers

The economical drivers of the tenant, housing company, and water-board are low water board fee, low sewerage taxes and the development of a new technology that might result in future benefits in all phases. The housing company also considers the low operational costs as driver. The water-board also considers the low energy costs as driver. The municipality had only the development of a new technology as economical driver. The consultant considers in the design phase only the development of a new technology as driver, however in the current phase they consider low water supply costs, low water board fee and low sewerage taxes as drivers. The main economical barrier for all actors is high installation costs in all phases. The tenants, water-board, and consultant also consider the high maintenance costs as barrier.

Social Drivers and Barriers

All actors had as social drivers: environmental friendly behaviour and a nice neighbourhood in all phases. The tenant, housing company and municipality also included a higher intensive contact between the neighbours as social drivers.

The social barriers for the tenant are health risks, risks for housing equipment and difficult technology. The housing company had as social barriers the risks for housing equipment and difficult technology. The water-board had as social barriers the risks for housing equipment and the acceptance of agriculture. The municipality had as social barriers the difficult technology, a decrease of tenants' interest, and the possible unprofessional new tenants. The social barriers for the consultant are health risks, risks for housing equipment, availability of a user of the urine, and difficult technology.

6.5 Gebers

In 1936 a convalescent home named 'Gebers' was located in 'Ornhem'. Ornhem is a district in Stockholm. Gebers stands on the shore of lake 'Drevviken' and has a living space over 3,500 m^2 and land of 3.2 hectares. In January 1995 is the tenant's organization EKBO (Ecological Collective Housing in Orhem) founded. Members of EKBO noticed the empty building of Gebers and initiated the idea to live there. In cooperation with the housing company HSB (the National Association of Tenants' Savings and Building Societies) a project was started to renovate the building. HSB took over the financial part and construction work and EKBO had all the initiatives, ideas, and practical solutions. EKBO's main ideas were collective social and ecological living. The decisions made were based on consensus to create as much basis support of all tenants. (Boverket, 1998 and website Ekbo) In 1998 the renovation was finished and the tenants moved in. The house consists of 32 apartments in which between 60 and 80 people are living over the years. All flats are rental. In the house many ecological items were installed. The water system includes water saving utilities and source separation of water waste.

6.5.1 Implemented Technology

The SSWMS in Gebers is based on separate collection of urine (yellow), grey, brown, and rainwater. The water saving utilities are the taps, shower, and toilet. Between 2001 and 2003 the water consumption is approximately 116 L/p.d, which is lower than normal. The quality of the water-streams is depicted in table 43 in appendix 7.1. The system's scheme is depicted in figure 10. An above aria view of the house is shown in appendix 7.1. The design is based on resource-saving and recycling (nutrients) living.

Rainwater

The rainwater is disconnected and infiltrated in the ground. However rainwater is not a priority in this building. (Hort, *pers. com.*)

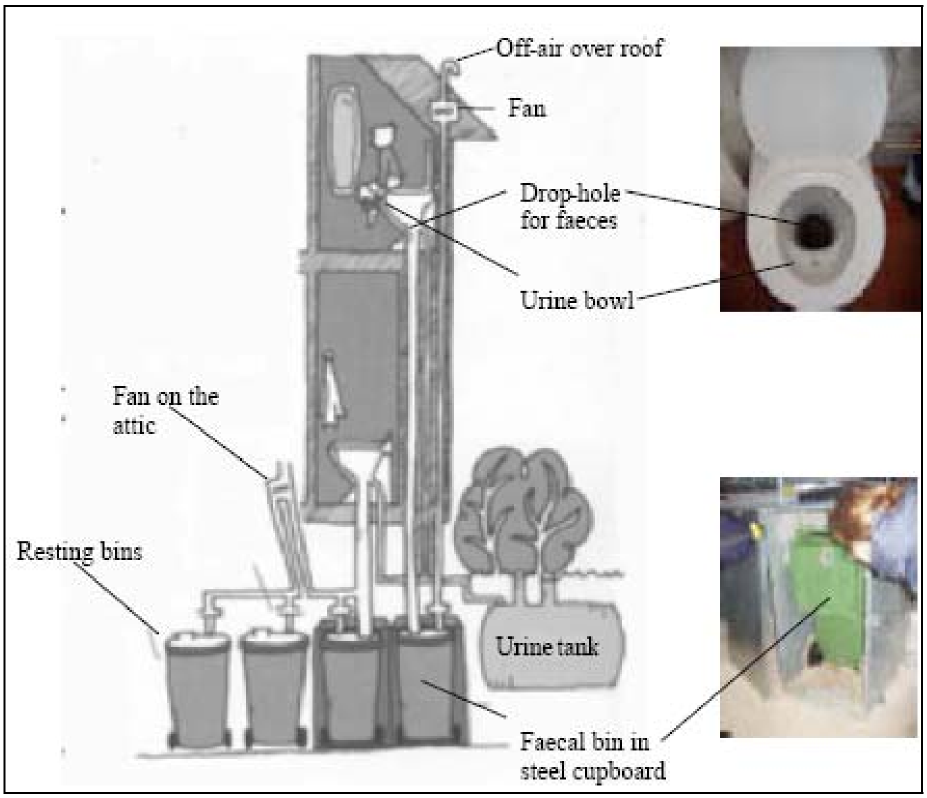
Grey water

The grey water amount is approximately 110 L/p.d (Palmquist and Jönsson, 2003). Originally EKBO wanted to treat it locally, yet Stockholm city gave no permit. The municipality wants to protect the lake 'Drevviken' from possible pollution. Therefore it is transported by a pipe on the bottom of the lake and treated in centralized WMS 'Hendriksdals' in Stockholm (Krantz, 2005). The pipe is also vulnerable for leakage. (Hort, *pers. com.*)

Urine

Thirty of the 32 households have a urine separating toilet (figure 10). They are single flush toilets delivered by the company 'Wost Man Ecology AB' (their "ES-Classic" model). The urine amount is approximately 1.77 L/p.d and flushed with 0.1 litre by gravity to three large tanks of 4 m^3 in the basement (Palmquist and Jönsson, 2003). The pipes are made of Polypropylene and have a diameter of 50 mm. The urine is transported 2-3 times/y to a farmer at lake 'Bornsjön'. There it is stored for six months in 3 x 150 m^3 tanks. In spring the farmer fertilizes approximately 2 hectares from Gebers' urine. (Hort*, pers. com.*)

Figure 10 Schematic view of toilet separation system Gebers (Krantz, 2005)



Brown (water)

The brown water consists of dry feces. The feces are collected by a drop-hole and a 200 mm wide pipe into a plastic sack in a 140 litre (or smaller) bin (Kranz, 2005). The bin is placed in a fire-resistance steel cupboard. This was a safety demand from the municipality. The feces are supposed to be dehydrated and decompose before being composted. Yet the dehydration and decomposing are not taking place in the storage time (Hort *pers. com*.). The urine should not end up in the feces bin, because it would attract flies, increases the sacks weight, removal frequency, and slows down the dehydration. Therefore men have to sit on the toilet. For children it is difficult because they usually urinate and defecate at the same time. (Kranz, 2005)

The air and odors from the dehydration receptacles in the basement are ventilated: "air is drawn from the bathroom through the down-pipe into the receptacle in the basement and from there up to a vent pipe on the roof" (website Ekbo). The amount of separated feces and toilet paper is approximately 0.22 L/p.d (Palmquist and Jönsson, 2003). When the bin is filled the households have to carry it out of the basement (is heavy) to empty it at the compost site (figure X). According to Krantz (2005) single-person households empty the bin every 3-4 months, while larger households empty it every month. If the bin is not emptied in time flies will start to appeal and disturb the tenants. The compost should be collected by a company 'Estra Manor' that uses it as a fertilizer. However due to the low compost amounts it is still not collected. (Hort*, pers. com.*)

Evaluating current system

The separation leads to a recycling potential for N, P, and K of respectively 90, 70, and 76 % (Palmquist and Jönsson, 2003). Yet approximately 30 % of the BOD is not recycled and discharged by the grey water. "The N:P:K:S relationships of urine mixture, feces, grey water, and biodegradable solid waste at Gebers were 15:1:3:1, 3:1:1:0.3, 2:1:2:3 and 6:1:3:0.6. Except for grey water this corresponded well to the crop uptake of macronutrients, which make them to potential fertilizers from a plant nutrients point of view" (Palmquist and Jönsson, 2003).

6.5.2 Performance SSWMS

Primary functions

The chance that tenants have contact with the wastewater is present. They have to empty the bin, therefore may be exposed to the feces. However no respondent is concerned about health risks (Krantz, 2005). The risks of recycling the compost (Karlsson, 2002) or urine (Höglund, 2001) are low. The chance that tenants have access to the mechanical equipment is present. The chance of calamities is very low (Hort *pers. com.*). A calamity could be a shut down of electrical power that is necessary to run the ventilators. If the vents do not work the smell is expected to be horrible (Krantz, 2005).

The WMS protects surface water and environment by means of prevention of discharges of oxygen demanding compounds and nutrients. The reuse of urine and compost reduces the amount of nutrients and organic matter discharged.

Sub functions

The WMS includes measures for rainwater management by rainwater infiltration. The maximum rainwater storage capacity is unknown. The WMS does not include measures for removal of ground or drainage water because that is unnecessary.

User-perspective

Table 24 depicts the investment and operational costs of the SSWMS, € 385/y. The total water installation costs are approximately 137,400 euro (Boverket, 1998). However the feces collection pipe is corroding and people are worried about its lifetime (Kranz, 2005). The yearly costs of urine transport are paid by the tenants and are approximately € 1170. The tenants get a discount of 10 % on the water supply (Hort, *pers. com.*).

Table 24 Investment and operational costs

Aspect	**Amount of households**	**Cost (€)**	**Cost (€/hh)**	**Expected lifetime** (y)**	**Cost (€/y)**
Grey water connection	32	42260	1320	100	243.7
Urine separating toilet and feces collection	30	95000	3170	30-50	
Urine transport					37
Water-supply					105
Total cost					**386**

The invisibility and comfort is measured by asking one tenant (Hort, *pers. com.*). The other results are reported by Krantz (2005); she interviewed 26 out of 32 households. The SSWMS makes him always (4) feel environmental concerned / friendly. He will recommend the system to other households in other neighbourhoods (3). He thinks that the visible part of the WMS equipment in or near the houses is nice (3). The WMS produces not at all (4) annoying noise levels. The WMS produces not at all (4) unpleasant odours. Krantz reported that 2 out of 26 experience from time to time unpleasant odours. Those tenants believe that the air pressure of the ventilation is to low.

The WMS does attract vermin very often (1). According to Kranz (2005) all 26 respondents experienced problems with flies. The flies are small fruit flies. The flies breed during the whole year, yet peak during summer months. Measurements to reduce the flies are: more frequently emptying the bin, spray chemical pesticides like Radar, close the toilet lid, stopping of food waste separation, and keeping fruit in plastic bags. Due to these “solutions” the flies’ problem decreased. (Krantz, 2005)

He has to perform maintenance activities, 12 hours a year for emptying the feces bin. He finds it not nice to do (1), however accept the system. All households experienced clogging of the urine pipe by crystals (Krantz, 2005). Therefore the pipes are cleaned regularly with a special brush and flushing with hot water and sodium hydroxide. They all face restrictions on products for maintenance or flushing trough the toilet; yet do not have a list of products. Especially a dry toilet changes people's awareness of what / what not to throw away in the toilet, because the garbage will all end up in the composting site (Krantz, 2005). The indoor volume of the feces pipe is 0.5 m^3/hh. The outdoor surface area of the compost site is approximately 0.3 m^2/hh.

Environmental

The amount of energy used by the grey and rainwater system is unknown. There are no chemicals used by the grey and rainwater system. The water consumption is approximately 84 m^3/hh (Hort, *pers. com.*). The amount of feces sludge is approximately 37.2 kg/hh.y (Palmquist and Jönsson, 2003). The amount of nutrients recycled is for N, P, and K respectively 9, 1, and 2.2 kg/hh.y (Palmquist and Jönsson, 2003). The effluent quality is higher compared to a conventional WMS.

The final comparison with the conventional WMS is visualized in the table below. For each indicator a +, a 0, and a – is given for respectively the better, the same, and worse than in the conventional system.

Table 25 Comparison with conventional WMS based on criteria

Criteria	Indicator	Comparison
Primary functions	Health protection	-
	Protection of surface water	+
Sub functions	Rainwater management	+
	Drainage management	0
User perspective	Costs	+
	Invisibility / comfort	-
	Robustness	-
Environment	Resource use	+
	Emissions	+

6.5.3 Actors

The actors and their role in the design and decision-making are presented in table 26. The initiative and ideas are founded by the tenants' organisation Ekbo (Hort, *pers. com.*). The housing company 'HSB' financed the project and owns the building (Westin, *pers. com.*). The final decisions where made by the tenants and housing company.

The municipality permitted the SSWMS however a connection to the conventional WMS was necessary for the grey water (Lundin, *pers. com.*). The water-board 'Stockholm Vatten' advised on the technology (Hellström, *pers. com.*).

Table 26 Actors in design and decision-making

	Description	**Name**	**Role**
1	Tenant organization	Ekbo	Initiator, ideas, take care of rennovation
2	Housing company	HSB Stockholm	Current manager owner hous
3	Municipality*	Stockholm city	Preconditions and demands
4	Water-board	Stockholm Vatten	Advice water system

* These actors were not involved in the design phase.

Responsibility

The tenants are responsible for the individual pipes of the water system and emptying the feces bin. The housing company is responsible for the collective parts of the WMS. 'Stockholm Vatten' is responsible for the grey water treatment.

6.5.4 Drivers and barriers

The drivers and barriers are divided in environmental, economical, and social aspects and are evaluated for the design, current, and future situation of the feces, urine, and rainwater separation. They are addressed in table 44 in appendix 7.2 with corresponding numbers to the actors. The municipality does not take part in the design and future phase (Lundin, *pers. com.*).

Environmental Drivers and Barriers

The tenant addresses water saving, reduction of water emissions, recycling of nutrients, protection of surface water for overflows, nice neighborhood, and nice environmental behaviour feeling as environmental drivers in all phases. Initially the tenant and housing company had recycling of water as driver; however in the current and future phase no recycling installation was installed. The housing company addressed water saving, recycling of nutrients, nice neighborhood, and nice environmental behaviour feeling as environmental drivers in all phases. The municipality addressed reduction of water emissions, recycling of nutrients, protection of surface water for overflows, nice neighborhood, and nice environmental behaviour feeling as environmental drivers. The water-board had water saving, reduction of water emissions, recycling of nutrients, protection of surface water for overflows, nice neighborhood, and nice environmental behaviour feeling as environmental drivers in all phases.

The tenant, housing company, and water-board had maintenance problems in only the design phase as environmental barrier. In the current and future phase these problems are solved. The housing company addressed health risks in the current phase and high energy use due to transport of urine in all phases as environmental barrier. The municipality had maintenance problems as environmental barrier. The water-board addressed health risks in all phases and smell in only the design phase as environmental barriers.

Economical Drivers and Barriers

The economical drivers of the tenant and housing company are low operational costs, low drink water costs, low water board fee, low sewerage taxes and the development of a new technology that might result in future benefits in all phases. The water-board had almost the same drivers, except for low drink water costs, yet included low costs of energy in all phases. The municipality had only the development of a new technology as economical driver.

The main economical barrier for the tenant, housing company, and water-board are high installation costs in all phases. The housing company also experienced the use for energy as economical barrier.

Social Drivers and Barriers

All actors had as social drivers: a higher intensive contact between the neighbours, environmental friendly behaviour, and a nice neighbourhood in all phases. The tenant also included the contributing effort to society and to be proud of the technology as social drivers. Especially all the research and visitors to the Gebers house resulted in a social awareness.

The social barriers for the tenant are health risks, disgusting maintenance, risks for housing equipment, difficult technology. One main social barrier is the uncertainty of the continuous recycling of the urine by the farmer. The housing company had as social barriers the risks for housing equipment and health risks. The water-board had as social barriers the risks for housing equipment, difficult technology, and health risks. The municipality had as social barriers the difficult technology, a decrease of tenants' interest, and the possible unprofessional new tenants.

