Sustainable Wastewater Treatment For a new Housing Area

- How to find the right solution -

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Table of contents

Preface

This production has been initiated and financed by Coalition Clean Baltic (CCB) to give support for long-term sustainable solutions for wastewater treatment in the Baltic Sea Region. We hope that the planning ideas and the treatment methods presented in this booklet will serve as inspiration to use more recourse saving technologies, for the benefit of society as well as the Baltic Sea environment.

Gunnar Norén
Executive secretary to CCB

Foreword

In Sweden, there are about one million households on the countryside that have no or badly functioning wastewater treatment. For these households, and for new houses constructed outside centralised wastewater systems, there is a great need for affordable and well functioning onsite solutions for wastewater treatment. This booklet is about how to plan and design such systems.

The booklet is based on a planning case in the municipality of Eskilstuna, Sweden where a housing company wanted to build a new housing area far from centralised systems. In order to get building permission, the company had to find a wastewater solution that could fulfil high requirements for public health and environmental protection. By using the method open wastewater planning the company was able to find the right solution.

The booklet is intended for planners, consultants and house owners primarily in the climate zone of the northern part of Europe.

Marika Palmér Rivera has provided the layout and translating work for the booklet. Support has also been given from Ebba af Petersens. The responsibility for the content of the report is entirely mine.

Peter Ridderstolpe
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Uppsala, Sweden April 2004

Introduction

When establishing new housing areas, solving the wastewater treatment is one of the most pressing issues. The first matter is to determine whether the area in question should be connected to the municipal sewage system or if wastewater should be treated locally. In Sweden, generous subsidies from the government during the 1970's and 1980's made it possible to construct ten thousands of kilometres of sewage pipes, thus connecting approximately 90% of the population to central treatment facilities. During the 1990's there has been a growing awareness that this may be neither cost-efficient nor sustainable in the long term. With the development of source separating systems and other local treatment methods, it has become clear that there are several alternatives to central wastewater treatment plants.

The primary goal for wastewater treatment has always been disease control and the protection of human health. Problems with polluted water bodies have added another objective, that of environmental protection and reduction of pollutants in effluent wastewater. When awareness of environmental concerns first arose, treatment was enhanced to reduce the oxygen consumption of effluent wastewater by introducing mechanical and biological treatment steps. After some time, this was discovered to be insufficient since problems with eutrophication of inland waters continued and even increased. The next step was consequently to invest in chemical precipitation in order to reduce the amount of phosphorous in the water. During the last decade, nitrogen removal systems have been installed in medium- and large-scale treatment plants in coastal areas in order to improve the situation in the sea.

Lately, environmental concerns have moved beyond solely recipient protection. In the old peasant society, recycling of nutrients from human waste to agricultural land was a natural part of everyday life. With the introduction of central treatment systems for water and waste, this principle was lost. But with more and more focus placed on ecological issues, and thus an increasing consciousness of the necessity for a more sustainable management of natural resources, this goal has been reintroduced for wastewater treatment. Discussions have focused mostly on the recirculation of phosphorous, which is justified by the fact that chemical fertilisers are produced from the limited resource of phosphorous rich minerals. However, the recycling of nitrogen is also important since the fixation of atmospheric nitrogen for chemical fertilisers is a very energy consuming process. In the long term, the only sustainable solution is to recycle all nutrients from human waste and wastewater to food production.

A starting point when planning wastewater treatment is the principle of Best Available Technology (BAT). It states that the best available technology that is reasonable from an economical and practical viewpoint should be used. This principle is incorporated into the Swedish Environmental Code as well as the European Union Water Framework Directive. The implementation of the BAT principle leads to a more flexible and effective legislation, since it allows for local adaptations.

With all the alternatives on the market today, choosing which sewage treatment solution to use can be a tricky business. The choice can be facilitated by using a planning method called open wastewater planning. Instead of primarily concentrating on different technical options, focus is placed on the goals of the treatment. All aspects are considered in the initial stages of planning, including hygienic, environmental and practical objectives. When these targets have been formulated into so called Terms of Requirement, different options for treatment are investigated. These options are then evaluated in relation to the Terms of Requirement and the solutions that fulfil the requirements are further investigated before a final decision is made.

In this report, the method of open wastewater planning is applied to the specific case of the establishment of a new housing area in Barva Park. This area is located in the countryside in the region of Lake Mälaren, in the south-central part of Sweden.

Open wastewater planning

This planning method places focus on the goals of the wastewater treatment rather than specific techniques. It uses the principle of Best Available Technology (BAT) and the "polluter-pays principle" as a starting point to formulate requirements for the treatment system. Different solutions for wastewater treatment are then considered in relation to the system requirements.

Requirements are formulated for all significant aspects of treatment, e.g. hygiene, recipient protection, sustainability, economy and reliability. In this way, effects and costs of wastewater treatment will be presented in an open process, and a real choice can be made by the users. When the focus lies on results and not on specific technical solutions, prejudices about treatment methods can be removed and locked positions opened.

When different treatment options are evaluated, investment and operational costs can many times be reduced compared to the outcome of a "conventional" planning process. A better treatment will usually be the result in terms of health and water protection as well as with regards to end products, such as sludge.

The planning process

As previously stated, this planning method places focus on the objectives of treatment. The first step in the process is thus to discuss targets and limits of the system and express them into Terms of Requirements (ToR). When this is done, the next step is to investigate different options and evaluate them according to the terms of requirement. However, some parts of the terms of requirement may be reformulated when the practical consequences of different options are seen, since technology usually implies a trade-off between different objectives. At least three separate options should be developed and described in terms of technical design and costs, in a way that makes it clear that they are feasible. Finally, these options are compared and evaluated and a decision for further planning and prospecting is made. A schematic description of the planning process is given in figure 1. Below, the process is described in more detail.

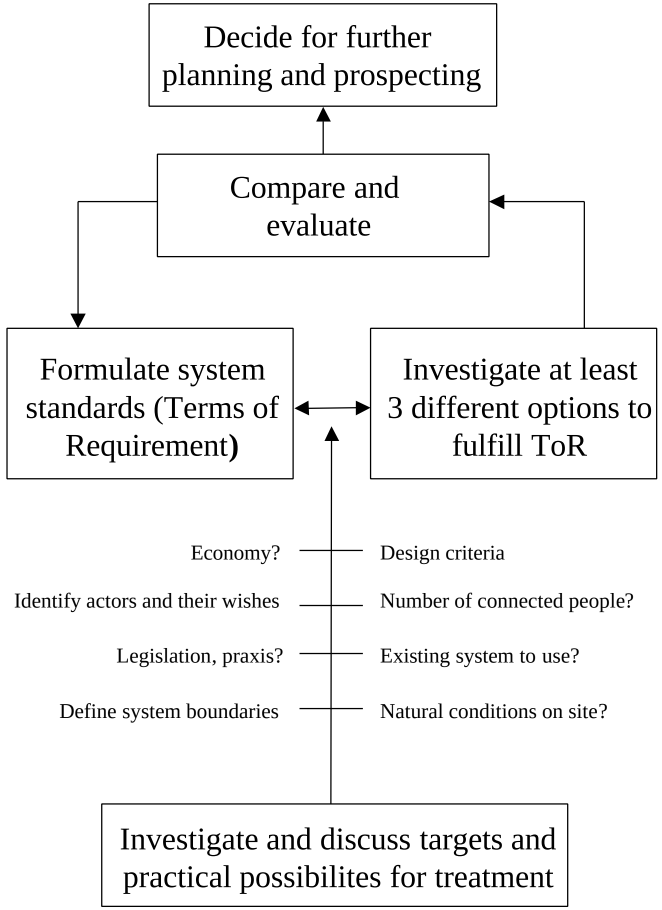

Figure 1. Schematic description of the open wastewater planning process.

Defining system targets and limits

This is the most important part of the planning process, since all subsequent planning is based on the Terms of Requirement set up. The system limits serve as the constraints for the future suggested solutions and should thus be determined as early as possible. Correctly identifying involved actors from the start will facilitate planning, since all relevant views can be taken into account at an early stage.

The first step is to investigate the planning prerequisites for the project. These include natural conditions of the location, such as groundwater level, soil quality and location of nearby lakes. Available infrastructure and the amount and quality of wastewater to be treated should also be made clear. It is important to define the initial requirements from the municipality and the principal for the future treatment system, which will serve as a starting point for formulating the Terms of Requirement.

Different possibilities for financing the construction and maintenance are also analysed at this stage. This can be broken down to the issue of who pays what and how much. It should be determined if the house owners are paying the actual costs or a "connection fee" or if the municipality will pay for parts of the system. The possibility of applying for grants should also be looked into.

The boundaries of the system should be defined, i.e. where the system begins and where it ends. This is important, for example, when calculating costs, when defining responsibilities or when deciding upon sampling points for outgoing water. Questions to answer include:

- Does the system start at the boundary of the garden or within the bathroom?
- Which houses are included and which are not?
- Where does the system end, i.e. which point divides the treatment system from disposal system and the recipient?

The planning prerequisites for Barva Park are described on page 10.

The actors and their roles must be identified. These actors should preferably be involved in the process from the beginning, which will facilitate the planning procedure and prevent disagreements later. Possible actors are:

- The municipality – environmental and planning authorities
- Land owner – owner of the land where (parts of) the treatment system is located, e.g. tanks, pipes and treatment facilities. Often synonymous with the house owner but not always.
- House owners – users and often owners of the system
- Entrepreneurs – handle transports and/or maintenance of the system. May be the farmers.
- Farmers – receivers of waste products, possibly also entrepreneurs
- Other stakeholders, such as neighbours with freshwater wells.

Then, the next step is to formulate the Terms of Requirement (ToR). This is done by the principal responsible for planning in co-operation with the supervisory authority. A possible treatment solution must be able to fulfil these requirements. The ToR should include all the primary functions of a wastewater management, i.e. sanitary aspects, water protection and recycling. Furthermore, the requirements should cover practical and economical aspects, such as user friendliness, reliability and preferred maximum investment and maintenance costs. The Terms of Requirement for Barva Park are given on pages 7 and 13.

Analysing possible solutions

When system targets and limits are defined, a number of possible solutions are analysed with respect to how well the Terms of Requirement can be fulfilled. The solutions must be feasible for the area in question. The possible solutions are tested against the ToR. Since no treatment option is perfect and choosing a technology always represent a trade-off between different treatment objectives, some aspects of the Terms of Requirement may have to be adjusted in order to obtain solutions that fulfil them.

At least three solutions should fulfil the requirements. These solutions are described in terms of technical design and economy that makes it clear that they are feasible. Treatment solutions fulfilling the Terms of Requirement for Barva Park are described on pages 20-31. The solutions that do not fulfil the requirements are discarded. Discarded solutions for Barva Park are discussed on page 19.

Choosing the final solution

The final step is to evaluate and compare the remaining solutions. All of them fulfil the Terms of Requirement and are possible to construct in the specific case, so the choice is made by the principal, in communication with the house owners (if different from principal). When a solution is decided upon, further planning and eventually the construction can take place. The final choice for Barva Park is discussed on page 32.

Figure 2. Different actors should be involved in the planning process from the beginning.

Requirements

The three primary objectives of wastewater treatment are:

- to prevent the spreading of diseases;
- to reduce discharge of nutrients and other pollutants to the environment;
- to facilitate the recirculation of nutrients.

In Sweden, requirements for sewage treatment facilities are decided by interpreting the general objectives of the Swedish Environmental Code and the EU legislation. A fundamental principle of the Environmental Code as well as and the European Water Framework Directive (WFD) is that the best available technology should be used, provided that measures are reasonable from an economic viewpoint. The principle of Best Available Technology (BAT) means that an adjustment should be made between environmental protection and management of natural resources on one hand, and economical and practical considerations on the other hand. At the small scale level (<2000 persons), there are thus no specific requirements on how much water quality must be improved or on effluent concentrations. It is clearly stated, however, that no sanitary nuisances are acceptable.

Barva Park is situated in the municipality of Eskilstuna and it is the Committee on Environmental Protection and Public Health of the municipality that has the inspection responsibility of the sewage treatment facilities. It is thus the responsibility of this authority to determine which costs are reasonable and what effluent water quality is necessary in order to fulfil the hygienic and environmental objectives stated above. The municipality requires a presentation of advantages and disadvantages of different technical solutions based on requirements for hygienic aspects, protection of receiving waters, recirculation potential, economy, energy, maintenance and user aspects.

Hygiene and disease protection

In order to avoid the spreading of diseases, outgoing water from sewage treatment should not create sanitary risks for the surroundings.

A reasonable requirement for effluent water is that it should meet hygienic standards for bathing water at the point where it is freely exposed to the public and/or terrestrial animals. To achieve such a high level of hygienisation, water from treatment must either be diluted in a big recipient or post-treated. Post-treatment (polishing) is often the most feasible option for small facilities. Typically, polishing is combined with the system outlet and constructed as a gravel ditch or a small wetland densely covered with grass or other macrophytes. The commission of the European Union has proposed new regulations for bathing water and the hygienic quality standards stated in that proposal are given in table 1.

Table 1. Microbiological parameters for the assessment of bathing water quality. EC Proposal for a Directive concerning the quality of bathing water, COM (2002)581 final.

	Excellent water quality	Good water quality	Methods of analysis
Intestinal Enterococci (I.E) in cfu/100 ml	100*	200*	ISO 7899-
Escherischia coli (E.C.) in cfu/100ml	250*	500*	ISO 9308-1

*Based upon 95 percentile evaluation

Groundwater is regarded as “food resource” and should be protected from microbial contamination as far as possible. It is therefore preferable to use surface water instead of groundwater as recipient. Infiltration as a means to treat wastewater should thus be avoided. Even though the houses in Barva Park will be supplied with water from a communal water supply, it is important that the groundwater is preserved from microbial impact of sewage water. Furthermore, there is a water supply just north of the exploitation area that should not be affected by the new settlement.

The wastewater treatment system should not cause nuisances such as smell, within the houses as well as outside. Rest products, e.g. sludge or source-separated fractions, must be handled in a hygienically safe manner.

Terms of Requirement for Barva Park

Hygiene and disease protection

All parts of the system and its management must reach a high level of hygiene and disease protection:

- High hygienic standard within all components in the system
- Wastewater should reach the standard of bathing water quality where it is directly exposed to the public and terrestrial wildlife.
- Collecting, transport and disposal of end products must be managed in a hygienically safe manner.

Water Protection

Ground water should not be used as recipient. Before discharge to surface waters the following elements must be reduced (calculated from what is produced in the system) to at least:

- Phosphorous: 50 % - 90%,

depending on recipient quality and size of the treatment facility (requirements on concentrations if justified by recipient quality)

- Nitrogen: 25%

(nitrogen should be transformed to nitrate.)

- BOD7: 90 %

Recycling

There must be realistic potential for recycling, to at least the following levels:

- Phosphorous: 50 % <u>or</u>
- All nutrients: 25 %

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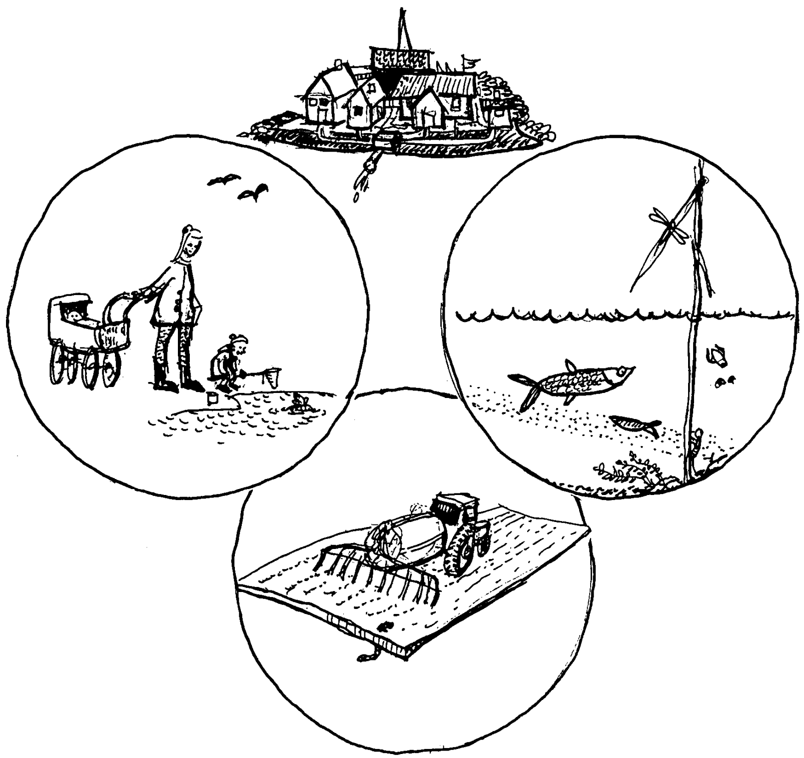


Figure 3. The three primary objectives of wastewater treatment; prevention of the spreading of diseases, protection of the environment and recirculation of nutrients.