7 DISCUSSION

7.1 Performance assessment

The performance assessment of the several sites is quite complicated. The assessment tool requires quantitative data that makes a quantitative comparison possible. However in many cases these data are unknown. There are several reasons for this lack of knowledge:

- First it is difficult to define the average conventional WMS. No study is done on a concrete conventional WMS. Therefore the aspects difficult to define are: space, calamities, maintenance, user-perspective, chemical use, energy consumption, and emissions per household.

- Several indicators in the performance tool are too widely defined. The answer on, for instance the question: 'What is the estimated useful lifetime of the WMS in years?' can be different for several parts of the system. Or on the question: 'To what extend does the final water quality comply with official quality standards?' you can give a percentage per parameter of the water-quality.

- Some indicators, for instance emissions, need a complete integrated assessment of mass-balances for energy, nutrients and other substances. However this integrated assessment is not possible to make because the content of many streams are unknown.

- Some aspects for instance the water and sludge quality are unknown. The involved actors in most cases have no interest in the system. Therefore they do not measure it. This also makes it difficult to assess if it is better than in a conventional WMS.

- It may also be that several water effluents are discharged. This makes it hard to define what are the removal efficiencies and final water qualities.

- The answer on the question: 'To what extend does the final water quality comply with futuristic EU quality standards (Water Framework Directive)?' also may give multiple answers. Yet another problem is that these EU quality standards are still not defined, which makes answering very skeptical.

- And some indicators demand a descriptive answer, for instance: ‘What is the chance that tenants get in contact with the wastewater?’ Especially the definition of ‘the chance’ makes it hard to answer. The comparison of this answer with the conventional WMS may be difficult.

- In some cases the actors that have the data are taken over by other actors. The new actors do not preserve the data.

- Some SSWMS are still partly connected to the centralized WMS. The quality of the still connected waste-stream and the effect on the treatment efficiency, energy use, sludge production etc. in the central WMS are not possible to define.

- It was not possible to receive the technical drawings of all sites.

Defining indicators is one thing, subsequently from these indicators a value must be given to the criterion. This step is also very difficult. The step of comparing the criterion of a site with the reference WMS is also difficult. To overcome these uncertainties the performance is not assessed quantitatively yet qualitatively. The several aspects are compared with the reference system and valued as worse, same and better performance.

And finally the most difficult part is the performance assessment in the Multi Criteria Comparison. Which value may be given to each criterion or in other words: ‘which is more important?’ The judgment of these values is subjective and may be different for different actors. Therefore this comparison is not done.

7.2 Drivers and Barriers

In the drivers and barriers assessment it is necessary to interview all actors involved in the design and decision-making. However some actors do not exist anymore or are not willing to participate in the research. To overcome this other actors are asked to give their view on the drivers and barriers of these ‘missing’ actors.

8 CONCLUSION

The conclusion is contains the comparison of the performance and the drivers and barriers.

8.1 Performance assessment

The several criteria of the performance of the SSWMS are compared with the reference WMS in table 27. The table presents that some sites may have less performance in the primary functions according the health protection yet better performance in protection of the surface water. Of the sub-functions the rainwater management is in all sites better than the reference system. The drainage management is better in the sites in the Netherlands, however the same in Sweden compared to the reference WMS.

Of the user-perspective the costs are except for Understenhöjden and Gebers all sites worse than the reference WMS. The invisibility and comfort are in most cases the same or better than the reference system, yet at Gebers due to the feces separation and related problems this aspect is worse. The robustness of all sites is worse than the conventional system. In all cases some problems appeared per year.

At the criteria Environment all sites score better in the use of resources, which could be water, nutrients, and energy. In almost all sites the emissions are less than in the reference system, yet at Ekoporten the emissions are partly worse.

Table 27 Performance assessment all SSWMS with reference WMS

Criteria	Indicator	Groene dak	Polder drift	Eko por ten	Skoga berg	Under stens höjden	Gebers
Primary functions	Health protection	-	-	0	0	0	-
	Protection of surface water	0	+	-	+	+	+
Sub functions	Rainwater management	+	+	+	+	+	+
	Drainage management	+	+	0	0	0	0
User perspective	Costs	-	-	-	-	+	+
	Invisibility / comfort	0	0	+	+	0	-
	Robustness	-	-	-	-	-	-
Environment	Resource use	+	+	+	+	+	+
	Emissions	0	+	+/-	+	+	+

8.2 Drivers and Barriers

Table 28 presents the main Dutch and Swedish drivers and barriers for the implementation of a SSWMS. A between the Netherlands and Sweden is the objective of water reuse. In most cases the Swedish tenants were not interested in the water-use. Yet a large part of their operational costs are defined by the water-use. Another difference is the recycling of nutrients that is actively addressed by all Swedish actors and is implemented in the new policy on WMS. In the Netherlands the nutrients are not very interesting.

In both countries health risks are important. Some health risks may be related to the lack of management and maintenance. Since the prevention of health risks is part of the primary functions they should be minimized. In Sweden is the protection of surface water, mainly the fragile lakes, very important. Therefore a local treatment plant may be a risk (by failure) for this quality. All actors address the high costs as an important barrier. Yet the distribution of costs and benefits is very diffuse over several actors. The discount on the water-board fee is part of this diffusion. The value of the SSWMS is for the water-boards in the Netherlands hard to define, because they have no interest/idea. In Sweden in some cases a discount is given, yet the proportion of the discount is not defined clearly. The last barriers is that in most urban areas already a conventional WMS is present, and several actors value the system on its reliability and cost effectiveness.

Table 28 Main Drivers and Barriers

Drivers	**Dutch**	**Swedish**
Water reuse	Yes	No
Emissions reduction	Yes	Yes
Recycling nutrients	No	Yes
Development technology	Yes	Yes
Social acceptable	Yes / no	Yes
Governmental involvement	No	Yes
Barriers		
Health risks	Yes	Yes
Management and maintenance problems	Yes	Yes
Pollution of surface water (lakes)	No	Yes
High costs	Yes	Yes
Discount on water-board fee	No	Yes
Conventional system is not a problem	Yes	No

9 RECOMMENDATIONS

9.1 Recommendations per SSWMS

In this study several SSWMS are investigated and their performance is assessed. Some recommendations to these sites are considered. For all cases it is recommended to monitor all flows and qualities of the wastewater streams, energy use, and sludge production to gain more insight in the treatment efficiency.

Het Groene Dak

In the case of 'Het Groene Dak' it is recommended to minimize the reuse of rainwater in the toilets and washing machines. The rainwater may be used in the toilet when tenants flush with a closed lid. This is recommended to prevent the health risks related with the rainwater quality. Subsequently is the current status of the grey water treatment, the reedbed and greenhouse, very bad. Since the housing company is responsible they have to improve the treatment system. To reduce the costs the tenants may address a discount on the water-board fee.

Polderdrift

In the case of 'Polderdrift' it is recommended to minimize the reuse of grey and rainwater in respectively the toilets and washing machines. The grey water may be used in the toilet when tenants flush with a closed lid. It might be interesting for the tenants to demand a discount on the water-board fee.

Ekoporten

In the case of 'Polderdrift' it is recommended to improve the grey water system or connect it to the conventional WMS. It is advised to inform the farmer on the collection of the urine. Another advice is to get insight in the medicine and hormone content of the urine.

Skogaberg

Not any recommendations are given for Skogaberg, since the implementation project is still developing.

Understenshöjden

Not any recommendations are given for Understenshöjden since the systems operates ok.

Gebers

It is advised to increase the contact with farmers that might be interested in the urine and compost use. It is also recommended to reduce the health risks as much as possible.

9.2 Recommendations for further research

Also some recommendations are given for further research to the assessment of more SSWMS. Further optimization of the performance assessment tool is needed; each indicator must have a single answer. The summation of the indicator values to a value per criterion needs further study. It might be wise to judge this by some experts. The Multi Criteria Comparison might be carried out if experts define the values of each criterion.

If data is missing it may be interesting to take samples, or assume the data by knowledge of other sites. It is also recommended to interview more tenants to increase the knowledge on their perception. The number of tenants that are interviewed should high that makes statistical generalization for the whole population possible. According research time it is advised to plan six weeks per site.

9.3 Recommendations for future SSWMS

For the implementation of new SSWMS some aspects are advised:

- The system should fulfill the primary and sub-functions; the separation of rain water is crucial. To protect the public health and environment the water reuse is not recommended, and monitoring and maintenance are necessary. Also a dry toilet system as in Gebers is according the health risks not recommended.

- The system should have low installation costs, since this is the main barrier of the actors. This may be succeeded by a complete disconnection of the centralized WMS. Because that may reduce the water-board fee, sewerage taxes, and amount of sewerage.

- In the design a balance should be made for water, nutrients, and energy of several separation options. From this balance the best technologies can be chosen and tested.

- The active involvement of the municipality and water-board are crucial for the knowledge on treatment and transport, maintenance, and cost-reduction. A very nice example is the project in Göteborg where the municipality is responsible for the project development.

- The maintenance of the system should be done by an expert, for instance the water-board. The maintenance is necessary to maintain the systems quality. Wrong maintenance may lead to health risks, calamities, high emissions, and high costs.

- In neighborhoods where a conventional sewerage system is already present it is advised to install urine separating toilets. Subsequently the conventional WTP will fulfill future quality standards, the nutrients may be reused, water use id reduced, and the extra installation costs may be low.

- The recycling of nutrients should become a major driver for new sites.

- The future tenants should be well informed by the maintenance activities they have to perform, what problems may arise, and what objective the system has. The tenants' experiences of already implemented sites should be addressed.

DEFINITION OF CONCEPTS

Barriers	Negative characteristic of the WMS
Black water	Toilet water with feces and urine
BOD	Biological oxygen demand
Brown water	Black water without urine
Cd	Cadmium
Cr	Chromium
Cu	Copper
COD	Chemical oxygen demand
DM	Dry matter
Drivers	Positive characteristic of the WMS
FC	Fecal Clien
Grey water	Waste water from washing, bath, and kitchen
Hg	mercury
Hh	household
K	Potassium
L/p.d	Litre per person and year
N	Nitrogen
Ni	Nickel
N-total	Total nitrogen
P	Phosphorous
Pb	Lead
P-total	Total Phosphorous
Performance	Cumulative process indicator of the WMS
SSWMS	Source separating WMS
WMS	Wastewater management system
WTP	Wastewater treatment plant
Zn	Zinc

LITERATURE

In this literature overview the books and articles are mentioned by name. The webpages are mentioned by the actor of the website.

Books and Articles

Bahlo, K. and G. Wach. (1992). *Naturnahe Abwasserreinigung*. Staufen bei Freiburg: Ökobuch-Verlag.

Bleuzé, P. (1995). *Mens- en milieuvriendelijk project vlek 17 Rijkerswoerd*. Notitie, samengesteld in opdracht van de Algemene Woningbouwvereniging Arnhem. opMAAT.

Bokström, P. (2002) *Case Study: "Source Separating Wastewater System in Ekoporten, Norrköping"*. Working Group 2, COST Action C8 Best practice for sustainable urban infrastructures(http://www.cf.ac.uk/archi/research/cost8/case/watersewerage/sweden-ekoporten.pdf)

Boverket. (1998). *Bygga och bi i Gebers, Varsam ombyggnad för resurshushållning och gemenskap*. ISBN: 91-7147-510-9.

Boverket. (2002). *Hushållning med kallt och varmt tappvatten. Individuell mätning och temperaturstyrning*. Karlskrona.

Brouwer, W. (1996). *Beoordeling bestek en tekeningen 'Grijwatercircuit vlek 17 Rijkerswoerd'*. Sector Stadswerken, Gemeente Arnhem.

C-mark. (2004). *Rapport risico analyse en beheersplan leidingwaterinstallatie's Polderdrift*. C-mark Watercosultants. Zwolle.

De Blois, M. (2004). *Provtagning på svartvatten från Skogaberg*. H2OLAND.

Geudens, P.J.J.G. (2005). *Tarievenoverzicht leidingwater per 1 januari 2005.* VEWIN Nummer ~ 2005/47/6218

Gustafsson, K. (2005). *Erfarenheter Av InFiltra kompaktfilter mellan åren 1993-2004*. WRS Uppsala AB.

Het Groene Dak. (1992) *De ontwikkeling van een ekologische woonwijk in Utrecht-Voordorp*. Evaluatierapport van Het Groende Dak, een vereniging van bewoners.

Höglund, C. (2001). *Evaluation of microbial health risks associated with the reuse of source-separated human urine.* Royal Institute of Technology (KTH) Department of Biotechnology, Applied Microbiology Swedish Institute for Infectious Disease Control (SMI) Department of Water and Environmental Microbiology. Stockholm

HSB Stockholm. (1994) *Brf Understenshöjden i Björkhagen: Stockholms första ekologiskt inriktade bostadsområde*, (Homeowners association Understenshöjden in Björkhagen: Stockholms first ecologically oriented housing development).

HSB Stockholm. (1997). *The story of Understenshöjden*. Stockholm Sweden.

Johansson, M. and M. Nykvist. (2001) *Closing the nutrient cycle, Summary from a unique research project in Sweden*. EcoEng Newsletter 1. http://www.iees.ch/EcoEng011/EcoEng011_F2.html

Jönsson, H. (2001). *Urine separation - Swedish experiences.* EcoEng Newsletter 1.

Jönsson, H. (2002). *Source separation of human urine – separation efficiency and effects on water emissions, crop yield, energy usage and reliability*. SLU, Swedish University of Agricultural Sciences. Ecosanres

Jönsson, H., A. Burström, and J. Svensson. (1998) *Mätning på två urinsorterande avloppssystem – urinlösning, toalettanvändning och hemvaro i en ekoby och i ett hyrsehusområde.* Rapport 228, Institutionen för lantbruksteknik, SLU, Uppsala.

Kanne, P. (2005). *Watergebruik thuis 2004*. TNS-NIPO and VEWIN.

Karlsson, A. (2002). *Utvärding Ekoporten 1996-2001.* Miljöinvest AB.

Karlsson, A. (2003). *Fortsatt rening av BDT-avlopp från Ekoporten, Norrköping.* Miljöinvest AB.

Karlsson, P. (2005). *Blackwater System Skogaberg, Brief project description*. City of Göteborg, Sweden.

Krants, H. (2005). *Matter that Matters, A study of household routines in a process of changing water and sanitation arrangements.* Linköping University Studies in Arts and Science No. 316.

Lemmen, G.B. and A.J. Oomens. (2001). *Effecten van afkoppelen, Beleidsverkenning naar effecten en grenzen van het sturen met hemelwater in bestaand stedelijk gebied*. Grontmij Advies & Techniek bv, Ministerie VROM.

Matthijs, H.C.P. and J. Balke. (1997) Meetprogramma naar de kwaliteit van kleinschalige afvalwaterzuivering in eigen beheer bij 'Het Groen Dak', een ecologisch nieuwbouwproject in de Utrechtse wijk Voordorp. Amsterdam Research Institute for Substances in Ecosystems (ARISE).

Medema, G.J., (17-03-2005) Telephone conversation. KIWA Water Research.

Mels, A., K. Kujawa, J. Wilsenach, B. Palsma, G. Zeeman and M. van Loosdrecht. (2004a). *Inventarisatie van mogelijkheden voor efficiënter afvalwaterketenbeheer door gescheiden inzameling en behandeling van stromen*. Concept ed.

Mels, A., G. Zeeman, I. Bisschops. (2004b). *Brongerichte inzameling en lokale behandeling van afvalwater - Inventarisatie van projecten in Nederland, Duitsland en Scandinavië*. Lettinga Associates Foundation. Concept ed.

Mörling, J. (2000) *Ekoporten: An Innovative Swedish Apartment Eco-Retrofit.* FFNS Arkitekter (http://www.cmhc-schl.gc.ca/en/imquaf/himu/inbu/inbu_010.cfm)

Palmquist H. and Jönsson H. (2003). *Urine, feces, greywater and biodegradable solid waste as potential fertilizers*. 2nd International Symposium on ecological sanitation "Ecosan - Closing the loop", Luebeck, Germany, April

Pötz, H. and P. Bleuzé. (1998). *Zichtbaar, Tastbaar, Zinvol*. De integratie van natuur en techniek in de vormgeving van stedelijk water. opMAAT duurzame architectuur en systeemontwikkeling. NAI Uitgevers, Rotterdam.