Recipient protection

In Sweden, no specific requirements for wastewater effluent are stated in the Environmental Code. Instead, the BAT-principle is used to determine which reduction requirements are reasonable in the specific case. National requirements and common practice as well as local conditions are taken into account when setting the requirements. Today, it is generally reasonable to demand a reduction of at least 75% for phosphorous and 90% for BOD from households not connected to municipal sewage treatment. Requirements for nitrogen reduction are based on conditions in regional and local recipients. A 50% reduction of nitrogen is generally required in coastal areas, but in the inland areas no general requirements are set. In Barva Park, a total nitrogen reduction of 25% is suggested. Neither national, regional or local conditions motivate higher requirements. However, it is desirable that nitrogen is discharged to the recipient as nitrate. If it is discharged as ammonia, a lot of oxygen will be consumed when it is transformed into nitrate in the recipient, which can result in oxygen deficiency. The presence of nitrate protects the water from becoming anaerobic, thus preventing smell and the forming of sulphuric acid and methane.

Infiltration has previously been the favoured method for wastewater treatment in single households in Sweden. There are, however, several reasons why surface water should be preferred as recipient over groundwater. As previously stated, microbial contamination of groundwater should be avoided. When surface water is used as recipient, it is easier to make reliable measurements of effluent water quality. Changes in the groundwater-soil system are slow and difficult to observe, which means that it may take a long time before negative impacts on groundwater are detected. By then it may be too late for remediation, even if the contamination source is removed.

Recycling

In order to achieve a system that is environmentally sustainable in the long term, nutrients present in wastewater should be recycled back to agricultural land. The main plant nutrients in sewage water are phosphorous, nitrogen, potassium and sulphur. Among them, focus is mainly placed on the recycling of phosphorous, which is especially important since it often is a growth-limiting nutrient and the mineral reserves of phosphorous are limited.

Nutrient recovery from wastewater has not been an issue in European wastewater treatment during the major part of the 20th century. This matter has only started to get attention during the last decade or so, which means that recycling systems still are under development. Although there are several treatment techniques that allow for nutrient recovery, there are nonetheless issues of organisation and logistics (e.g. concerning the handling of rest products) and public acceptance to resolve before recycling of nutrients in wastewater becomes widespread.

The Swedish Environmental Agency has adopted a long-term strategy with the objective of returning nutrients in wastewater to the soil, where they are needed, without creating health hazards or environmental problems. Some municipalities in Sweden now require 50% recycling of all nutrients from wastewater treatment systems outside centralised wastewater collecting systems.

On a European level, the recovery of nutrients from wastewater is not yet on the legislative agenda. But European Union environmental policy is under development, and it is possible that nutrient recycling will be included in the objectives for wastewater treatment in the future.

BAT makes it possible also for one-family facilities to reach the level of 75% recycling of phosphorous today or in the near future. For Barva Park, however, when balancing resource management against economical and practical considerations, a reasonable requirement is at least 50% recycling of phosphorous or at least 25% recycling of all major plant nutrients.

Energy and materials

The wastewater treatment should economise with natural resources and try to attain low use of energy and use renewable energy sources. As the energy consumption for treatment of sewage is of minor importance compared to sanitary aspects and nutrient discharge, no standards on use of energy and materials have been made in the Terms of Requirement.

Legislation of the European Union

Sewage treatment in the European Union is regulated by the Water Framework Directive (Directive 2000/60/EC) and by the Urban Wastewater Treatment Directive (Directive 98/15/EEC).

The Urban Wastewater Treatment Directive (UWWTD) regulates wastewater discharge from agglomerations of more than 2000 people. Requirements are given as effluent concentration limits of the parameters biological oxygen demand (BOD), chemical oxygen demand (COD) and TSS (total suspended solids). Limits for total phosphorous and total nitrogen are only given for areas that are classified as sensitive and subject to eutrophication. Minimum percentages of reduction are also given for the parameters, which in sensitive areas are 80% and 70-80% for total phosphorus and total nitrogen, respectively. A comparison between the UWWTD and requirements set up in this study is given in table 2.

Wastewater treatment for communities of less than 2000 inhabitants is not specifically regulated in European Union legislation. However, the Water Framework Directive states that all member states are obligated to implement sufficient measures so as to prevent deterioration of surface water and groundwater status. The starting point of the directive is the protection of both human health and of ecological quality and its objective is to improve the overall quality of European waters. Good water status of both surface and groundwater should be achieved before 2015. In the Water Framework Directive, it is also stressed that member states are obligated to ensure that polluters of water resources use the Best Available Technology (BAT) in order to reduce the environmental impact.

Good surface water status means both good ecological status and good chemical status. The definition of good ecological and chemical status is given in detail in the directive. For e.g. nutrients, high status is defined as nutrient concentrations remaining within the range normally associated with undisturbed conditions. Good status is achieved when nutrient concentrations do not exceed the levels established so as to ensure the functioning of the ecosystem.

Table 2. Comparison between the Urban Wastewater Treatment Directive and requirements set up in this study.

	Case study	UWWTD 5- 2 000 pe	UWWTD 2 000 – 10 000 pe	UWWTD 10 000 – 100 000 pe
Hygiene	Demands set up for protection: - In the system - When discharging water - When managing rest products	-	-	-
Recipient	P > 50 % N > 25% COD > 90% 40 – 100 kg O_2/pe, year	-	P - N - COD >80% 225 kg O_2/ pe, year	P* >80% N* >75% COD > 90% 60 kg O_2/pe, year
Recycling	P > 50 % alternatively N P K S >25%	-	-	-

*Stated requirements are for areas classified as sensitive and subject to eutrophication.

Adaptations to the local situation

For any single-family home wastewater treatment system to be successful, it has to be well adapted to local circumstances. In order to achieve a successful recycling of nutrients, co-ordination and co-operation with local farmers is required.

Planning prerequisites for Barva Park

In Barva Park, a private company is developing a new housing area with 25-30 houses. It is situated in the countryside, far from the municipal sewage collection system and connection to a municipal treatment plant is therefore not possible. The target group of the housing company is horse-owners, and the area will thus include stables and fields for pasture. An aerial photograph of the area with a sketch of the planned housing area is given in figure 2.

The area is of about 8 hectare and consists of agricultural land with pastures and open fields. The pastures are undulating with alternating hills of boulders and flat areas with clay soil that used to be old arable land. The main part of the area is drained towards north-east through open ditches and culverts to lake Mälaren. A minor part of the area is dewatered towards south-west where the water is collected in a system of ditches that leads the water through a fire dam north to lake Mälaren.

In the area where most of the houses are planned, the earth layer is very shallow and the permeability is very low. Therefore the groundwater supply is low and unreliable and the housing area will receive drinking water from the municipal drinking water plant.

The main interest from the housing company is to find a wastewater system that is simple, functional and cheap for the house owners. Installations should be user friendly and should not involve restrictions in the use of the building. Transport and treatment of wastewater and waste products should be reliable. Environmental ambitions should be set high, but not lead to considerable extra costs.

The company prefers a pre-designed technique that is not directly dependent on local circumstances. This way, the company can feel confident that the wastewater treatment is possible to arrange on each site. Furthermore, application for permissions as well as projecting and construction of the sewage system is simplified.

The wastewater systems should be possible to build individually for each house. The reason for this is that it is not known how fast the houses will be sold. From a financial viewpoint, a stepwise construction of the wastewater system in pace with house sales is preferable. The company also wants to offer the customer the free choice of location of their house within the exploitation area, without being restricted by a planned group-wise exploitation of the area.

The possibility of using end products from the wastewater treatment as fertiliser in the fields of the housing area may be considered. Since horses will be living in the area, however, horse manure may be sufficient for fertilising the local fields. In that case, it is important to establish contact with farmers in the vicinity, in order to find an outlet for the rest products as to achieve sufficient recycling of nutrients.

Figure 4. Aerial photograph of the area, with a sketch of the planned housing area.

Practical considerations

As stated above, the primary objectives of wastewater treatment are the protection of human health and the environment. For those objectives to be fulfilled in the long term, practical aspects of the treatment system have to be considered.

Reliability

A basic requirement is that the system is technically reliable. This means that it is well tested and robust, and that the treatment objectives can be fulfilled all year around and for varying loads.

Economy

The sewage treatment should be feasible from an economical viewpoint. It is reasonable to demand that the cost of a private single-family sewage system should not exceed the cost for the municipal treatment in the area. The cost for connecting to the municipal sewage treatment plants in Sweden is normally somewhere between 6000 and 10 000 €. The following yearly charge is usually around 200–300 € per household.

User aspects

Sewage installations should fulfil basic requirements from the residents regarding comfort, user friendliness and maintenance. It should be possible to understand how the system works without an instruction. Installations should suit old people as well as children, handicapped and middle aged.

Irrespective of technical solution, it is essential that the residents use the system correctly. Therefore, information about the system is crucial. Water consumption and type and amount of detergents used are examples of factors that have large impact on function and efficiency of the system. Water fees can also have an effect on the behaviour of users.

Users should be able to feel confident that the treatment system will function as promised and that stated objectives are fulfilled. It is not sufficient to have a reliable system if the user perceives it as unreliable, unhygienic or deficient in any other way.

Flexibility

A flexible system can easily be adapted to changes in circumstances, such as changes in loads. Other flexibility aspects may be that the treatment system should be possible to construct for both single households and groups of houses, or that it could be built on various different sites.

Responsibility and control

Ownership and management of the sewage treatment facilities can be organised in different ways. One option is that each facility is owned and managed separately by each household. Each facility can also be owned separately by the household, but managed together with other facilities by all the owners. A third alternative is that a joint organisation (the municipality or a joint association) owns and manages the systems.

Private ownership requires less planning and co-ordination. But collective ownership facilitates projecting, construction and maintenance for the individual. The municipal supervisory authority gets a strong opponent to direct their demands towards. A co-ordinated management leads to a more effective operation and maintenance at the same time as it is easier for the supervisory authority to get their demands fulfilled. Irrespective of organisation form, it is important to define clear boundaries between private and collective responsibility and to assign a principal that can account for the performance according to the Terms of Requirement.

For practical and economical reasons, control of small sewage systems cannot be carried out in the same way as for big treatment plants. Instead, empirical data from carefully performed measurements on sewage systems or techniques in other places can be used to estimate the performance. To enable control of the treatment function, treatment facilities such as filters should be designed with a sampling point for outgoing water. For source separating systems, nutrient amounts and contents can be measured in collected urine solution or blackwater.

Practical requirements for Barva Park

Economics

- Annual costs should not exceed 1 000 Euro per household.
- Investment should not exceed 10 000 Euro per household
- Operation should not exceed 500 Euro per year and household

Reliability

Technology must be tested and robust, giving few surprises. It should function properly all year round and for varying loads.

Flexibility

It should be possible to construct the treatment system individually for each household. Preferably, the system should be able to adapt to increased loads.

User aspects

The system must be easy to use for all different categories of users. Technical components must not pose limitations on the use of the property.

Responsibility

Boundaries between private and common responsibility must be clear, as well as boundaries between the responsibility of the owner, the entrepreneurs and the supervisory authority.

Control

The proper function of the treatment system must be possible to verify.

How to calculate costs

Although health and environmental concerns set the most important requirements for wastewater treatment solutions, economical considerations often determine whether a treatment system is feasible or not. It is therefore crucial that the costs of the different alternatives are calculated properly.

First of all, total investment cost within the system for each alternative has to be calculated. After that, operation and maintaining costs are estimated. This is done by listing all components of the treatment and the management, and estimating the unit price and the total cost for each component. Table 3 can be used for this purpose.

To calculate the yearly cost, the investment costs have to be distributed over the amount of time before investments should be depreciated. The annual cost is thus the investment cost divided by the depreciation time (in years) plus interests. For the alternatives presented in this report, depreciation time is set to 25 years for treatment facilities and 50 years for pipes, interest to 6% and inflation to 2%. The following unit prices for cost estimation were used:

Emptying of sludge:	50 €/m^3
Emptying and spreading of urine:	40 €/m^3
Manpower:	35 €/hour

The total cost each year is the sum of the annual cost (depreciation + interest) and the management costs.

Table 3. Table for calculating costs

	Amount (units, days, m^3)	Unit price	Sum
Investment costs			
Toilet	__	__	__
Other equipment	__	__	__
Pipes	__	__	__
Flushing pipes	__	__	__
Inspection/flow splitter wells	__	__	__
Collection tanks	__	__	__
Septic tank	__	__	__
Materials for filter bed	__	__	__
Materials for disposal system			
Installation costs	__	__	__
Management costs			
Emptying of septic tank	__	__	__
Emptying of other tanks, such as tanks for urine or blackwater	__	__	__
Chemicals, service etc	__	__	__
Maintenance	__	__	__
Total cost			__

Figure 5. Economy is an important aspect to consider when choosing a wastewater treatment system.

Amounts of water and pollution

Amounts of water

Since the housing area is new, the exact number of persons in each house is not known at this stage. For planning purposes, it is assumed that the sewage system will receive wastewater from one family with children, living permanently in the house. This means a relatively high production of water and pollutants. The basis for dimensioning is that the household consists of four people with an average stay at home of 18 hours per day.

Dimensioning of technical components is dependent on water flows. With the installation of equipment especially designed for low water usage, the amount of greywater can be reduced to 80 l/p,d without influencing the behaviour of residents. This is the target for water consumption in e.g. modern eco-villages. However, to be on the safe side, the total water consumption in Barva Park is assumed to be closer to conventional levels. Dimensioning flows are given in table 4. Water saving equipment can be seen in figure 6.

Table 4. Flows per household

	Mixed wastewater[1]	Greywater[2]
Average flow	0.7 m^3/d	0.5 m^3/d
Maximum flow per week	1.0 m^3/d	0.8 m^3/d
Maximum flow per day	1.5 m^3/d	1.2 m^3/d
Maximum flow per hour[3]	200 l/h	150 l/h
Minimum flow per day	Approx. 0.2 m^3/d	0.2 l/h

[1] Calculated as 4 persons à 175 l/person (incl. leakage into pipes)
[2] Calculated as 4 persons à 140 l/person (incl. leakage into pipes)
[3] Maximum daily flow / 8 hours

The households in Barva Park are estimated to have an intensive use of lavatories, showers, dishwashers and washing machines, as the households include children and teenagers. On the other hand, the houses will be equipped with water saving devices and piping will be made in order to avoid leakage as much as possible. In discussion with the housing company, it was decided to use 175 l/p,d for system design.

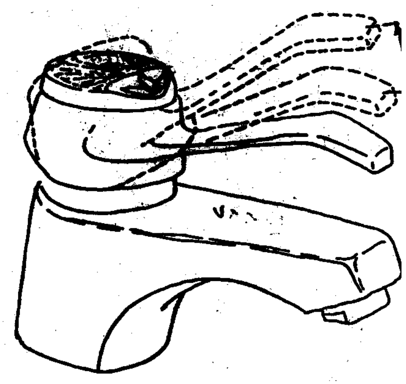
Amounts of nutrients and pollutants

The content of nutrients and pollutants in domestic wastewater, i.e. wastewater from households, depends on the behaviour of the residents. Factors that influence the wastewater composition are e.g. what kind of food the residents eat and which detergent and household chemicals they use. Since this is not possible to determine for each site, standard figures are used for dimensioning.

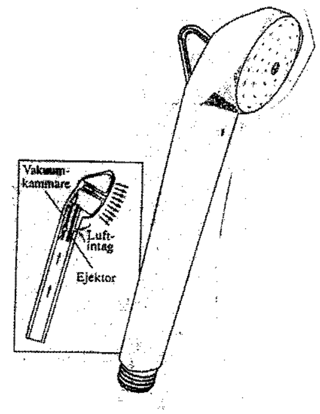
Domestic wastewater can be divided into three major fractions: urine, faeces and greywater. Most of the nutrients, about 80-90% of the total nitrogen and 50% of the total phosphorous in wastewater can be found in urine. At the same time the amount of pollutants and pathogens in this fraction is very small. The faeces contain approximately 25% of the phosphorous, a large amount of organic matter and almost all of the pathogens. Greywater amounts to about 75% of the total flow and contain only a small fraction of the nutrients, but a considerable amount of oxygen consuming organic matter. Total amounts of nutrients and pollutants as well as distribution between different sewage fractions for the households in Barva Park have been calculated with Swedish standard figures and are given in table 5.

Table 5. Distribution of nutrients and pollutants from one household (4 people) and for the fully established housing area (25 households). The table is based on standard values from the Swedish Environmental Protection Agency (4425).

Parameter	Content in different fractions			One household (80% presence)	Total Barva Park (25 households = 100 persons)
	Faeces	**Urine**	**Greywater**		
Pathogens	High	Low	Relatively low		
BOD – Biochemical Oxygen Demand kg/ household*year	9.6	4.8	42	45	1 100
Phosphorous kg/ household*year	0.8	1.44	0.2-0.7	2,2	55
Nitrogen kg/ household*year	2.2	16	1.3	15	380
Potassium kg/household*year	1.3	3.8	0.8	5	120
Heavy metals	Occurs	Negligible	May occur		
Organic pollutants		Negligible	May occur		
Water (incl. flush water) l/household*day	25-50	6-12 (of which urine 5)	500 - 1500		



(a)



(b)

Figure 6. Examples of water saving equipment: (**a**) mixer; (**b**) showerhead

Possible solutions

In new constructions, there is more freedom to choose between different types of solutions for the sewage treatment than in already built houses. All the installations have to be made from start and it is therefore an opportunity for choosing equipment with low water usage or for installing source-separating equipment, something that can be very expensive in already built houses.