Senden, W. (2003a). *Quick scan collectieve regenwatersystemen.* Kiwa N.V. Water Research

Senden, W. (2003b). *Beleidsonderbouwende monitoring huishoudwater.* Onderzoek naar de kwaliteit van huishoudwater en effecten van het gebruik op het milieu en de klant. Kiwa N.V. Water Research

SEVU (1992). *Het groene dak, een ecologisch nieuwbouwproject in utrecht.* Stuurgroep Experimenten Volkshuisvesting Utrecht.

Soons, J. (2003). *Grey water: characteristics, treatment, reuse and recycle*. Case study: Polderdrift Arnhem, The Netherlands. Wageningen Universiteit, Sectie Milieutechnologie.

Stein, N. And A. Luising. (9 december 2002) *Verslag van gesprek met Ad van Ruiven*, tenant and contactperson Polderdrift, Wageningen Universiteit/TU Delft.

Stichting Rioned. (2002), *Riool in cijfers 2002-2003*.

Torjusen, G. (2002). *Environmental Systems Analysis of sewerage alternatives in an urban district "Blackwater System – Skogaberg" A pilot project in Göteborg*. Environmental Programme Institution for Thematic Education and Research Campus Norrköping, Linköpings University, Sweden.

Van Buuren, J. (2004). *Water and waste management in developing countries*. Lectures at Environmental Technology group of the Wageningen University.

Verna Ecology. (unknown). *Short facts about Understenshöjden*.

Vinnerås B. (2001). *Faecal separation and urine diversion for nutrient management of household biodegradable waste and wastewater*. Swedish University of Agricultural Sciencies, Department of Agricultural Engineering.

VROM Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer. (2004). *Inzameling, transport en behandeling van afvalwater in Nederland.* Situatierapport 'Stedelijk Afvalwater' ex art 16, Richtlijn 91/271/EEG.

WRS, Water Rivival Systems Uppsala AE. (2001). *Market Survey, extremely low flus toilets plus urine divertinf toilets and urinals for collection of black water and/or urine*. SwedEnviro report No 2001:1.

Witteveen+Bos. (1993) *Ontwerp Grijswaterfilter*. Witteveen+Bos Raadgevende ingenieurs b.v. Deventer.

Websites

Ekbo, homepage. http://www.ekbo.se/. (8-12-2005)

Ekoby, homepage. http://www.ekoby.org/cs9.html. (9-12-2005)

Fujita research, homepage. http://www.fujitaresearch.com/reports/ecovillage.html. (9-12-2005)

Gemeente Utrecht. homepage. http://www.utrecht.nl/. (10-05-2005)

Het Groene Dak, homepage. http://www.groenedak.nl/. (14-03-2005)

Hydron. Homepage. http://www.hydron.nl. (10-05-2005)

KNMI, homepage. http://www.knmi.nl/reindex.html?/voorl/klimaat. (09-03-2005)

Lettinga Associates Foundation (LeAF), homepage. http://www.ftns.wau.nl/lettinga-associates/Organisatie/werkgroepen/DESAR2.htm. (10-01-05)

MD at BB Innovation & Co. AB., Website. http://www.dubbletten.nu/english-presentation/english-presentation.htm. (12-12-2005)

Swedish Environmental Protection Agency. Homepage http://www.internat.naturvardsverket.se/. (12-12-2005)

APPENDIX 1 METHODOLOGY

The used tools to gather information are given in this appendix. Firstly the letters to the households and stakeholders are presented. Subsequently the interviews for the households and the drivers and barriers are given.

1.1 Letter for households

March, 2005

Wouter van Betuw
Rijnsteeg 8 BGA 006
6708PP Wageningen
The Netherlands

Subject: Research on decentralized wastewater management system

Dear Madam or Sir:

This letter is addressed to you because your neighborhood is part of a research of the Wageningen University in the Netherlands. My name is Wouter van Betuw, master student at this university, and performing research to new wastewater management systems in Sweden and in the Netherlands. I have selected your neighborhood because it has a new concept of wastewater management. This means that your water in the house is separated based on its quality and the possibilities to recycle it.

In the Netherlands also new concepts of this wastewater management systems are installed. The systems in Sweden are interested because they are different. I would like to compare the Swedish and Dutch systems. I am interested in how the systems perform in technical way and also in user perspective. This means that I would like to know what you, as a user, think of, and what experiences you have with the system. I am also interested in the participation of you in the decision-making of developing the system from the start.

I would like to ask your participation in this research by means of answering some questions. I am coming to your neighborhood and would like to ask you some questions about the wastewater management system. Unfortunately I do not speak Swedish, so the asked questions would be in English.

The interview would not take allot time, I think about 30 minutes. The interview will be hold in the week of 28-03 - 01-04.
I hope that you would like to participate in my research. And I am looking forward to meet you.

Respectfully,

Wouter van Betuw
Student Environmental Technology
Wageningen University (in the Netherlands)

1.2 Letter for Stakeholders

March, 2005

Wouter van Betuw
Rijnsteeg 8 BGA 006
6708PP Wageningen
The Netherlands

Subject: Research on decentralized wastewater management system

Dear Madam or Sir:

This letter is addressed to you because you were stakeholder in the decision-making of implementing a new wastewater management system. My name is Wouter van Betuw, master student at Wageningen University in the Netherlands, and performing research into new wastewater management systems in Sweden and in the Netherlands. I have selected your neighborhood/project because it has a new concept of wastewater management. This means that the water in the house is separated based on its quality and the possibilities to recycle it.

In the Netherlands also new concepts of this wastewater management systems are installed. The systems in Sweden are interesting because they are different. I would like to compare the Swedish and Dutch systems. I am interested in how the decision-making process that led to the implementing of the system was carried out. I would like to know what your participating role was, and how much influence you had in the decision-making. I am also interested in what the criteria for you, as participating stakeholder, were determining to implement the system or not. In other words: What aspects of the system do you like/dislike? I would like to ask your participation in this research by means of answering some questions. I am coming to your office and would like to ask you some questions about the wastewater management system. Unfortunately I do not speak Swedish, so the asked questions would be in English.

The meeting would not take allot time, I think about 1 hour. I would like to schedule a meeting with you at your office. **The meeting will be hold in the week of 28-03 - 03-04.** I hope that you would like to participate in my research. And I am looking forward to meet you.

Respectfully,

Wouter van Betuw
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1.3 Questionnaire for households

HOUSEHOLD SURVEY

(Introduce yourself)
I am…
We are currently conducting a survey as part of this project to find out…
Your opinion is important to us…
The interview will take us only around…minutes.
All the information you give will be strictly confidential and not shown to anyone else…

Questionnaire No:………………..............Institution:…………………………………….
Date:……………Respondent name: ……………………………………………Age:……
Address: Street…………………………………………………….. No……………….
District:……………………………… Ward:…………………………………..

General questions

1. How many persons are at least for the 70% of the days present in the household?

   …………persons

2. For how long do you live in the neighbourhood?

   ………….years

3. What is your source of water for drinking?

   ……………………………………………………………………………………….

4. What is your source of water for other uses?

   ……………………………………………………………………………………….

5. How much drinkwater do you spend per month?

   ……………………………………………………………………………………….

6. How much do you pay for the water supply per month/m3?

   …………….euros/month or ……euros/m3

Wastewater management system questions

7. Do you have a non conventional, waste water management system in your house?

   Yes – 0 No – 1

8. Which kind of toilet?

   …………………………………………

9. For how long do you already have the wastewater management system?

……………years / months

10. What elements are part of the wastewater management system, who is the owner of it? Who is responsible?

Elements Owner Responsible

Rainwater system yes/no ………………………………

……………………………….

Greywater system yes/no ………………………………

……………………………….

Blackwater system yes/no ………………………………

……………………………….

Urine collection yes/no ………………………………

……………………………….

11. (Only answer if you know) How many years is the estimated useful life of the wastewater management system? Who is the owner?

Rainwater collection………..years …………………………………….(owner)

Greywater system……………years …………………………………….

Blackwater system………….years …………………………………….

12. Are there special elements in the system with a lower estimated useful life then the general system?

Elements Years

……………………………………….. ……………

……………………………………….. ……………

13. How much money did you pay to realize/build the wastewater management system and what was included in this price?

Total: ……………euros

Elements included: Cost (if you know it)

………………………………….. ………………euros

………………………………….. ………………euros

………………………………….. ………………euros

………………………………….. ………………euros

14. How much do you pay to the local government for sewerage tax per year?

…………….. euros

15. How much do you pay to the water-board for wastewater treatment per year? …………….. euros

16. How much water per year do you save because of the wastewater management system? ………………..m3/year

17. How much money do you save on governmental taxes? ……….euro/year

18. Which volume of above-ground indoor space does the wastewater management system takes up in your house? ………………….m^3
19. Which volume of the above-ground outdoor space does the wastewater management system takes up? ………………….m^3
20. What flat surface area of the above-ground outdoor space does the wastewater management system takes up? ………………….m^2

21. Who was the owner of the above-ground outdoor? What is the price per m^2? ……………………………………………….
…………Euro/ m^2

22. Which amount of energy do you estimate that you use for the wastewater management system? ……………........kw/hour/year

Questions on maintenance

23. Do you have to perform maintenance by yourself? Yes/No(if no go to question 30)
24. Which activities do you have to do for the good maintenance of the wastewater management and how many hours do they take to you per month?

Activity	Hours/month
……………………………………………….	…................…
……………………………………………….	……………………...
……………………………………………….	……………………...

25. Which products do you have to add to the wastewater management system for its well maintenance and operation? Which amount per month do you spend? And what is their price per kilos or liters?

Product	Amount/month (kg or l)	Price (kg or l)
…………………………..	………………………………….	………………..
…………………………..	………………………………….	………………..

26. Are their restrictions on products to use for maintenance? Yes No
27. Do you have a list of these product? Yes No
28. Which safety measures do you take to deal with the products from the system during these operation and maintenance activities?

Black water ……………………………………………………………………………..
Rainwater ……………………………………………………………………………..
Grey water ……………………………………………………………………………..
Sludge ………………………………………………………………………………

29. What do you think of the operation and maintenance activities to be done?
    - ☐ Really disgusting - 0
    - ☐ Not nice - 1
    - ☐ Do not care - 2
    - ☐ Nice to do - 3
    - ☐ Very nice to do – 4

30. How many times per year does the wastewater management system prefers ge-neral maintenance? By who is it done? And how much do you have to pay for it?

Activities: Amount Actor Price

Rainwater sedimentation tank cleaning ………. t/year ……………………………………….. …E/y

Greywater sedimentation tank cleaning ……… t/y ……………………………………………. …E/y

Reetbed filter maintenance ………t/y……………………………………………. …E/y

Water pipe system ………t/y……………………………………………. …E/y

System inspection ………t/y……………………………………………. …E/y

Other ………t/y ……………………………………………. …E/y

31. Have you suffered some kind of calamity (explosion, collapse…) due to the wastewater management system? Explain.

……………………………………………………………………………………………………
………………………………

32. Did you experience any problem with any of the parts of the wastewater management system?

Yes - 0 No – 1

33. Which parts of the wastewater management system failed/was out of order? What was the problem? When and how often does it happen? How did you solve it and who did it?

Part of the system	Problem	When? (Date)	often? (t/m /y)	Solution	Solved

Questions on user perspectives

34. Does the wastewater management system make you feel environmental concerned?

- ☐ Always- 0
- ☐ Very often - 1
- ☐ Sometimes - 2
- ☐ A little bit- 3
- ☐ Not at all - 4

35. Can you recommend the system to other households in other neighbourhoods?

- ☐ Not at all - 0
- ☐ Not without improvement - 1
- ☐ Do not know - 2
- ☐ Yes I will – 3
- ☐ Yes I will actively recommend it – 4

36. What do you think of the visible part of the wastewater management equipment in or near your houses?

- ☐ Really awful - 0
- ☐ Annoying - 1
- ☐ Not disturbing - 2
- ☐ Nice - 3
- ☐ Beautiful - 4

37. Does the system produce annoying noise level in your opinion?

- ☐ Always- 0
- ☐ Very often - 1
- ☐ Sometimes - 2
- ☐ A little bit- 3
- ☐ Not at all – 4

38. Does the process produce unpleasant odours in your opinion?

- ☐ Always - 0
- ☐ Very often - 1
- ☐ Sometimes - 2
- ☐ A little bit- 3
- ☐ Not at all - 4

39. In which months do the unpleasant odours occur?

Jan – Feb – March – April – May – June – July – Aug – Sept – Oct – Nov – Dec

40. Does the system attract vermin?

- ☐ Always - 0
- ☐ Very often - 1
- ☐ Sometimes - 2
- ☐ A little bit- 3
- ☐ Not at all - 4

41. What kind of benefits of the wastewater management do you experience?

…………………………………………..
…………………………………………..
…………………………………………..
…………………………………………..
…………………………………………..

42. Which amount of compost do you estimate is produced per year in your house?

…………………kg/year

43. Which amount of sludge do you estimate is produced per year in your house?

…………………kg/year

The interview is over now. Thank you again for answering our questions.

1.4 Questionnaire for stake holders

Drivers and Barriers SURVEY

Questionnaire No:……………….............Institution:…………………………………….
Date:……………Respondent name: ………………………………………………Age:……
Address: Street…………………………………………………….. No……………….
District:……………….…………… Ward:…………………………………..

Questions on design

1. Did you participate in the design period of the neighbourhood?

Yes or No

2. What period of time did the design period take?

…….. year

3. Which actors where involved in the design period? What was their role?

Actor Role

1………………………………………………
…………………………………………………………………………..
2………………………………………………
…………………………………………………………………………..
3………………………………………………
…………………………………………………………………………..
4………………………………………………
…………………………………………………………………………..
5………………………………………………
…………………………………………………………………………..

6………………………………………………

…………………………………………………………………………..

7………………………………………………

…………………………………………………………………………..

8………………………………………………

…………………………………………………………………………..

4. On what way were decisions made? Consensus or Authority

5. Did you agreed with the decision-making process?

Yes / no

6. Which actor was responsible for the final decision on the design?

…………………………………….

7. How often per month/year did you had a meeting with the actors?

…………………………times/month

Environmental drivers and barriers design period

8. What kind of environmental aspects of the wastewater management system were important for you and other actors that involved the implementation **positively**? Which are realized? Which will be realized/removed in thee future?

	design	current	future
Water saving			
Prevention of drying out of soil			
Reduction of water emissions			
Recycling of water			
Protection surface water			
Protection of ground water			
Recycling of nutrients			
Reduction of energy use			
Nice neighbourhood			
Nice environmental behaviour feeling			
Other …………………			
Other …………………			
Other …………………			

9. What kind of environmental aspects of the wastewater management system were important for you and other actors that involved the implementation **negatively**? Which are realized? Which will be realized/removed in thee future?

	design	current	future
Health risks			
Flooding risks			
Use of chemicals			
Maintenance problems			
High energy use			
Other …………………			
Other …………………			
Other …………………			
Other …………………			
Other …………………			
Other …………………			

Economical drivers and barriers

10. What kind of economical aspects of the wastewater management system were important for you and other actors that involved the implementation **positively**? Which are realized? Which will be realized/removed in thee future?

	design	current	future
Low design costs			
Low operational costs			
Low drink water costs			
Low energy costs			
Low sewerage taxes			
Low water-board taxes			
Development new technology			
Other …………………			
Other …………………			

11. What kind of economical aspects of the wastewater management system were important for you and other actors that involved the implementation **negatively**? Which are realized? Which will be realized/removed in thee future?

	design	current	future
High design costs			
High operational costs			
High energy costs			
High sewerage taxes			
High water-board taxes			
Other …………………			
Other …………………			
Other …………………			

Social drivers and barriers

12. What kind of social aspects of the wastewater management system were important for you and other actors that involved the implementation **positively**? Which are realized? Which will be realized/removed in thee future?

	design	current	future
Intensive contact with neighbors			
Environmental friendly			
Nice neighbourhood to live			
Other …………………			
Other …………………			
Other …………………			

13. What kind of social aspects of the wastewater management system were important for you and other actors that involved the implementation **negatively**? Which are realized? Which will be realized/removed in thee future?

	design	current	future
Difficult technology			
Risks of housing equipment			
Health risks			
Other …………………			
Other …………………			
Other …………………			

Current status Wastewater management system

14. Did you participate in the period of building until now of the neighbourhood?

Yes or No

15. What period of time is the system working? …….. year
16. Which actors are involved in the period of building until no? What was their role?