There are advantages and disadvantages of both source separating and end-of-pipe treatment solutions. Separation of different wastewater fractions at the source facilitates nutrient recycling since nutrients are not diluted nor contaminated by heavy metals or organic pollutants in greywater. Treatment can also be more effective when greywater (or greywater together with faeces) is relieved from the nutrient rich urine and/or faeces fractions. However, source-separating systems require motivated users to function properly. End-of-pipe solutions do not require any major commitment of the users. But it is more difficult to obtain end products of high quality that will be of interest to farmers. For any treatment solution to be sustainable, whether it is end-of-pipe or source-separation, local farmers have to be willing to apply the nutrient-rich end products to their land.

Filter techniques for greywater or mixed wastewater

Whether using a source separating or an end-of-pipe solution, some kind of filter treatment for either greywater or mixed wastewater is needed in most cases. Infiltration has so far been the most common treatment method, but the use of groundwater as recipient for mixed wastewater is no longer considered appropriate. Instead, some kind of filter bed should be used.

For greywater, infiltration may still be acceptable but filter beds are preferred since it is hard to control the effectiveness of the infiltration. Different options for filter treatment of greywater or mixed wastewater are given in table 6. Before treatment in a filter bed, or infiltration, suspended solids and fat has to be removed in a septic tank.

Table 6. Filter treatment of source-separated or mixed wastewater*. All filter treatment requires prior solids removal in a septic tank.

Treatment	Greywater	Mixed wastewater*
Infiltration	Appropriate	Not appropriate
Sand filter bed	Appropriate	Appropriate
Sealed sand filter	Appropriate	Recommended
Sealed compact filter	Recommended	Appropriate

*Mixed wastewater has to be pre-treated, e.g. with precipitation, for the treatment system to achieve sufficient reduction of phosphorous.

Individual or collective solutions

In Barva Park, one of the initial requirements of the housing company was that sewage treatment should be built individually for each house. The reason for this was to enable a step-wise construction of treatment facilities in pace with house sales, which the company preferred from a financial viewpoint. The company also wanted to offer the customer a free choice of location of their house within the exploitation area, without being restricted by a planned group-wise exploitation of the area. With individual treatment systems, large investments in infrastructure such as pipes are avoided.

There are, however, some advantages of arranging the treatment system for a group of houses. Some co-ordination benefits can be obtained, e.g. in terms of equipment and tank volumes. For example, in source-separating systems, a common treatment facility for greywater can be built. Maintenance is simplified when there is only one treatment facility to attend to.

All solutions suggested in this report could also be built for a group of houses.

Solutions not fulfilling the Terms of Requirement

During planning, many possible solutions are discussed and compared to the requirements initially proposed. It is discovered that some solutions do not fulfil the Terms of Requirement and they are therefore discarded. This part of the process is generally not reported. However, finding out which treatment systems that are not suitable in a specific case is also a very important part of planning. Below, some solutions discarded for Barva Park are discussed.

One source-separating system did not fulfil the requirements. *Blackwater diversion with treatment of greywater in a compact filter* is a sewage solution where the blackwater is collected separately from the greywater, which is treated on-site. For the system to fulfil the requirements of nutrient recycling collected blackwater should be used in agriculture. This should take place locally in order to avoid long transports and keep costs down. However, blackwater contains pathogens and has to be treated before application to agricultural land. There are no local farmers interested in handling blackwater and thus the solution is not feasible.

Several end-of-pipe treatment solutions have been considered during early stages of planning. One of these solutions is the use of *a package treatment plant*. This treatment technique resembles the process in wastewater treatment plants, where the wastewater, after removal of solids in a septic tank, pass through a biological treatment step followed by chemical precipi-tation. The system is dependent on regular supply of electricity as well as chemicals and thus requires a lot of maintenance. This makes the solution less robust and reliable than desired, as well as too expensive. Effluent water does not fulfil hygienic requirements for bathing water and the water has to be lead through a polishing ditch before release to recipient.

Another end-of-pipe solution is the *treatment of mixed wastewater in a combined vertical and horizontal filter*. Mixed wastewater is led to a septic tank and thereafter through a filter bed. The water first passes through the vertical filter, which is equivalent to a normal compact filter bed. The horizontal filter is made up of phosphorous absorbing material, such as Norwegian leca. This technique was developed in Norway where it is used for both single households and groups of houses. It is not used for single households in Sweden, however. This treatment technique was discarded for Barva Park since it was considered to require too large an area and to be too expensive to construct individually for each household.

Chosen solutions

Four solutions fulfil the requirements for Barva Park, see table 7. Three of them are source separating and one is treatment at the end-of-pipe. Detailed descriptions of the solutions are given on the following pages.

Table 7. Principal solutions described in the report.

Alternative	Solutions	Described on pages
1	Urine diversion with dry handling of faeces, and treatment of greywater in a compact filter	20 – 21
2	Urine diversion with vacuum toilet and treatment of greywater in a compact filter.	26 – 27
3	Urine diversion in water closet and treatment of urine-relieved wastewater in a sealed sand filter	28 – 29
4	Mixed wastewater treatment with chemical precipitation, biological treatment in a sand filter and polishing in wetland/ditch.	30 – 31

Alternative 1. Urine diversion with dry handling of faeces, and treatment of greywater in a compact filter bed

The system is based on a type of toilet where urine is diverted in the front part of the toilet and flushed with a small amount of water. Faeces and paper falls without water from the rear part of the toilet to a ventilated collection container, placed directly below. The treatment system is illustrated in figure 7.

Urine, containing most of the plant nutrients, is collected in a closed tank and can be used as fertiliser. The faecal fraction (faeces and paper) is the infectious fraction of the sewage water. By drying it in the collection chamber, smell and pathogens are reduced. After drying, the waste product can be burnt or composted for later use in the garden, or by a farmer.

As urine and faeces are collected separately, the remaining water is relieved from most of the nutrients and pathogens. This grey water is therefore rather harmless from an environmental viewpoint and can be treated in a compact filter bed (see next spread).

Engineering and dimensioning

A urine-diverting toilet in vitreous china is used for diverting urine and faeces, see figure 8. There are also simpler products in plastic. Collection of faeces takes place in an airtight space where the container is placed. This space is preferably placed below the system of joists, if possible in the basement, with a service hatch to reach the containers from the outside. In Barva, where plans are to build houses on a concrete slab, the space should be arranged below the slab and accessible for service and replacement of containers. The space should be drained and ventilated, and a downfall-pipe for faeces and a urine pipe should go through the slab.

The urine solution is led in gravity sewers to a collection tank, preferably located in the same place as the septic tank for grey water. The design and size of the storage volume should be dimensioned to ensure security against overloading and a suitable emptying interval (e.g. one year). If the urine solution is to be used locally as fertiliser, a minimum storage time of 6 months, undisturbed, should be guaranteed on site. Thus, for storing on site, two volumes are needed – one, which is being filled, and one that is full and stored for six months. If a farmer will spread the urine, the final storage can take place at the farm.

The amount of urine solution produced is estimated to approx. 1.3 l/pd, with the assumption that residents are at home 15 hours a day. The total amount of urine solution produced in a household of 4 persons is therefore almost 2 m^3/year. The tank is placed below ground and filled from the bottom to avoid unnecessary loss of ammonia. The tank should not be ventilated. To avoid repletion, it should be equipped with an alarm.

Flexibility and user aspects

Technical components for dry urine diversion are simple and robust, and can be built individually for each household. Correct installation is important to prevent leakage of water into the tank. The residents should be well informed of how to use the system, e.g. how to keep flush water amounts down, and how to avoid smell and flies in the faecal containers.

Handling of end products

The total production of urine in Barva Park when fully established (ca 100 persons) is approximately 50 m^3 annually. Urine is a good inorganic fertiliser, and nutrient production is estimated to about 300 kg N and 40 kg P per year, sufficient for 3-4 hectares of cereal production. The urine can be used locally within the agricultural fields and pastures of the horse farm. The urine can also be used within other agriculture. In the municipality where Barva Park is located, a system is being developed for handling and spreading of human urine.

Changing of collection chambers for faecal matter is preferably done by the homeowner. Collection of filled containers, however, for composting and final disposal, can be done centrally. The annual production of faecal matter is about 40-80 kg per household.

Possibility of fulfilling the requirements

Reliability	Toilet system: Well-tested, simple technique, tolerant for peaks in load. Grey water: Treatment with septic tank and filter bed is a conventional technique, reliable if proper solids removal in the septic tank is assured.
Economy	The cheapest of the systems presented. Investments: approx. 6000 € Maintenance: approx. 200 € per year
Responsibility and control	Samples can be taken on effluent from the filter bed.
Sanitary aspects	Low risk. Urine is virtually pathogen free, at least after 6 months storage, and can be spread without sanitary risks. As the faecal matter is removed, most pathogens are removed. The remaining grey water contains comparatively little pathogens.
Reduction and recycling	Very high reduction and a high potential for nutrient recycling. By collecting urine separately, about 60% of phosphorous and 80% of nitrogen in household wastewater is removed. With the faecal matter, 20% P and 10% N is removed. A major part of the nutrients in urine and faeces can be recycled back to agriculture. In the grey water treatment especially BOD is removed, but also further nutrients.

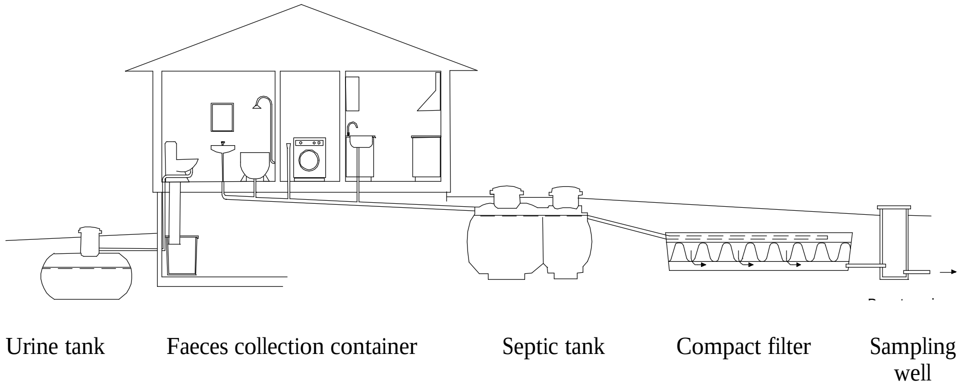


Figure 7. Schematic description of the system for alternative 1.

Figure 8. Example of a urine-diverting toilet with dry handling of faeces.

Greywater treatment

Greywater has a relatively low content of pathogens and nutrients. However, it contains a fair amount of oxygen consuming organic matter that needs to be removed in treatment. In this treatment system, greywater is pre-treated in a septic tank before treatment in a sealed compact filter. The compact filter is illustrated in figure 9.

When compact filter technique is used for treatment of greywater, a better spreading of the water and a better oxygenation is obtained, which creates a safer biological process. A fine geo-textile (artificial filter media) is used in the filter, which forces the wastewater trough tiny holes. The beneficial microbes in the biofilm on the surface of the textile will thus have close access to the organic matter and pathogens in the wastewater, which enhances the degradation of organic matter and the elimination of pathogens.

Engineering and dimensioning

The grey water is led in gravity sewers to a septic tank where solids and fats are removed. It is important that the septic tank functions properly in order to avoid clogging of the subsequent treatment steps. The outlet from the tank should be constructed in such a way as to prevent fat and floating material, as well as settled matter, from leaving the tank. A filter on the outlet pipe, e.g. a polyethylene screen, is one way to increase the efficiency of the septic tank in removing suspended solids. A septic tank of 1 m^3 could be sufficient for one household but to secure high degree of suspended solids removal, a tank with a volume of 2 m^3 is recommended.

The area needed for a compact filter bed is calculated from hydraulic load and BOD-load. If the dimensioning flow is 800 l/d and maximal hydraulic load is 125 mm/d during shorter periods, the required surface area is about 6 m^3.

The artificial filter media consist of folded geo-textile sustained on PE-plastic, thus creating valleys and ridges. The construction is based on the idea of so called *controlled clogging,* which means that the bottoms are clogged but infiltration takes place at the walls, see figure 9. The artificial filter media is placed on a layer of well sorted washed sand with a thickness of at least 0.3 m with drainage at the bottom. The entire compact filter should be placed above the groundwater surface. Partial infiltration to groundwater is acceptable. Effluent water is led to system for storm water run-off (see next spread). A sampling well is placed at the outlet.

Flexibility and user aspects

Once located, the septic tank volume can not be increased. The compact filter bed can be somewhat overdimensioned, in order to allow for future increases in load.

This treatment technique has a limited reduction of phosphorous, and it is thus crucial that only phosphate free detergents are used in the household. Toxic chemicals should not be used, since they may have a negative impact on biological activity in the compact filter.

The septic tank should be monitored every two to four years and emptied when necessary. The compact filter should not require maintenance during its effective lifetime, which is at least 15 years.

Handling of end products

Sludge from septic tanks is collected by an entrepreneur. It has a low nutrient content and is of little interest for agriculture. The sludge can be transported to a sewage water treatment plant, or disposed of in e.g. vegetation-covered drainage beds.

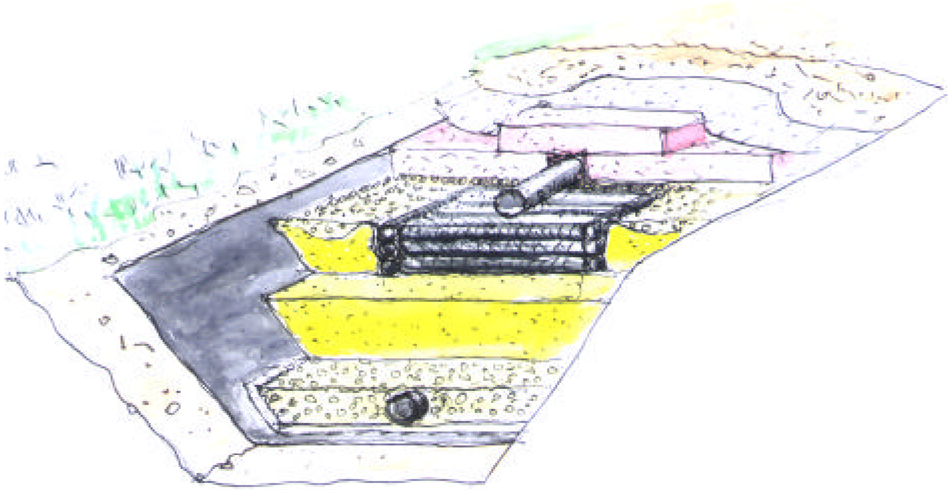


Figure 9. A schematic view of the compact filter used for greywater treatment.

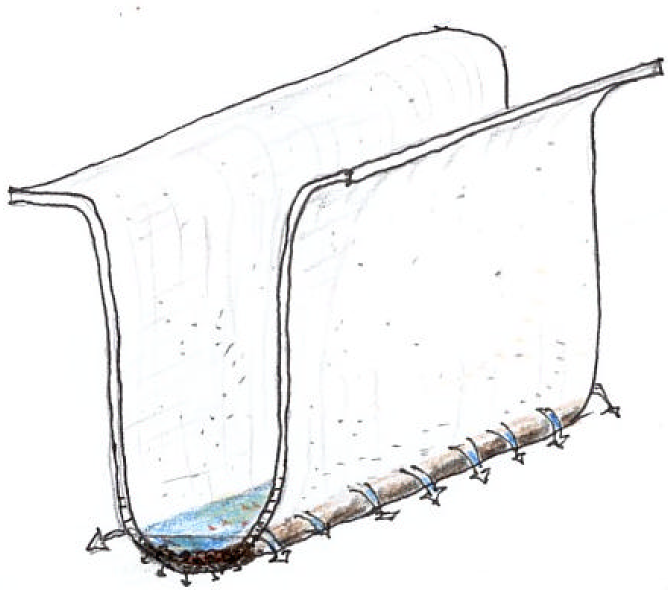


Figure 10. Section of an artificial filter media in the compact filter (as seen in figure 9) built up by foamed geotextile. Water is distributed horizontally by so called controlled clogging

Outlet for effluent water

After treatment in the filter bed, outgoing water has to be discharged into a recipient. The technical solution for this is fairly straightforward, but nevertheless has to be considered when planning the wastewater treatment.

In Barva Park, owners of the neighbouring property to the new housing area were concerned that the effluent water would turn their lands into swamps. Therefore, a detailed plan for the outlet had to be presented to the supervisory authorities.

From the filter bed, the water is led through an infiltration ditch down to an open storm water ditch, which is located on public property, outside the private housing area. Effluent water from wastewater treatment is thus run off together with storm water to a local recipient, which in this case is Lake Mälaren. This is illustrated in figure 13. The total amount of effluent water from the housing area when fully established (30 households) is maximum 0.2 – 0.3 l/s. Storm water runoff from the area is roughly 0.7 – 1.0 l/s. Thus, the effluent from wastewater treatment will not have a major impact on run-off water volumes.

The infiltration ditch is used as a buffer and compensation reservoir, and is described in figure 11. A drainage pipe of the type used for drainage in agriculture is placed in the ditch with macadam around it. The macadam layer below the drainage pipe should be at least 0.1 m. The ditch is then refilled.

The open storm water ditch is illustrated in figure 12. It is lined with a geo-textile over which a drainage pipe is placed. The pipe should be surrounded by sand. A layer of macadam is placed over the sand. The sides of the ditch should be sloping and the grass growing on the sides should be cut.