Actor Role

1………………………………………………

…………………………………………………………………………..

2………………………………………………

…………………………………………………………………………..

3………………………………………………

…………………………………………………………………………..

4………………………………………………

…………………………………………………………………………..

5………………………………………………

…………………………………………………………………………..

17. How often per month/year did/do you had a meeting with the actors?

…………………………times/month

Future status Wastewater management system

18. Are their any changes on the system equipment that you think will happen in the future?

…………………………………………………………….

…………………………………………………………….

…………………………………………………………….

…………………………………………………………….

19. Are their any changes on the involvement of actors that you think will happen in the future?

…………………………………………………………….

…………………………………………………………….

…………………………………………………………….

1.5 Performance assessment

				Reference	Cluster 1	Cluster 2a			Cluster 2b	
			Units	site 0	Understens	Groene Dak	Polderdrift	Skogaberg	Ekoporten	Gebers
Primairy	**1**	***Does the wms protects public health by means of safe transport and treatment of human waste?***	***yes/no***	yes	yes	no	yes	no	yes	unknown
functions	1a	What is the chance that tenants get in contact with the wastewater?	kwalitative description	by sewerage clogging	not present	always	always	equal to conventional	not present	contact with feces
	1b	What is the chance that tenants have access to the equipment?	kwalitative description	not present	not present	always	present	not present	present	present
	1c	What is the chance that tenants are exposed to calamities?	calamity/y	15198	0	0.1	0.1	0	not present	not present
	1d	Is the risks for public health higher then maximum acceptable infection-risks by biological pathogens?	yes/no	no	no	yes	yes	not present	no	unknown
	2	***Does the wms protects surface water quality and the environment by means of prevention of discharges of oxygen demanding compounds and nutrients?***	***yes/no***	yes	yes	unknown	yes	yes	yes	yes
	2a	What is the treatment efficiency for phosphorous removal?	%	79	41	unknown	unknown	80	89	70
	2b	What is the treatment efficiency for Nitrogen removal?	%	68	57,4	unknown	unknown	80	83	90

	2 c	What is the treatment efficiency for BOD removal?	%	97	unknown	unknown	unknown	unknown	98	30
	2 d	What is the treatment efficiency for COD removal?	%	91	25	unknown	unknown	unknown	96	24
	2 e	What is the probability of a batch of final product failing to comply with official quality standards?	amount/year		0	unknown	unknown	unknown	2	0
Sub -	**3**	***Does the WMS include measures for rainwater management?***	***yes/no***	yes	yes	yes	yes	yes	yes	yes
functions	3 a	What is the maximum rain water intensity the system can treat/transport?	m3	unknown	360	5	> 70	unknown	not known	unknown
	4	***Does the WMS include measures for removal of groundwater or drainage water?***	***yes/no***	yes	no	yes	yes	no	no	not present
	4 a	Is there a need for removal of local ground water or drainage water?	yes/no	yes	no	yes	yes	no	no	no
User-perspective	**5**	***What are the costs per household per year?***	***euro/year***	572	512	628	1011	710	1506	386
Costs	5 a	What is the capital investment per household in EURO of the WMS?	euro	4375	6845	6002	10878	9400	17800	4490
	5 b	How many persons are for 70% of the night present in the household?	persons	2	2	2	2	2	2	2
	5 c	What is the estimated useful life of the WMS in years?	year	20-25	13-30	15-50	10 till 50	25	10-50	30-100
	5 d	Wat is the annual per household operating cost in EURO of the wms?	euro/year	335	192	303	420	200	540	142

Invisibility / Comfort	**6**	***Is the system meeting the desires of the housholds with respect to comfort and (in)visibility?***	***yes/no***	yes	yes	yes	yes	yes	yes	yes/no
	6 a	Is there a modified toilet system (i.e. no 'conventional' water flush toilet)?	yes/no	no	yes	yes	no	no	yes	yes
	6 b	Does the wastewater management system make you feel environmental concerned / friendly?	0-1-2-3-4	0	4	3	2	3	4	4
	6 c	Can you recommend the system to other households in other neighbourhoods?	0-1-2-3-4	3	3	2	3	3	3	3
	6 d	What do you think of the visible part of the wastewater management equipment in or near your houses?	0-1-2-3-4	2	3	3	3	2	2	3
	6 e	Does the system produce annoying noise level in your opinion?	0-1-2-3-4	4	4	4	4	4	4	4
	6 f	Does the process produce unpleasant odours in your opinion?	0-1-2-3-4	4	2	3	3	4	3	4
	6 g	Does the system attract vermin?	0-1-2-3-4	4	4	4	4	4	4	1
	6 h	Do you have to perform maintenance to the system?	yes (1) / no (0)	no	1	0	1	1	0	1
	6 i	What do you think of the maintenance activity of the system?	0-1-2-3-4	not relevant	2	Not	3	1	3	1
	6 j	How much time does the maintenance activity require from its users?	h/y	0	32	2	8	0,5	0	12
	6 k	How much time does the maintenance activity require from	h/y	0	8	16	8	2100	416	0

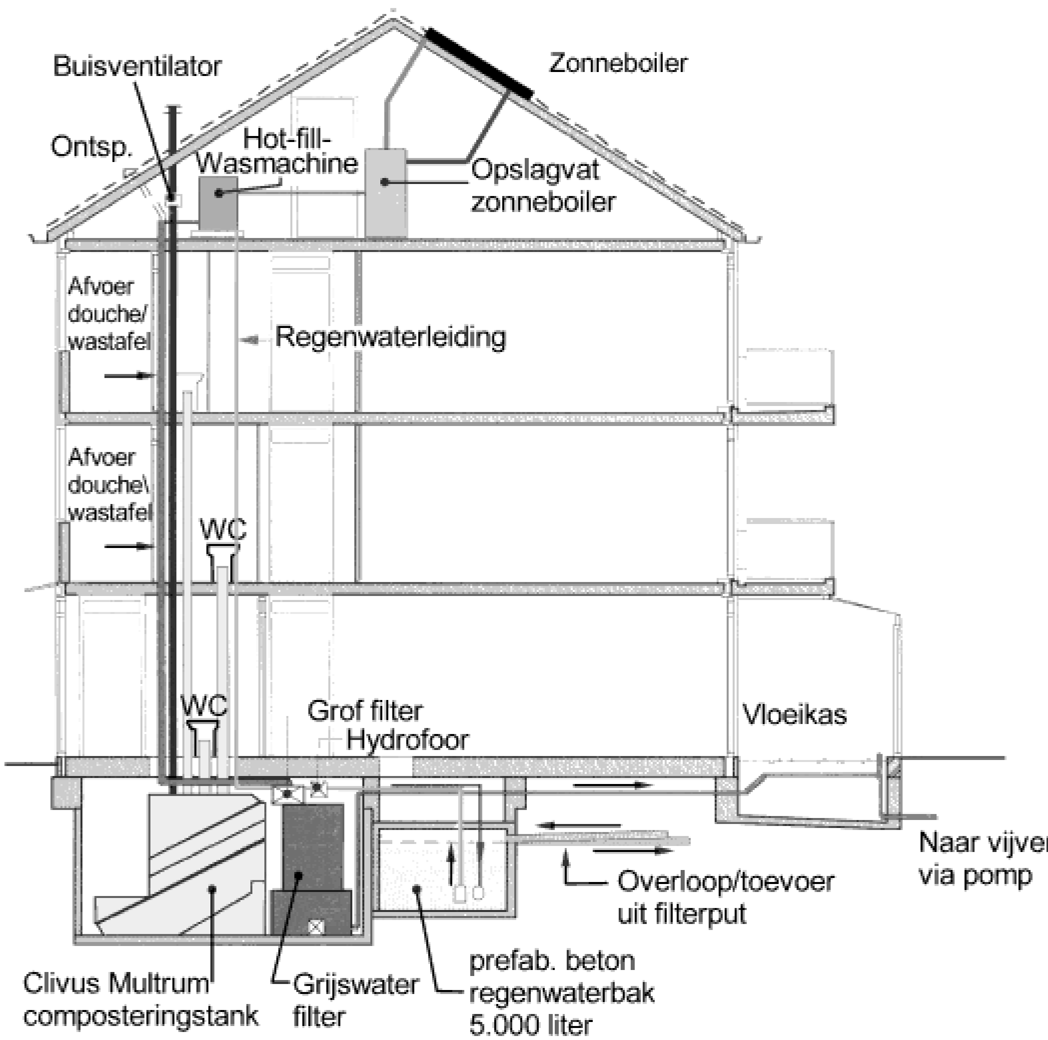
		other actors?								
	6 l	Are their restrictions on products for maintenance or flushing trough the toilet?	yes (1) / no (0)	1	1	1	1	1	1	1
	6 m	Do you have a list of these products?	yes (1) / no (0)	0	0	1	1	1	1	0
	6 n	What volume of above-ground indoor space does the wms equipment require expressed in m3 per household?	m3/hh	0	0	10	0	0,2	2,7	0,5
	6 o	What volume of above-ground outdoor space does the wms equipment require expressed in m2 per household?	m2/hh	unknown	20	14.7	13.25	0,75	17	0,3
Robust ness	**7**	***Is there a (risk of) system failure?***	***yes/no***	yes	yes	yes	yes	yes	yes	no
	7 a	Did you experience any problem with any of the parts of the wastewater management system?	yes (1) / no (0)	0	1	1	1	1	1	1
	7 b	What is the amount of system failures per year?	amoun t/y	0,0019	2	0.2	1.2	1	3,7	2
Environ mental	**8**	***What is the quantity of resources used in the wms?***	***severa l***							
Resour ces use	8 e	What is the amount of energy used by the wms per household per year?	kWh/y	unknown	-35	8	unknown	unknown	unknown	unknown
	8 d	What is the amount of chemicals used by the wms per household per year?	kg/y	unknown	unknown	0	0	unknown	0	0
	8 f	What is the water use per household per year?	m3/y	93	117	32	50	146	82	84
	9	**What is the quantity of resources produced in the wms?**	**severa l**							

	9a	What is the sludge production per household/year?	kg	45	unknown	8	12.5	unknown	28	37,2
	9b	What is the volume of reusable water per household per year?	m3/y	0	unknown	18.25	25	0	0	0
	9c	What is the amount nutrients recycled by the wms per household per year?	kg/y	0	3,5	0	0	unknown	5152	6,1
Emissions	**10**	***What is the quality of the final products?***					unknown			
	10a	To what extend does the final water quality comply with official quality standards?		ok	ok	unknown	unknown	unknown	higher	unknown
	10b	To what extend does the final water quality comply with futuristic EU quality standards (Water Framework Directive)?		not yet	unknown	unknown	unknown	unknown	unknown	unknown

APPENDIX 2 SOURCE SEPARATING IN 'HET GROENE DAK'

2.1 Description of the technology

Figure 11 Grey and rainwater scheme in house (website groene dak)



Doorsnede waterbesparende installaties "Het Groene Dak"

Figure 12 Above view Het Groene Dak (website groene dak)

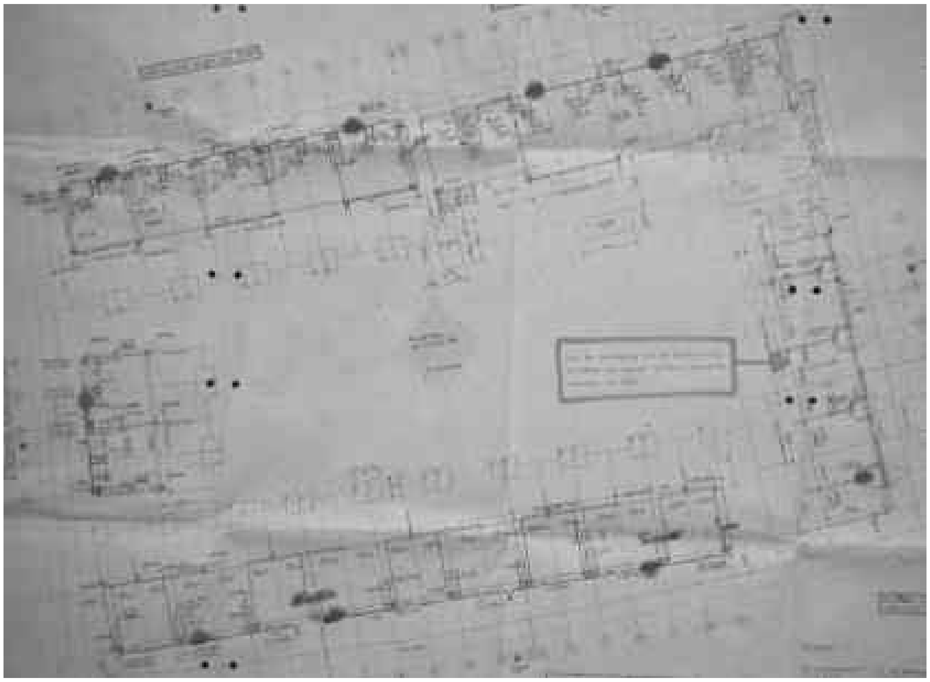


Figure 13Grey water pre-treatment (website groene dak)

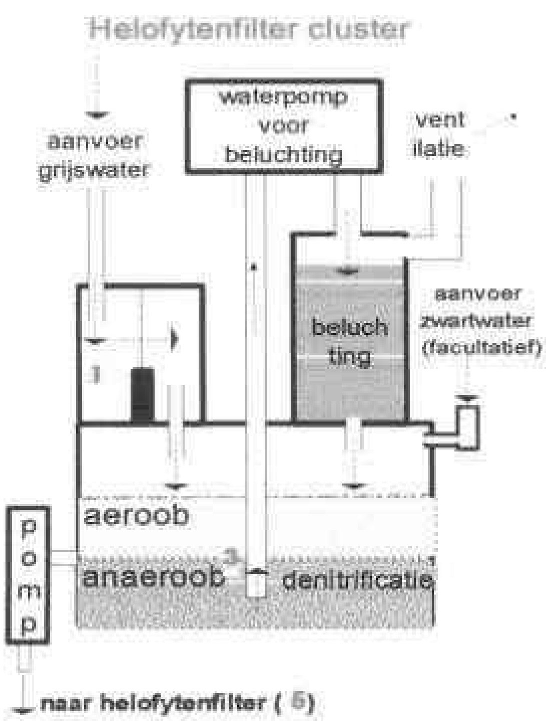


Figure 14 Michél Post and greenhouse with fewer plants (visit 22-03-2005)

Figure 15 Maintenance pond (website groene dak)

Table 29 Average concentrations in (mg/l) and spread in brackets of grey water, effluent of pre-treatment and reedbed/greenhouse; E-coli are measured 3 times and give and average in living cells/ml (Matthijs en Balke, 1997)

Cluster 1				Cluster 2		
	Grey water[1]	Effluent pre-treatment	Effluent reedbed	Grey water[1]	Effluent pre-treatment	Effluent greenhouse
CZV	341 (196)	154 (26)	108 (6)	1013 (47)	180 (99)	63 (12)
BZV_5	74 (32)	26 (4)	3 (1)	322 (21)	27 (2)	4
N-total	74.4 (13.8)	27.9 (11.4)	10,1 (2,0)	56.0 (17.1)	10.6 (5.5)	11.9 (2.1)
NH_4-N	58.1 (16.9	12.3 (7.3)	0,2 (0,0)	32.6 (11.8)	3.0 (1.5)	0.4 (0.4)
NO_3-N	2.9 (0.4)	7.2 (1.5)	5,4 (1,9)	3.9 (1.7)	2.6 (0.7)	8.0 (1.7)
P total	9.1 (0.5)	3.8 (1.3)	0,5 (0,03)	7.5 (0.6)	3.1 (0.5)	0.6 (0.2)
PO_4-P	4.1 (0.5)	1.8 (0.8)	0,2 (0,05)	2.9 (0.3)	1.3 (0.3)	0.3 (0.1)
E-Coli	-	1123	1	-	1973	163

2.2 Drivers and barriers

In the table below the results of the interviews are addressed. The table 30 highlights the drivers and barriers of the tenants' 'Water Group' (Post, *pers. com.*) and by the former housing company 'Woningstichting Juliana' (Smeijer, *pers. com.*) in the design, current and futuristic phase.