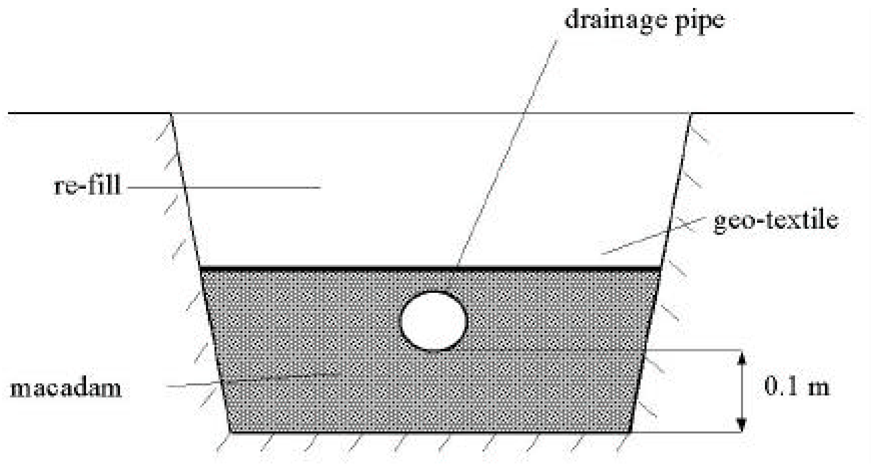


Figure 11. Infiltration ditch

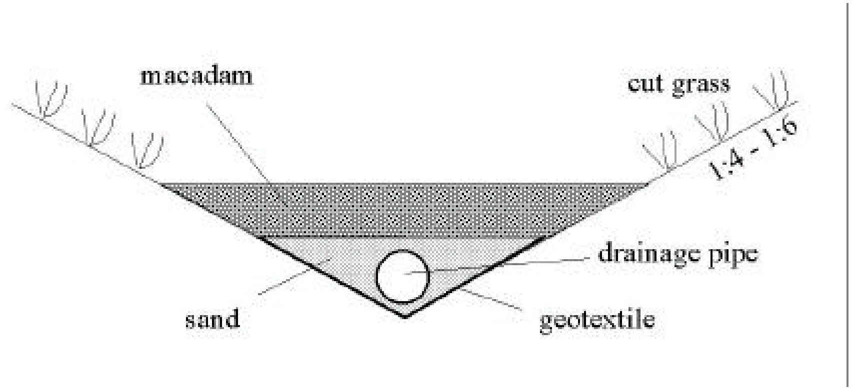


Figure 12. Open stormwater ditch

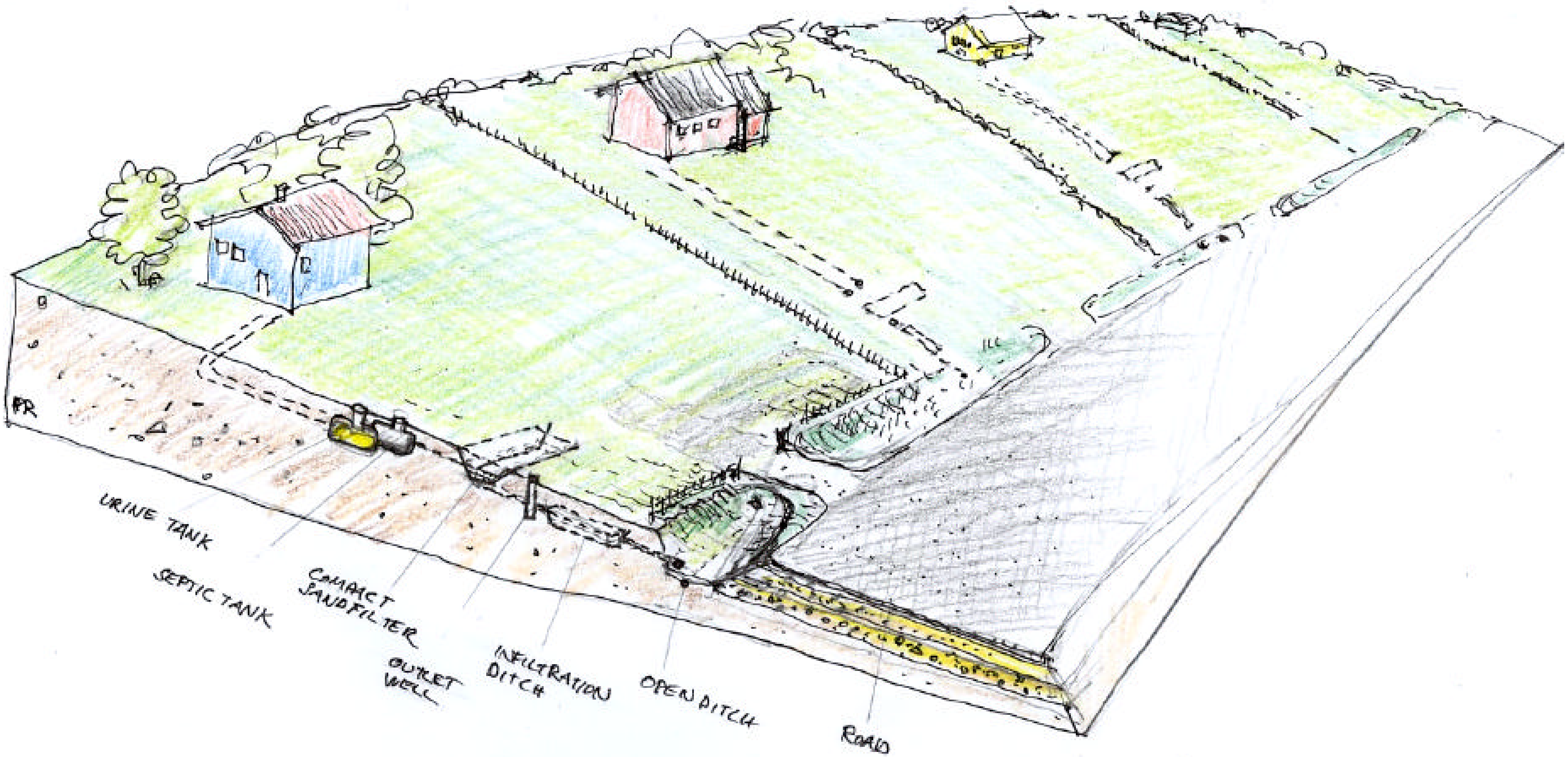


Figure 13. Design of the outlet of treated wastewater for the housing area in Barva Park.

Alternative 2. Urine diversion with a vacuum toilet and treatment of grey water in a compact filter bed

In this system, a new type of extremely low-flush toilet, based on urine diversion with vacuum flushing of faeces, is used. The urine and faecal fractions are collected individually. The system allows organic waste from the kitchen to be transported with vacuum and collected together with the faeces fraction. The treatment system is illustrated in figure 14.

As urine and faeces are collected separately, the remaining water is relieved from most of the nutrients and pathogens. This grey water is therefore rather harmless from an environmental viewpoint and is treated as described in alternative 1.

Engineering and dimensioning

The system is possible through a new type of toilet available on the market in Sweden, see figure 15. The toilet is made of vitreous china. Urine is diverted in the front bowl and faeces together with paper and a small amount of water is flushed down in the rear bowl. Urine is flushed in gravity sewers to a collection tank as described in alternative 1.

The vacuum generator that sucks the faecal water is located directly on the collection tank, which normally is a closed tank placed underground. The dimensioning is based on an estimated yearly production. For one household in Barva, it is assumed that 8 flushings (of 0.5 l) are done on average per day. Consequently, the required storage volume is at least 1.5 m^3. If organic waste from the kitchen is included, a larger storage volume is needed.

For description of the urine separation, see alternative 1.

Flexibility and user aspects

The system can be built individually for each household. The distance between toilet and collection tank for faecal water should not exceed 25 m and the pipes for urine should neither be too long, in order to avoid clogging. The grey water, however, can be led long distances in gravity sewers or e.g. to a communal greywater treatment. The water should be mechanically treated before pumping.

When the system is built, it is difficult to increase volumes and areas. It is therefore important that installations are dimensioned correctly and with an extra margin. The residents must be informed on how to use the system correctly, especially to not flush the toilet unnecessarily.

Handling of end products

Total volume of faecal water from Barva Park, when all houses are established, can be estimated to approximately 40 m^3. This water contains about 20 kg phosphorous and 60 kg nitrogen. If organic household waste is added, the amounts are more than doubled.

The faeces-containing water can be used in agriculture or other crop production, e.g. energy forest. It must, however, be hygienised before use. The willingness of farmers to utilise this water cannot be taken for granted. It is therefore important to investigate the possibilities of recycling the faecal water before choosing this sewage solution.

The handling of urine and end products from grey water treatment are described in alternative 1.