Table 30 Drivers and Barriers in decision-making of 'Het Groene Dak'

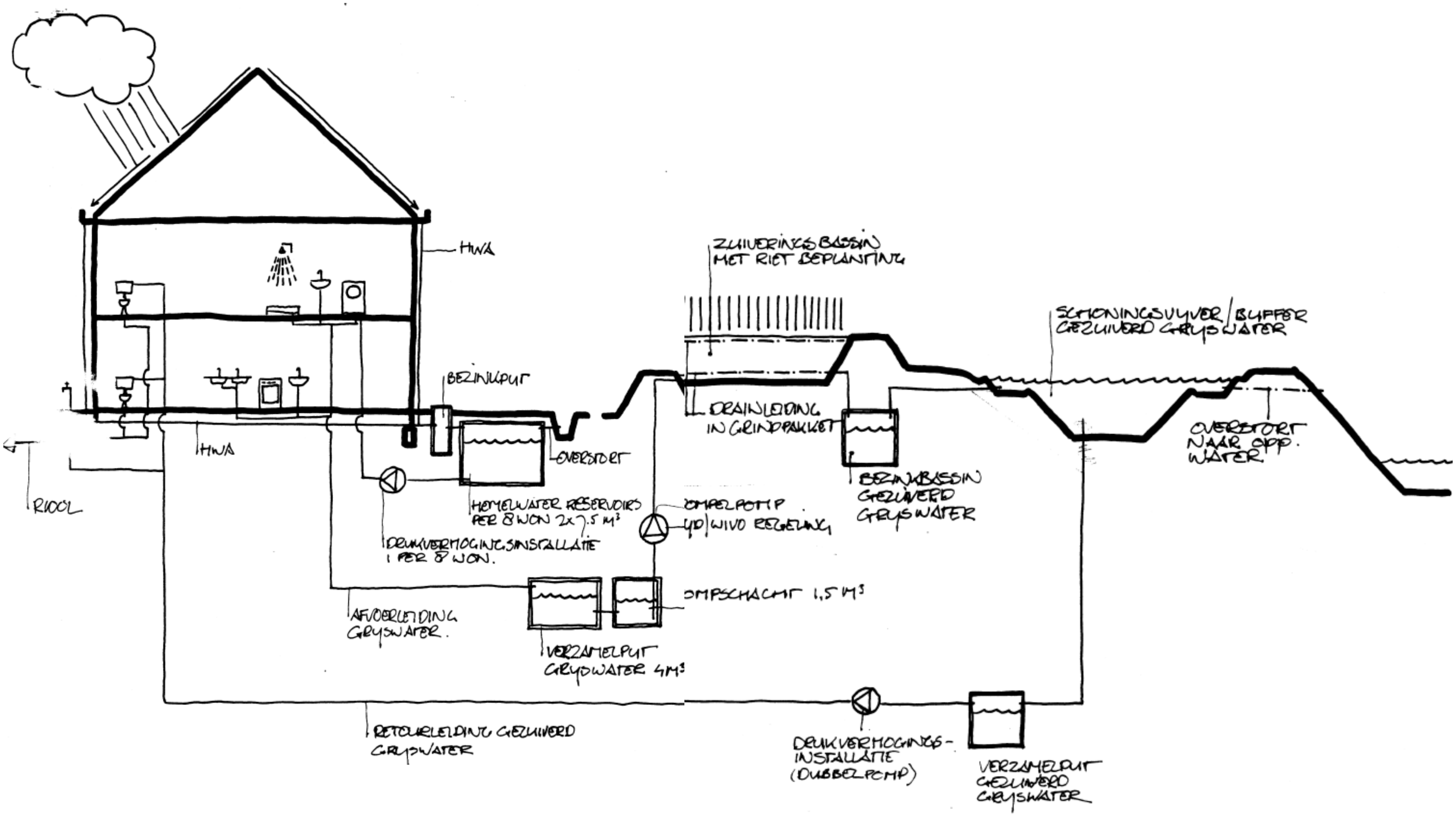
	Actor →	1. Tenant			3. 'Woningstichting Juliana'		
Criteria↓	**Phase → Aspect ↓**	design	current	future	design	current	future
Environmental drivers	Water saving	Yes	Yes	Yes	Yes	*No involvement due to take over by other housing company.*	
	Prevention of drying out of soil	Yes	No	No	Yes		
	Reduction of water emissions with high nutrients and pathogens concentration	Yes	No	No	Yes		
	Recycling of water	Yes	Yes	Yes	Yes		
	Protection surface water for overflow	Yes	No	No	No		
	Protection of ground water	Yes	No	No	Yes		
	Nice neighbourhood	Yes	Yes	Yes	Yes		
	Nice environmental behaviour feeling	Yes	No	No	No		
	Environmental label/advertising	No	No	No	Yes		
	Prevention of production polluted sludge[1]	Yes	??	??	??		
	Protection of damage to the landscape by flooding, erosion, and treatment plants[1]	Yes	??	??	??		
Environmental barriers	Health risks	No	Yes	Yes	No		
	Flooding risks	No	Yes	Yes	No		
	Maintenance problems	No	Yes	Yes	Yes		
	High energy use	No	Yes	Yes	No		
	Material consumption	Yes	Yes	Yes	No		
	Smell	No	No	No	Yes		
	Sound	No	No	No	Yes		
Economical drivers	Low water supply costs	Yes	No	No	Yes		
	Low energy costs	Yes	No	No	Yes		
	Low sewerage taxes	Yes	No	Yes	Yes		
	Low water board fee	Yes	No	Yes	No		

	Development new technology	Yes	Yes	Yes	Yes	
Economical barriers	High design costs	Yes	Yes	Yes	Yes	
	High operational costs	No	Yes	Yes	Yes	
	High energy costs	Yes	Yes	Yes	No	
	Risks of renting to new tenants	No	No	No	Yes	
	Risks of mall function / replacements	No	Yes	No	Yes	
Social drivers	Intensive contact with neighbours	Yes	Yes	Yes	Yes	
	Environmental friendly	Yes	No	No	Yes	
	Nice neighbourhood to live	Yes	Yes	Yes	Yes	
Social barriers	Difficult technology	Yes	Yes	Yes	No	
	Management of new tenants	No	No	No	Yes	

[1]Not from the interview but from the website of Het Groene Dak

APPENDIX 3 SOURCE SEPARATING IN 'POLDERDRIFT'

3.1 Description of the technology



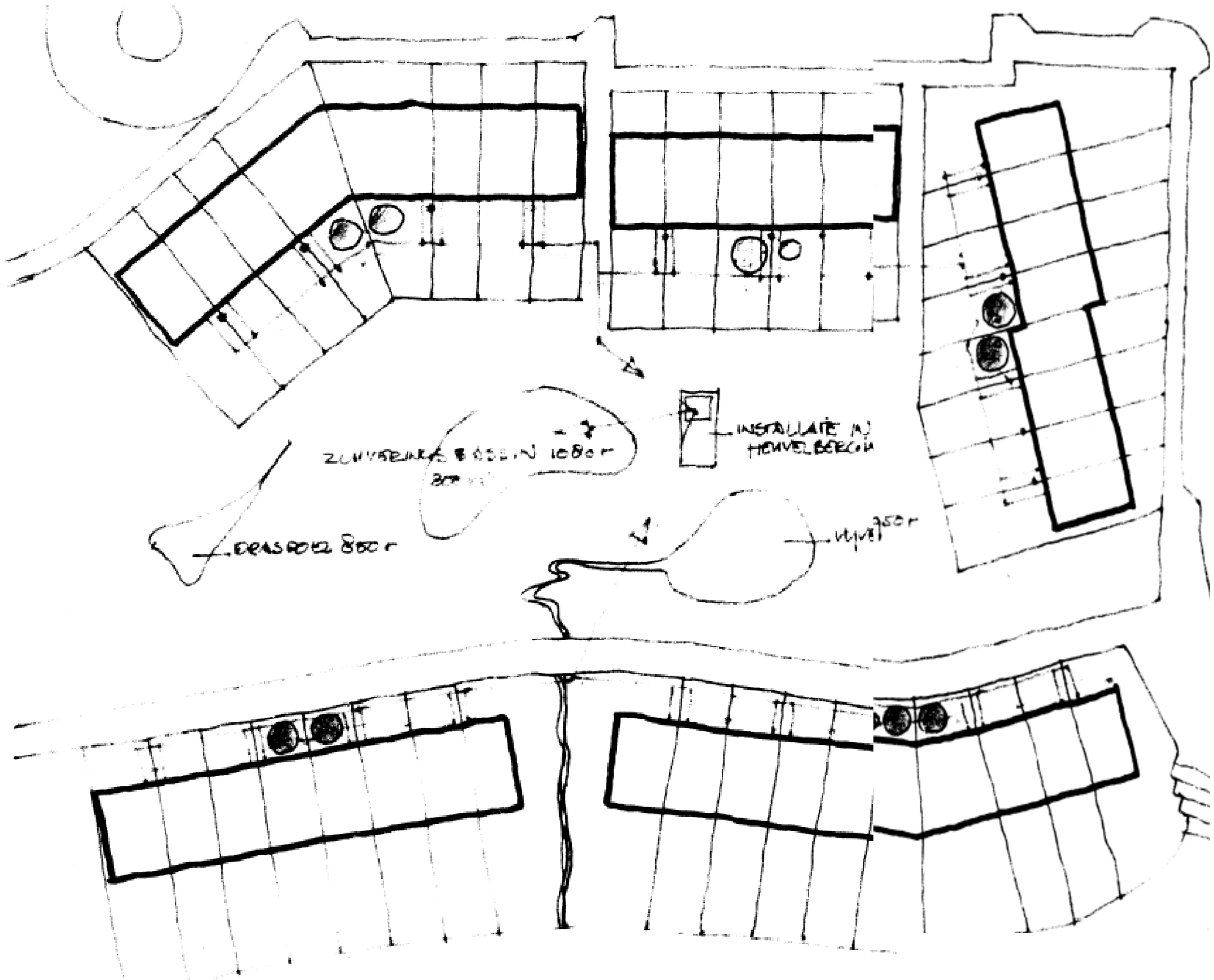


Table 31 Expected treatment capacity grey water system (Bahlo and Wach, 1992)

	Effluent houses (mg/l)	**Effluent sedimentation (mg/l)**	**Effluent reedfilter (mg/l)**	**Treatment efficiency (%)**
BZV_5	253	190	10	95
CZV	409	383	26	93
N-total	12	5	0.3	87
P-total	5	3	2	44

Table 32 Grey water after sedimentation (Soons, 2003): four samples (retention time 1, 2 days)

Aspect	**Unit**	**Grey water after sedimentation**	
		Average value	Spread
COD	(mg O_2/l)	322	296 – 342
suspended		54	33 – 75
colloidal		109	82 – 137
dissolved		159	139 – 185
COD/ BOS_{20}	(mg O_2/l)	88 %	1 measurement
N-Kjeldahl	(mg N/l)	19.6	11.1 – 28.3
NH_4-N	(mg N/l)	3.7	1.4 – 5.9
P-total	(mg P/l)	3.3	2.5 – 5.6
PO_4-P	(mg P/l)	0.6	0.2 – 1.9
E-Coli	/100 ml (x 10^5)	7.7	1 – 220

Table 33 Rain and grey water quality (C-mark, 2004)

Aspect	Unit	Clean rainwater tank	Influent rainwater washing machine	Clean grey water tank	Grey water outdoor valve
Temperature	°C	18	18	19	19
Acidity	pH		7.20	7.55	5.75
Saturation index (SI)			0.27	-0.11	-2.71
Aggressive carbonic acid (CO_2)	Mg/l		< 0.5	2.03	5.31
Carbonic acid (CO_2)	Mg/l		8.4	6	5.6
Conductance	mS/m		42	23	6
Hydrogen carbonate (HCO_3)	Mg/l		238	120	17
Chlorine (Cl)	Mg/l	9	18	11	< 5
Sulfate (SO_4)		9	16	10	< 5
Calcium (Ca)	Mg/l	8	65	65	6
Iron (Fe)	Mg/l	0.02	0.01	0.37	0.03
Manganese (Mn)	Mg/l	0.02	< 0.01	< 0.01	0.02
Escherichia coli	/100ml	< 1	< 1	250	350
Coli-group E.F. (37 °C)	/100ml	< 1	< 1	250	400
Coli amount (37 °C)				0+/10-	0+/10-
Coli amount (44 °C)				10+/0-	9+/1-
Aeromonas species(30 °C)	/100ml	100	150	80	55

3.2 Drivers and barriers

In the table below the results of the interviews are addressed. The table 34 highlights the drivers and barriers of the tenants (Ruiven, *pers. com.*), architect 'opMAAT', by the current housing company 'Portaal' (Engelen, *pers. com.*), municipality 'Arnhem' (Warnshuis, *pers. com.*), in the design, current and futuristic phase.

Table 34 Drivers and Barriers in decision-making of 'Polderdrift'

	Actor →	1. Tenant			2. 'opMAAT'		
Criteria↓	**Phase → Aspect ↓**	design	current	future	design	current	future
Environmental drivers	Water saving	Yes	Yes	No			
	Prevention of drying out of soil	No	No	No			
	Reduction of water emissions with high nutrients and pathogens concentration	Yes	Yes	Yes			
	Recycling of water	Yes	Yes	Yes			
	Protection surface water for overflow	No	No	No			
	Protection of ground water	No	No	No			
	Nice neighbourhood	Yes	Yes	Yes			
	Nice environmental behaviour feeling	No	No	No			
Environmental barriers	Health risks	No	No	Yes			
	Flooding risks	No	Yes	??			
	Maintenance problems	No	Yes	Yes			
	High energy use	No	Yes	Yes			
	Smell	No	Yes	Yes			
Economical drivers	Low design costs	Yes	No	Yes			
	Low water supply costs	No	Yes	Yes			
	Low energy costs	No	No	No			
	Low sewerage taxes	No	No	No			
	Low water board fee	Yes	No	Yes			
	Development new technology	Yes	Yes	Yes			
Economical barriers	High design costs	No	Yes	Yes			
	High operational costs	Yes	Yes	Yes			
	High energy costs	Yes	Yes	Yes			
Social drivers	Intensive contact with neighbours	Yes	No	No			
	Environmental friendly	Yes	Yes	Yes			
	Nice neighbourhood to live	Yes	Yes	Yes			

Social barriers	Smell	No	Yes	No			

	Actor →	3. Portaal			4. Arnhem		
Criteria↓	**Phase → Aspect ↓**	design	current	future	design	current	future
Environmental drivers	Water saving	No involvement	Yes	Yes	No	Yes	Yes
	Prevention of drying out of soil		No	No	No	Yes	Yes
	Reduction of water emissions with high nutrients and pathogens concentration		Yes	Yes	Yes	Yes	Yes
	Recycling of water		Yes	Yes	Yes	Yes	Yes
	Reduction of energy use		No	No	Yes	Yes	Yes
	Protection surface water for overflow		Yes	Yes	Yes	Yes	Yes
	Protection of ground water		Yes	Yes	Yes	Yes	Yes
	Nice neighbourhood		Yes	Yes	Yes	Yes	Yes
	Nice environmental behaviour feeling		Yes	Yes	Yes	Yes	Yes
	Micro- biotope in neighbourhood		Yes	Yes	No	No	No
Environmental barriers	Health risks		Yes	Yes	No	No	No
	Flooding risks		No	No	Yes	Yes	Yes
	Maintenance problems		Yes	Yes	Yes	Yes	Yes
	Use of chemicals		Yes	Yes	Yes	Yes	Yes
	High energy use		Yes	Yes	No	No	No
Economical drivers	Low water supply costs		Yes	Yes	Yes	Yes	Yes
	Development new technology		Yes	Yes	Yes	Yes	Yes
Economical barriers	High design costs		Yes	Yes	Yes	Yes	Yes
	High operational costs		Yes	Yes	Yes	Yes	Yes
	High energy costs		Yes	Yes	??	??	??
	High sewerage taxes		No	No	Yes	Yes	Yes
Social drivers	Intensive contact with neighbours		Yes	Yes	Y/N[1]	Y/N	Y/N
	Environmental friendly		Yes	Yes	Yes	Yes	Yes
	Nice neighbourhood to live		Yes	Yes	Yes	Yes	Yes
Social barriers	Health risks		Yes	Yes	Yes	Yes	Yes
	Acceptance of new tenants		Yes	Yes	Yes	Yes	Yes
	Difficult technology		No	No	Yes	Yes	Yes
	Risks of housing equipment		No	No	Yes	Yes	Yes

1 Y/N means yes or no

APPENDIX 4 SOURCE SEPARATING IN 'EKOPORTEN'

4.1 Implemented technology

Figure 16 Above view Ekoporten

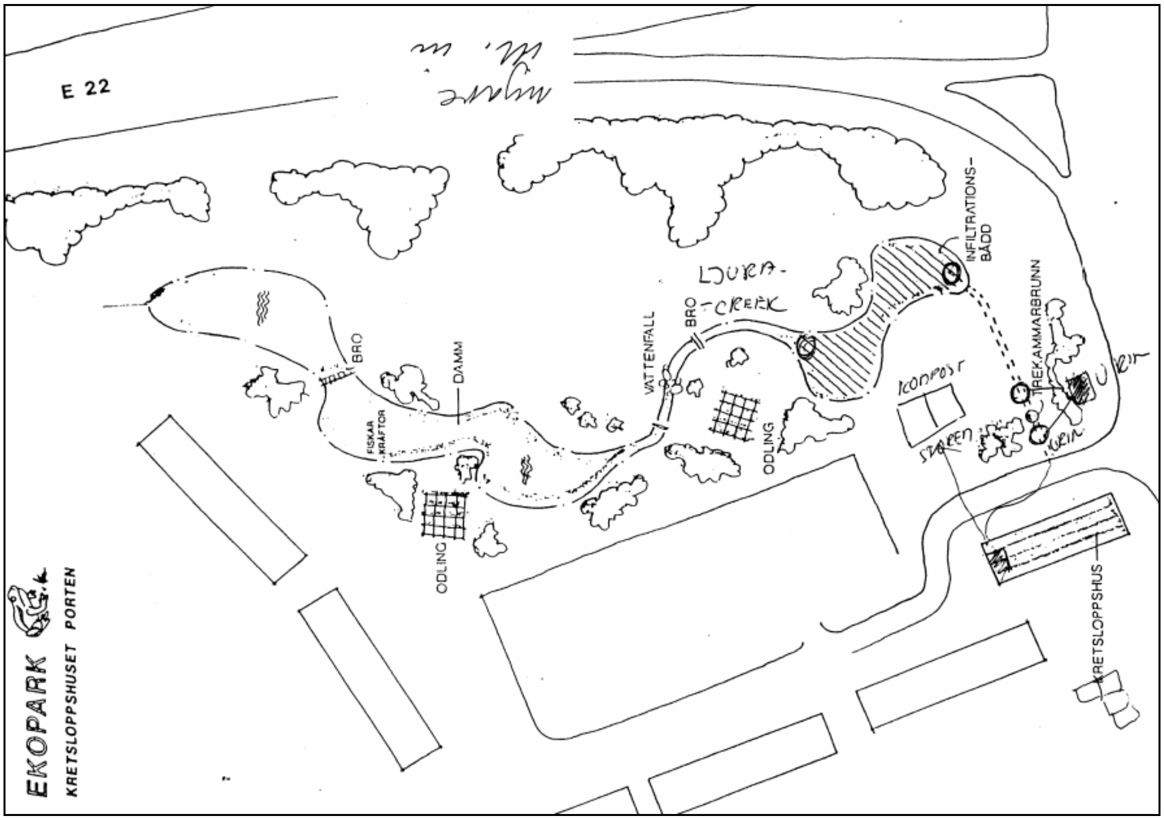


Figure 17 System scheme Ekoporten

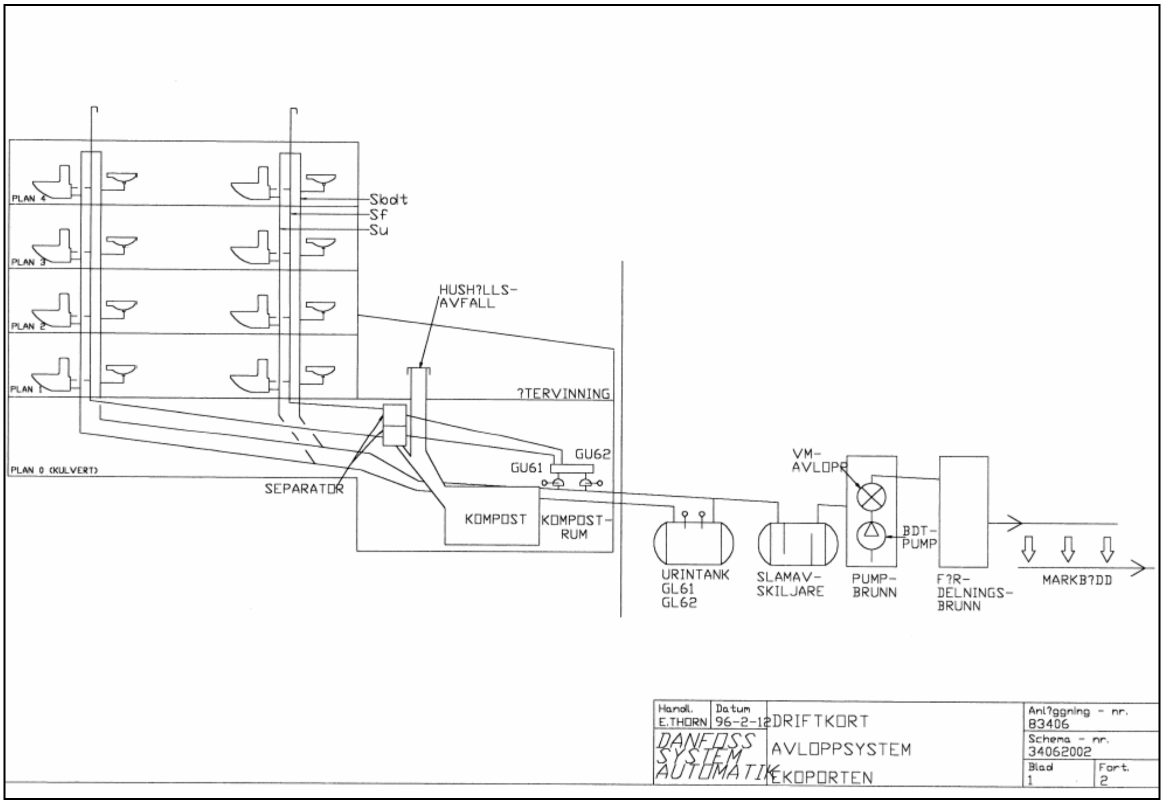


Table 35 Collected daily amounts and the concentrations of elements in the urine, feacal flushwater, greywater, and biodegradable solids waste (average + standard deviation) (Vinnerås, 2001)

Parameter	Unit	Urine mixture	Faecal water	Greywater	Biod. solid
Volume	kg/day, 35p	45.9±5.3	1 006±19	3 640±1645	7.9±2.4
TS	g/kg	8.51±0.93	0.66±0.09	0.57±0.49	261±24
N	g/kg	2.49±0.60	0.10±0.01	0.016±0.003	6.86±0.09
P	g/kg	0.28±0.05	0.125±0.001	0.004±0.001	1.10±0.21
K	g/kg	0.98±0.21	0.49±0.01	0.040±0.005	2.40±0.19
Cu	mg/kg	1.82±0.35	0.057±0.003	0.11±0.02	3.70±0.20
Cr	mg/kg	0.013±0.002	0.004±0.001	0.009±0.007	3.19±3.54
Ni	mg/kg	0.040±0.007	0.006±0.001	0.008±0.002	0.41±0.07
Zn	mg/kg	0.18±0.08	0.26±0.02	0.13±0.06	8.01±0.67
Pb	mg/kg	0.019±0.011	0.025±0.004	0.014±0.007	2.47±2.27
Cd	µg/kg	0.58±0.24	0.34±0.11	0.30±0.12	33.1±21.5
Hg	µg/kg	0.43±0.24	$<0.15^{\alpha}$	$<0.10^{\alpha}$	$<2.5^{\alpha}$

α) Less than given detection limit.

Table 36 Removal efficiency of the reedbed in Ekoporten in time (Karlsson, 2003)

Year	**Removal efficiency (%)**				
	BOD_7	COD	Susp. Solids	N-Total	P-Total
1997	88	84	82	58	76
1998	97	90	84	62	69
1999	98	92	89	36	61
2000	98	94	96	54	78
2001	92	90	70	50	58
2002	94	84	68	42	44

The treatment efficiency of the reedbed is studied by Gustafsson (2005).

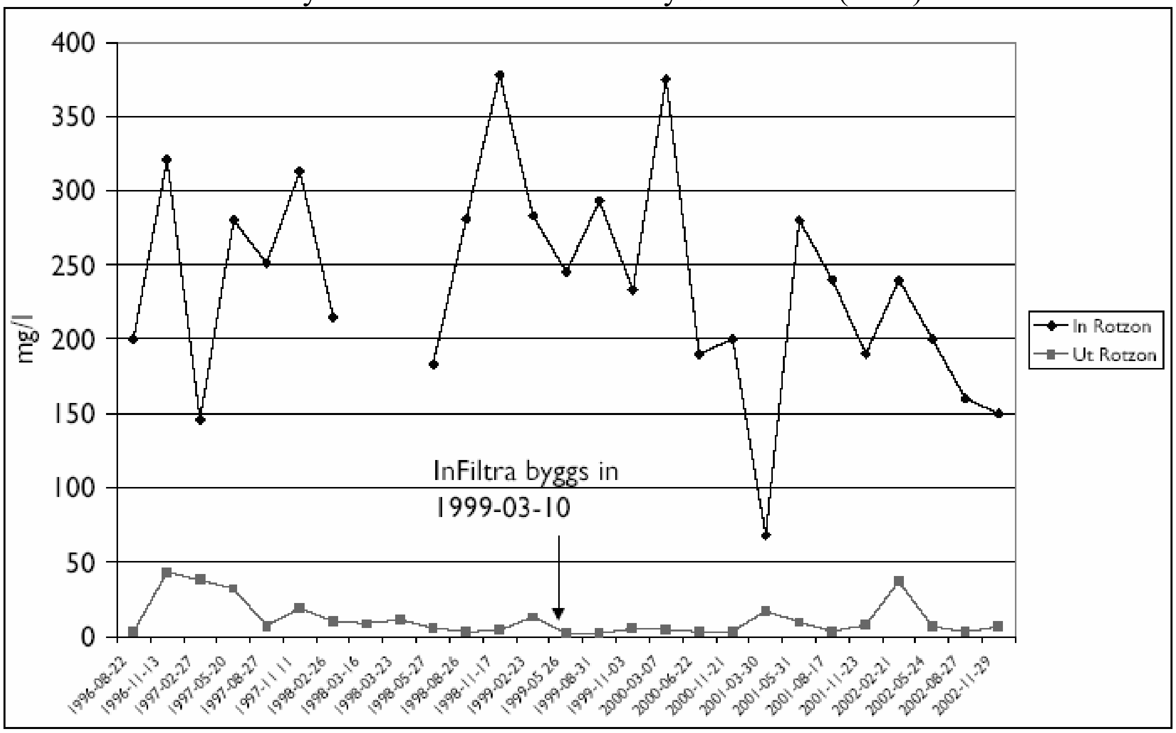


Figure 18 BOD7 concentration in infleunt and effluent of the reedbed in Ekoporten

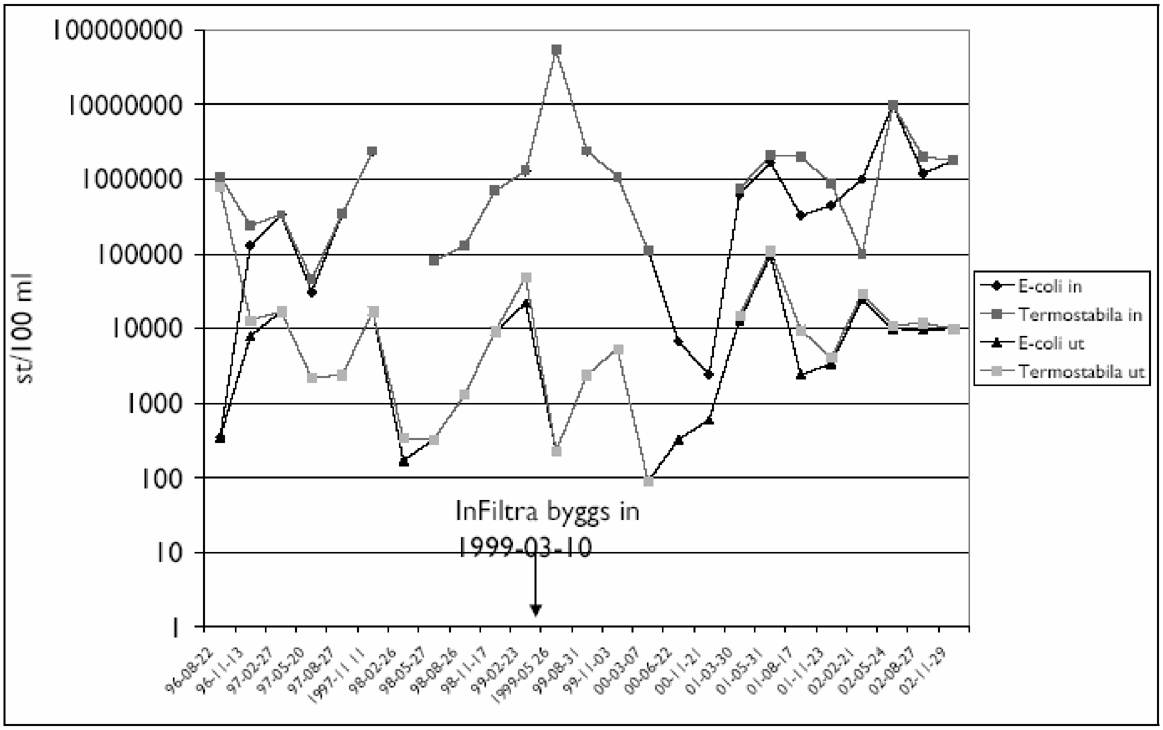


Figure 19 Amount indicator organism in influent and effluent of the reedbed in Ekoporten

The compost composition for N, P, and K as % of Total solids is depicted in table.

Table 37 Compost composition as % of TS in Ekoporten

Year	N-total (% of TS)	P-total (% of TS)	K (% of TS)
1997	1.6	0.65	0.6
1998	1	0.4	0.3
1999	1.6	0.7	0.45

4.2 Drivers and barriers

In the table below the results of the interviews are addressed. The table 38 highlights the drivers and barriers of a tenant (Lind, *pers. com.*), an external consultant 'MiljöInvest' (Karlsson, *pers. com.*), by the current housing company 'Markarydsbostäder' (Käkelä, *pers. com.*), municipality 'Norrköping' (Franzen, *pers. com.*), in the design, current and futuristic phase.

Table 38 Drivers and Barriers in decision-making of 'Ekoporten'

	Actor →	1. Tenant			2. 'MiljöInvest'		
Criteria↓	**Phase → Aspect ↓**	design	current	future	design	current	future
Environmental drivers	Water saving	No involvement	Yes	Yes	No involvement	No	No
	Reduction of water emissions with high nutrients and pathogens concentration		Yes	Yes		Y/N	Y/N
	Recycling of nutrients		Yes	Yes		Yes	Yes
	Nice neighbourhood		Yes	Yes		Yes	Yes
	Nice environmental behaviour feeling		Yes	Yes		Yes	Yes
Environmental barriers	Health risks		No	No		No	No
	Maintenance problems		Yes	Yes		Yes	No
	High energy use		No	No		Yes	Yes
	Higher emissions		No	No		Yes	No
Economical drivers	Low water supply costs		Yes	Yes		No	No
	Low water board fee		No	No		Yes	No
	Development new technology		Yes	Yes		Yes	Yes
Economical barriers	High design costs		Yes	Yes		Yes	Yes
	High operational costs		Yes	Yes		Yes	Yes
	High energy costs		No	No		Yes	Yes
Social drivers	Intensive contact with neighbours		Yes	Yes		Yes	Yes
	Environmental friendly		Yes	Yes		Yes	Yes
	Nice neighbourhood to live		Yes	Yes		Yes	Yes
Social barriers	Difficult technology		No	No		No	No
	Health risks		No	No		No	No

	Actor →	3. 'Markarydsbostäder'			4. 'Norrköping'		
Criteria↓	**Phase → Aspect ↓**	design	current	future	design	current	future
Environment	Water saving	No	Yes	Yes	No	No	No

al drivers	Reduction of water emissions with high nutrients and pathogens concentration	involvement	Yes	Yes	involvement	Yes	Yes
	Protection of surface water		Yes	Yes		Yes	Yes
	Protection of ground water		No	No		Yes	Yes
	Recycling of nutrients		Yes	Yes		Yes	Yes
	Nice neighbourhood		Yes	Yes		No	No
	Nice environmental behaviour feeling		Yes	Yes		No	No
Environmental barriers	Health risks		Yes	Yes		Yes	Yes
	Maintenance problems		Yes	Yes		Yes	Yes
	Nice neighbourhood		No	No		Yes	Yes
Economical drivers	Low taxes for organic waste		Yes	Yes		No interest in costs	
	Development new technology		Yes	Yes			
Economical barriers	High design costs		Yes	Yes			
	High operational costs		Yes	Yes			
	More rent		Yes	Yes			
Social drivers	Intensive contact with neighbours		Yes	Yes		No	No
	Environmental friendly		Yes	Yes		Yes	Yes
	Nice neighbourhood to live		Yes	Yes		Yes	Yes
Social barriers	Difficult technology		Yes	Yes		Yes	Yes
	Health risks		Yes	Yes		Yes	Yes

APPENDIX 5 SOURCE SEPARATING IN 'SKOGABERG'

5.1 Description of the technology

Figure 20 Above view Skogaberg

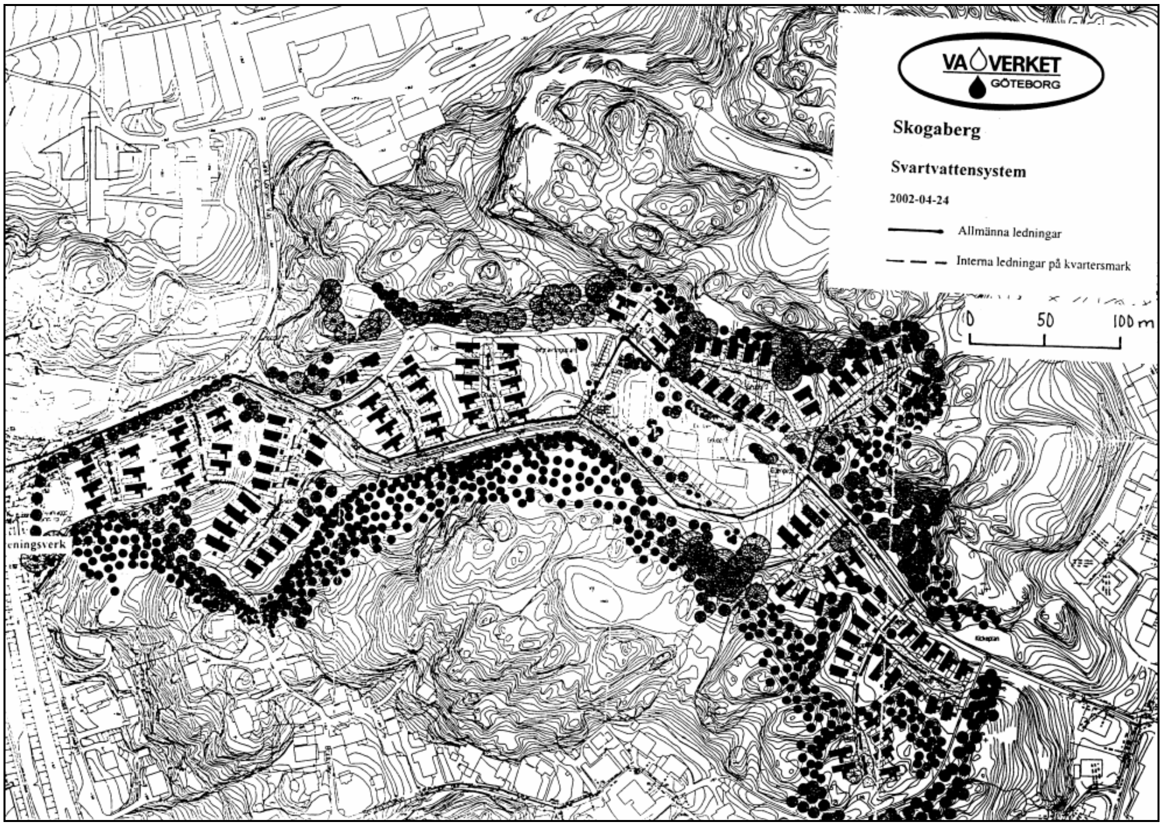


Table 39 Quality black water mixture (de Blois, 2004)

Parameter	Total daily amount (g/d)	Specific amount* ((g/p.d)
Suspended solids	2180	29
COD	4210	56
BOD	2250	30
TOC	1440	19
N-total	490	6,6
P- total	67	0,9
K	220	2,9

*** 75 persons**

5.2 Drivers and barriers

In the table below the results of the interviews are addressed. The table 40 highlights the drivers and barriers of an external consultant 'H2OLAND' (Blois, *pers. com.*), the housing company 'Egnahemsbolaget' (Gustavsson, *pers. com.*), the architect 'Sweco FNNS' (Aleby, *pers. com.*), recycling board municipality 'Göteborg' (Karlsson and Aarsrud, *pers. com.*), Va-Verket (Water and Sewers work) municipality 'Göteborg' (Bokesjö, *pers. com.*), Gryaab (sewerage and treatment department) municipality 'Göteborg' (Mattsson, *pers. com.*), in the design, current and futuristic phase.

Table 40 drivers and barriers Skogaberg

	Actor →	1. H2OLAND			2. 'Egnahemsbolaget'		
Criteria↓	**Phase → Aspect ↓**	design	current	future	design	current	future
Environmental drivers	Reduction of water emissions with high nutrients and pathogens concentration	No	No	Yes	No	No	No
	Recycling of nutrients	Yes	Yes	Yes	Yes	Yes	Yes
	Protection surface water for overflow	No	No	Yes	No	No	No
	Nice neighbourhood	Yes	Yes	Yes	Yes	Yes	Yes
	Nice environmental behaviour feeling	??	??	??	Yes	Yes	Yes
Environmental barriers	Health risks	Yes	Yes	Yes	No	No	No
	Flooding risks	Yes	Yes	Yes	No	No	No
	Use of chemicals	Yes	Yes	Yes	No	No	No
	Maintenance problems	Yes	Yes	Yes	Yes	No	Y/N
	High energy use	Yes	Yes	No	No	No	No
	Calamity Acid doses	Yes	Yes	Yes	No	No	No
	High water use	No	No	No	Yes	Yes	Yes
	Smell	Yes	Yes	Yes	No	No	No
Economical drivers	Low water board fee	Yes	No	Yes	No	No	No
	Low sewerage taxes	No	No	Yes	No	No	No
	Development new technology	Yes	Yes	Yes	Yes	Yes	Yes
Economical barriers	High design costs	Yes	Yes	Yes	Yes	Yes	Yes
	High operational costs	Yes	Yes	Yes	Yes	Yes	Yes
Social drivers	Intensive contact with neighbours	Yes	Yes	Yes	Yes	Yes	Yes
	Environmental friendly	Yes	Yes	Yes	Yes	Yes	Yes
	Nice neighbourhood to live	Yes	Yes	Yes	Yes	Yes	Yes
	Do good things for the whole community	No	No	No	Yes	Yes	Yes

Social barriers	Risk of housing equipment	Yes	Yes	Yes	Yes	Yes	Yes

	Actor →	3. 'Sweco FNNS'			4. 'Recycling board'		
Criteria↓	**Phase → Aspect ↓**	design	current	future	design	current	future
Environmental drivers	Protection surface water for overflow	Yes	Yes	No	No	No	No
	Recycling of nutrients	Yes	Yes	Yes	Yes	Yes	Yes
	Reduction of energy	Yes	No	No	No	No	No
	Nice neighbourhood	Yes	Yes	Yes	Yes	Yes	Yes
	Nice environmental behaviour feeling	Yes	Yes	Yes	No	No	No
	Use of environmental friendly materials	Yes	Yes	Yes	No	No	No
	Minimizing demolition surroundings	Yes	Yes	Yes	No	No	No
Environmental barriers	Use of chemicals	No	No	No	Yes	No	Yes
	Maintenance problems	Yes	No	No	Yes	Yes	Yes
	High energy use	No	No	No	Yes	Yes	Yes
	Recycling of fertilizers in agriculture	Yes	Yes	Yes	No	No	No
Economical drivers	Low energy costs	Yes	No	No	No	No	No
	Low sewerage taxes	Yes	No	No	No	No	No
	Low water board fee	Yes	No	No	No	No	No
	Development new technology	Yes	No	No	Yes	Yes	Yes
Economical barriers	High design costs	Yes	Yes	Yes	Yes	Yes	Yes
	High operational costs	Yes	Yes	Yes	Yes	Yes	Yes
Social drivers	Intensive contact with neighbours	No	No	No	No	No	No
	Environmental friendly	Yes	Yes	Yes	Yes	Yes	Yes
	Nice neighbourhood to live	Yes	Yes	Yes	Yes	Yes	Yes
	Same as in conventional	No	No	No	Yes	Yes	Yes
Social barriers	Not visible environmental behaviour	Yes	Yes	Yes	No	No	No
	Conventional thinking	No	No	No	Yes	Yes	Yes

	Actor →	5. VA-Verket			6. Gryaab		
Criteria↓	**Phase → Aspect ↓**	design	current	future	design	current	future
Environmental drivers	Reduction of water emissions with high nutrients and pathogens concentration	Yes	Yes	Yes	Yes	Yes	Yes
	Protection surface water for overflow	No	No	No	Yes	Yes	Yes
	Recycling of nutrients	Yes	Yes	Yes	Yes	Yes	Yes
	Nice neighbourhood	No	No	No	No	No	No

	Nice environmental behaviour feeling	No	No	No	Y/N	Y/N	Y/N
Environmental barriers	Health risks	Yes	Yes	Yes	No	No	Yes
	Flooding risks	Yes	Yes	Yes	Yes	Yes	Yes
	Maintenance problems	Yes	Yes	Yes	Yes	Yes	Yes
	High energy use	Yes	Yes	Yes	Yes	Yes	Yes
	Use of chemicals	Yes	Yes	Yes	Yes	Yes	Yes
	Medicines and hormones in agriculture	Yes	Yes	Yes	No	No	No
	No space in ground	Yes	Yes	Yes	No	No	No
	Resources use	Yes	Yes	Yes	No	No	No
Economical drivers	Development new technology	Yes	Yes	Yes	Yes	Yes	Yes
	Low garbage costs	No	No	No	Yes	Yes	Yes
Economical barriers	High design costs	Yes	Yes	Yes	Yes	Yes	Yes
	High operational costs	Yes	Yes	Yes	Yes	Yes	Yes
	High energy costs	Yes	Yes	Yes	Yes	Yes	Yes
	High sewerage taxes	No	No	No	Yes	Yes	Yes
	High water-board fee	No	No	No	Yes	Yes	Yes
	Use of ground	No	No	No	Yes	Yes	Yes
	Up scaling technology not possible	Yes	Yes	Yes	Yes	Yes	Yes
Social drivers	Intensive contact with neighbours	No	No	No	Yes	Yes	Yes
	Kitchen disposer is luxury	Yes	Yes	Yes	Yes	Yes	Yes
	Nice neighbourhood to live	No	No	No	Yes	Yes	Yes
Social barriers	Difficult technology	Yes	Yes	Yes	Yes	Yes	Yes
	Health risks	Yes	Yes	Yes	No	No	No
	Sewer blockage near the houses	No	No	No	Yes	Yes	Yes

APPENDIX 6 SOURCE SEPARATING IN 'UNDERSTENSHÖJDEN'

6.1 Description of the technology

The above view from the Understenshöjden neighborhood is depicted in figure XX.

Figure 21 Above view Understenshöjden

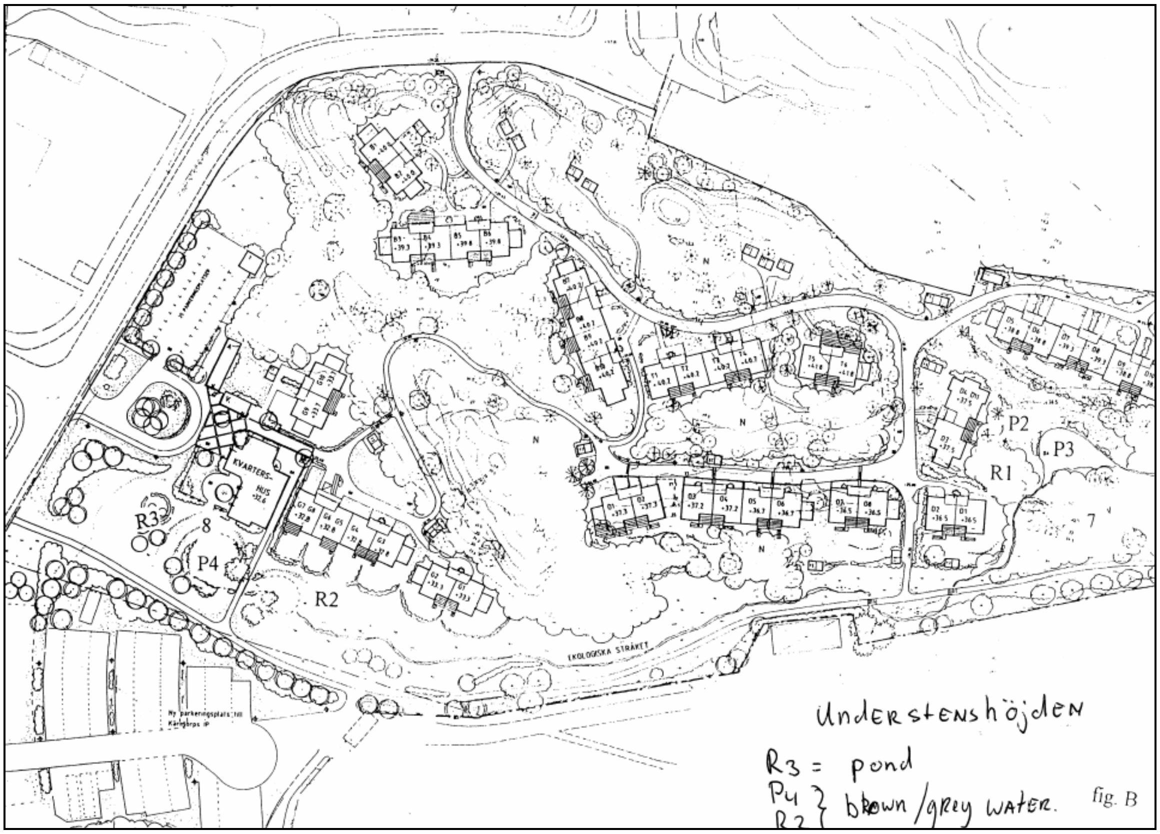


Figure 22 Technical scheme WMS Understenshöjden

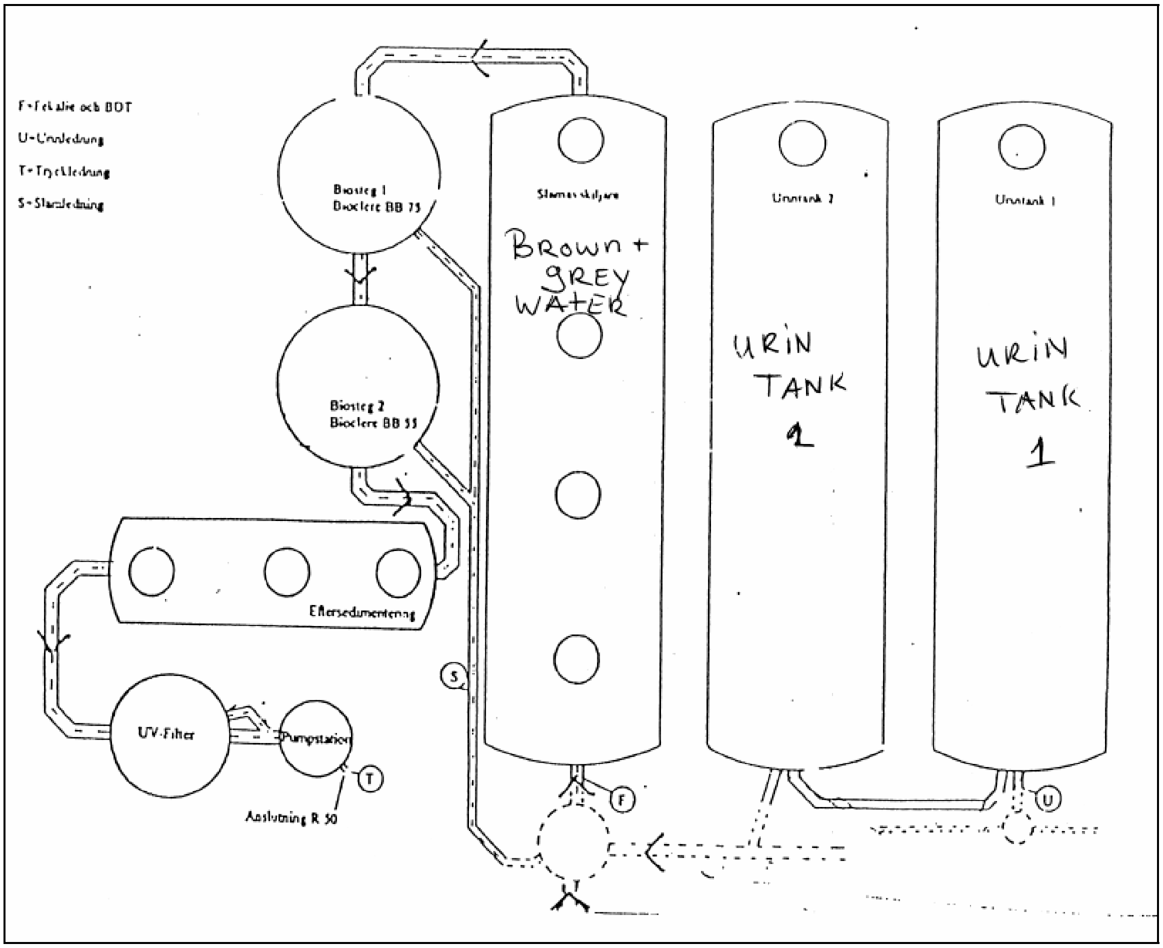


Table 41 Urine quality of Understenshöjden per person per day (Jönsson, et. al., 1998)

Parameter	Unit	Value
pH		9.1
Total Solids	g/pd	10.9
N-total	g/pd	4.9
P-total	g/pd	0.42
K-total	g/pd	1.34
Mg	Mg/p.d	14.9
Fe	Mg/p.d	0.52
Pb	Mg/p.d	< 0.014
Cd	Mg/p.d	< 0.0014
Cu	Mg/p.d	3.3
Cr	Mg/p.d	0.026
Hg	Mg/p.d	0.0006
Ni	Mg/p.d	0.082

6.2 Drivers and barriers

In the table below the results of the interviews are addressed. The table 42 highlights the drivers and barriers of the tenants (Sederlund, *pers. com.*), by the housing company 'HSB Stockholm' (Westin, *pers. com.*), municipality 'Stockholm' (Lundin, *pers. com.*), water-board 'Stockholm Vatten' (Hellström, *pers. com.*), consultant 'VERNA Ecology' (Johansson, *pers. com.*), in the design, current and futuristic phase.

Table 42 Drivers and Barriers Understenhöjden

	Actor →	1. Tenant			2. 'HSB Stockholm'		
Criteria↓	**Phase → Aspect ↓**	design	current	future	design	current	future
Environmental drivers	Water saving	Yes	Yes	Yes	Yes	Yes	Yes
	Reduction of water emissions with high nutrients and pathogens concentration	Yes	Yes	Yes	Yes	No	No
	Recycling of nutrients	Yes	Yes	Yes	Yes	Yes	Yes
	Protection surface water for overflow	Yes	Yes	Yes	Yes	No	No
	Reduction of energy use	Yes	Yes	Yes	Yes	No	No
	Nice neighbourhood	Yes	Yes	Yes	Yes	Yes	Yes
	Nice environmental behaviour feeling	Yes	Yes	Yes	Yes	Yes	Yes
Environmental barriers	Health risks	No	No	No	No	Yes	Yes
	Maintenance problems	Yes	Yes	Y/N	Yes	Yes	Yes
Economical drivers	Low operational costs	No	No	No	Yes	Yes	Yes
	Low sewerage taxes	Yes	Yes	Yes	Yes	Yes	Yes
	Low water board fee	Yes	Yes	Yes	Yes	Yes	Yes
	Development new technology	Yes	Yes	Yes	Yes	Yes	Yes
Economical barriers	High design costs	Yes	Yes	Yes	Yes	Yes	Yes
	High operational costs	Yes	Yes	Yes	No	No	No
Social drivers	Intensive contact with neighbours	Yes	Yes	Yes	Yes	Yes	Yes
	Environmental friendly	Yes	Yes	Yes	Yes	Yes	Yes
	Nice neighbourhood to live	Yes	Yes	Yes	Yes	Yes	Yes
Social barriers	Difficult technology	No	Yes	Yes	Yes	Yes	Yes
	Risks of housing equipment	Yes	Yes	Yes	Yes	Yes	Yes
	Health risks	Yes	Yes	Yes	No	No	No

	Actor →	3. 'Stockholm'			4. 'Stockholm Vatten'		
Criteria↓	**Phase → Aspect ↓**	design	current	future	design	current	future

Environmental drivers	Reduction of water emissions with high nutrients and pathogens concentration	Yes	Yes	Yes	Yes
	Protection surface water for overflow	Yes	Yes	Yes	Yes
	Recycling of nutrients	Yes	Yes	Yes	Yes
	Nice neighbourhood	Yes	Yes	Yes	Yes
	Nice environmental behaviour feeling	Yes	Yes	Yes	Yes
Environmental barriers	Use of chemicals	No	Yes	Yes	Yes
	Maintenance problems	Yes	Yes	No	No
	Smell	No	No	Yes	Yes
Economical drivers	Low energy costs	No	Yes	Yes	Yes
	Low sewerage taxes	No	Yes	Yes	Yes
	Low water board fee	No	Yes	Yes	Yes
	Development new technology	Yes	Yes	Yes	Yes
Economical barriers	High design costs	Yes	Yes	Yes	Yes
	High operational costs	No	Yes	Y/N	Y/N
Social drivers	Intensive contact with neighbours	Yes	No	No	No
	Environmental friendly	Yes	Yes	Yes	Yes
	Nice neighbourhood to live	Yes	Yes	Yes	Yes
Social barriers	Difficult technology	Yes	No	No	No
	Risks of housing equipment	No	Yes	Yes	Yes
	Acceptance agriculture	No	Yes	Yes	Yes
	Decrease of interest tenants	Yes	No	No	No
	New tenants less professional	Yes	No	No	No

	Actor →	5. 'VERNA Ecology'		
Criteria↓	**Phase → Aspect ↓**	design	current	future
Environmental drivers	Water saving	Yes	Yes	No comment
	Reduction of water emissions with high nutrients and pathogens concentration	Yes	Yes	
	Recycling of water	Yes	No	
	Protection surface water for overflow	Yes	Yes	
	Recycling of nutrients	Yes	Yes	
	No chemicals	Yes	Yes	
	Nice neighbourhood	Yes	Yes	

	Nice environmental behaviour feeling	Yes	Yes	
Environmental barriers	Maintenance problems	Yes	Yes	
Economical drivers	Low water supply costs	No	Yes	
	Low sewerage taxes	No	Yes	
	Low water board fee	No	Yes	
	Development new technology	Yes	No	
Economical barriers	High design costs	Yes	Yes	
	High operational costs	Yes	Yes	
	High energy costs	Yes	Yes	
Social drivers	Environmental friendly	Yes	Yes	
	Nice neighbourhood to live	Yes	Yes	
Social barriers	Difficult technology	No	Yes	
	Risks of housing equipment	No	Yes	
	Health risks	No	Yes	
	Available user urine	Yes	No	

APPENDIX 7 SOURCE SEPARATING IN 'GEBERS'

7.1 Description of the technology

Table 43 Quality of waste water streams and solids per person and year of Gebers (Palmquist and Jönsson, 2003)

	Unit	Urine mixture	Faeces + toilet paper	Greywater	Biodegradable solid waste
Wet mass	kg	646	81[a]	40150	67
TS	kg	7.0	18.6[a]	14.6	16.5
BOD_7	g	1829	1223	7700	1051
COD	g	3720	1668	17500	2931
N	g	3830	710	510	324
P	g	250	250	220	57
K	g	820	280	350	182
S	g	230	78	584	33
Cu	mg	17.2	635	2370	162
Cr	mg	0.16	49	149	182
Ni	mg	4.2	82	241	89
Zn	mg	107	16940[b]	2255	675
Pb	mg	4.2	13.5	88	40
Cd	mg	0.08	5.7	5.5	2.5
Hg	mg	0.16	3.2	1.1	2.7

a) The use of toilet paper was: 8.5 kg TS per person and year
b) This value is probably partly due to corrosion from the galvanised pipes which were a part of the system

Figure 23 Above view of Gebers

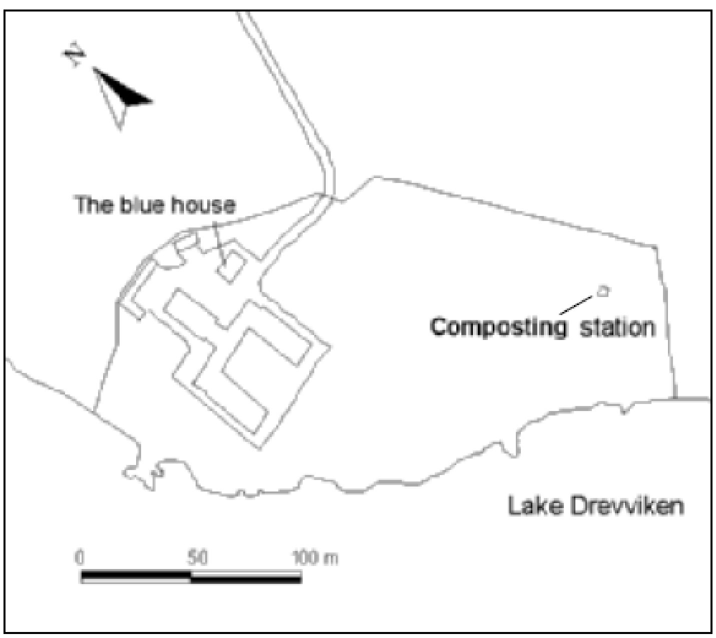


Figure 24 Compost facility at Gebers

7.2 Drivers and barriers

In the table below the results of the interviews are addressed. The table 44 highlights the drivers and barriers of the tenants (Hort, *pers. com.*), by the housing company 'HSB Stockholm' (Westin, *pers. com.*), municipality 'Stockholm' (Lundin, *pers. com.*), water-board 'Stockholm Vatten' (Hellström, *pers. com.*), in the design, current and futuristic phase.

Table 44 Drivers and Barriers of Gebers

	Actor →	1. Tenant			2. 'HSB Stockholm'		
Criteria↓	**Phase → Aspect ↓**	design	current	future	design	current	future
Environmental drivers	Water saving	Yes	Yes	Yes	Yes	Yes	Yes
	Reduction of water emissions with high nutrients and pathogens concentration	Yes	Yes	Yes	No	No	No
	Recycling of water	Yes	No	No	Yes	No	No
	Recycling of nutrients	Yes	Yes	Yes	Yes	Yes	Yes
	Protection surface water for overflow	Yes	Yes	Yes	No	No	No
	Reduction of energy use	No	No	No	Yes	No	No
	Nice neighbourhood	Yes	Yes	Yes	Yes	Yes	Yes
	Nice environmental behaviour feeling	Yes	Yes	Yes	Yes	Yes	Yes
Environmental barriers	Health risks	No	No	No	No	Yes	No
	Maintenance problems	Yes	No	No	Yes	No	No
	High energy use due to transport urine new farmer	No	No	No	Yes	Yes	Yes
Economical drivers	Low operational costs	Y/N	Y/N	Y/N	Yes	Yes	Yes
	Low drink water costs	Yes	Y/N	Y/N	Yes	Yes	Yes
	Low sewerage taxes	Yes	Y/N	Y/N	Yes	Yes	Yes
	Low water board fee	Yes	Y/N	Y/N	Yes	Yes	Yes
	Development new technology	Yes	Yes	Yes	Yes	Yes	Yes
Economical barriers	High design costs	Yes	Yes	Yes	Yes	Yes	Yes
	High operational costs	Y/N	Y/n	Y/N	No	No	No
	High energy costs	No	No	No	Yes	Yes	Yes
Social drivers	Intensive contact with neighbours	Yes	Yes	Yes	Yes	Yes	Yes
	Environmental friendly	Yes	Yes	Yes	Yes	Yes	Yes
	Nice neighbourhood to live	Yes	Yes	Yes	Yes	Yes	Yes
	Contributing effort to society	Yes	Yes	Yes	No	No	No
	Proud of technology	Yes	Yes	Yes	No	No	No
Social	Difficult technology	No	Yes	Yes	No	No	No

barriers	Risks of housing equipment	Yes	Yes	Yes	No	Yes	Yes
	Health risks	Yes	Yes	Yes	No	Yes	Yes
	Disgusting	Yes	Yes	Yes	No	No	No
	Continuity farmer to use urine	Yes	Yes	Yes	No	No	No

	Actor →	3. 'Stockholm'			4. 'Stockholm Vatten'		
Criteria↓	**Phase → Aspect ↓**	design	current	future	design	current	future
Environmental drivers	Water saving		No		Yes	Yes	Yes
	Reduction of water emissions with high nutrients and pathogens concentration	No involvement	Yes	No involvement	Yes	Yes	Yes
	Protection surface water for overflow		Yes		Yes	Yes	Yes
	Recycling of nutrients		Yes		Yes	Yes	Yes
	Nice neighbourhood		Yes		Yes	Yes	Yes
	Nice environmental behaviour feeling		Yes		Yes	Yes	Yes
Environmental barriers	Health risks		No		Yes	Yes	Yes
	Maintenance problems		Yes		Yes	No	No
	Smell		No		Yes	No	No
Economical drivers	Low operational costs		No		Yes	Yes	Yes
	Low energy costs		No		Yes	Yes	Yes
	Low sewerage taxes		No		Yes	Yes	Yes
	Low water board fee		No		Yes	Yes	Yes
	Development new technology		Yes		Yes	Yes	Yes
Economical barriers	High design costs		No		Yes	Yes	Yes
Social drivers	Intensive contact with neighbours		Yes		Yes	Yes	Yes
	Environmental friendly		Yes		Yes	Yes	Yes
	Nice neighbourhood to live		Yes		Yes	Yes	Yes
Social barriers	Difficult technology		Yes		Yes	Yes	Yes
	Risks of housing equipment		No		Yes	Yes	Yes
	Health risks		No		Yes	Yes	Yes
	Acceptance agriculture		No		Yes	Yes	Yes
	Decrease of interest tenants		Yes		No	No	No
	New tenants less professional		Yes		No	No	No