Possibility of fulfilling the requirements

Reliability	Technique not tested, few installations made. Grey water: see alternative 1
Economy	Investments: approx. 7000 € Maintenance: approx. 200 € per year
Responsibility and control	Samples can be taken on effluent from the filter bed.
Sanitary aspects	Low risk. Urine is virtually pathogen free, at least after 6 months storage and can be spread without sanitary risks. As the faecal matter is removed, most pathogens are removed. The remaining grey water contains comparatively little pathogens. Faecal water has to be treated before application on agricultural land.
Reduction and recycling	Very high reduction and a high potential for nutrient recycling. By collecting urine separately, about 60% of phosphorous and 80% of nitrogen in household wastewater is removed. With the faecal matter, 20% P and 10% N is removed. A major part of the nutrients in urine and faeces can be recycled back to agriculture. In the grey water treatment especially BOD is removed, but also further nutrients.

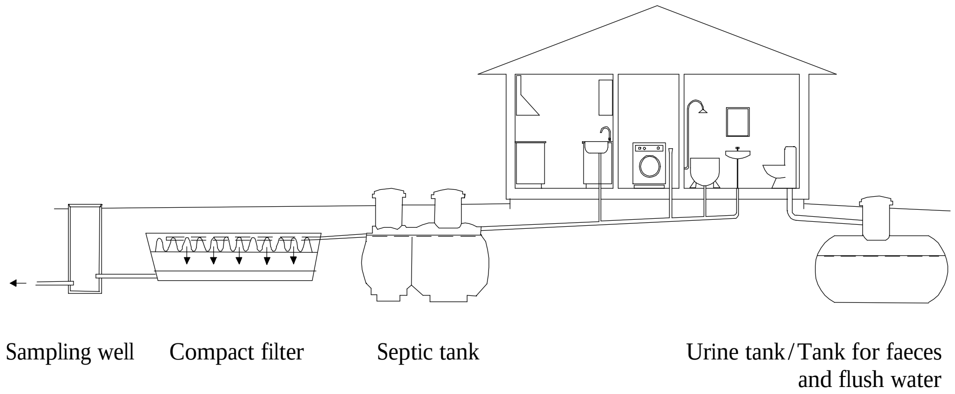


Figure 14. Schematic description of the system for alternative 2. *Note that the urine tank and the tank for faeces and flush water should be two separate tanks with separate pipes from the toilet.*

Figure 15. Example of a urine-diverting vacuum toilet.

Alternative 3. Urine diversion in water closet and treatment of urine-relieved wastewater in a sealed sand filter bed

The system is based on a double-flushed urine-diverting water closet. Urine is diverted to the front bowl and flushed with a small amount of water. Faeces and paper are flushed as usual with 3-4 litres of water. In this system, only the urine is collected in a tank. The faecal fraction is piped together with the grey water to treatment. The treatment system is illustrated in figure 16.

A major part of the plant nutrients in household sewage emanates from urine. By initially diverting the urine, the wastewater is relieved from a large part of nutrients. As urine is nutrient-rich and contains very low amounts of pathogens, it is very good as fertiliser. As precaution, however, the urine should be stored for six months, to kill of any pathogens that still may exist.

The remaining wastewater contains high levels of BOD and pathogens, and also some nutrients. An appropriate treatment for this is an aerated biological filter, e.g. a sand filter bed. The water is first pre-treated in a septic tank, and then led to the filter bed.

Engineering and dimensioning

Today, there are three manufacturers of double-flushing urine-diverting water closets in vitreous china in Sweden (with some different models). One example is shown in figure 17. In Germany and Norway double-flushing toilets are also accessible on the market (see information list in the end of the booklet). The urine is led in gravity sewers to a collection tank, which should be placed adjacent to the septic tank for the remaining wastewater. See alternative 1 for further description of how to handle the urine fraction.

The amount of produced urine solution with this system is estimated to slightly more than in alternative 1. A suitable storage volume is 3 m^3 for a yearly production in one household.

The urine-relieved wastewater can be treated in several different ways. For Barva Park it is advisable to use technique that can be applied independently of the conditions at the site.

A sealed sand filter bed is suggested as the primary alternative, since it fulfils the above requirement. The technique is similar to the one described in alternative 1, with the difference that the water after biological treatment is filtered through a layer of sand. This is needed to increase the separation of pathogens, and for adsorption of remaining phosphorous. Since the area needed for the filter bed is calculated from hydraulic load and BOD-load and the loads will be higher for mixed wastewater than greywater, the filter area will be larger than for the compact filter in alternative 1.

Flexibility and user aspects

Technical components are simple and robust. The system can be built individually for each household, or together for a group of households. When building on larger scale, some co-ordination benefits can be made.

Users have to be informed how to use the toilet, as to ensure separation between urine and faeces in the toilet. Phosphate detergents and harsh household chemicals should not be used.

Handling of end products

Total yearly production of urine solution from Barva Park when fully established is just above 60 m^3. Handling of the urine is described in alternative 1.

Sludge from septic tanks (app. 75 m^3 in total for the whole Barva Park) is collected by an entrepreneur. This sludge can be used in agriculture, provided that the content of heavy metals and other pollutants is low. It is of little nutrient value, though, and there might not be much interest for this product among farmers. If so, the sludge can be disposed of in a sludge drainage bed or in a sewage treatment plant.

Possibility of fulfilling the requirements

Reliability	Toilet system: The technique is well tested, many installations are made in single-family households as well as in block of flats. Treatment: Sandfilter is a conventional technique, but sealed sandfilter beds are quite new.
Economy	Investments: approx. 6000 € Maintenance: approx. 200 € per year
Responsibility and control	Samples can be taken on effluent from the filter bed.
Sanitary aspects	Important to treat mixed wastewater sufficiently. A polishing ditch is therefore added before releasing the water into receiving waters. Urine is virtually pathogen free, at least after 6 months storage, and can be spread without sanitary risks.
Reduction and recycling	High reduction and high potential for nutrient recycling, although not as high as in alternative 1 and 2. By collecting urine separately, about 60% of phosphorous and 80% of nitrogen in household wastewater is removed, and can be recycled back to agriculture.

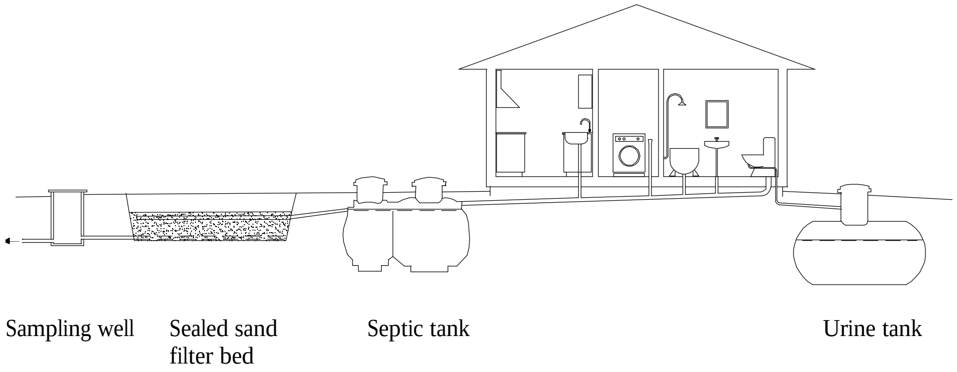


Figure 16. Schematic description of the system for alternative 3.

Figure 17. Example of a double-flushed urine diverting toilet. There are several different models available on the market.

Alternative 4. Mixed wastewater with treatment through chemical precipitation, biological treatment in a sand filter bed and polishing in wetland/ditch

In this system, all wastewater from the house is mixed and piped to a septic tank followed by a sand filter bed. This system is very common in Sweden. However, to achieve a high phosphorous reduction and make recirculation of this nutrient possible, precipitation chemicals are added to the system. This produces an extra amount of phosphorous rich sludge, which is collected in the septic tank.

The chemical precipitation also helps to remove BOD in the septic tank thus liberating capacity for further biological purification in the filter bed. Besides BOD and pathogen removal, efficient nitrification can be expected. In the subsequent polishing ditch, pathogen levels are reduced still more and a further reduction of nitrogen occurs through denitrification. The treatment system is illustrated in figure 18.

Engineering and dimensioning

Conventional toilet and pipe system is used. Dosage of precipitation chemicals takes place indoors, directly into the pipe system. The dosage unit is placed e.g. below the kitchen sink, or in the laundry room, where it is connected to a water pipe, sewage and electricity. A container for liquid chemicals (aluminium chloride) is placed in connection to the dosage unit, see figure 19.

The dosage can be made related to, e.g. water flow, toilet flushings, or a fixed time schedule. In this example, dosage is based on estimated flows and habits of the family.

It is important that the septic tank is large enough to make precipitation and sedimentation possible even at high flows. Also, a larger volume than usual is needed for sludge storage. A septic tank volume of at least 4 m^3, e.g. in two connected tanks, is recommended.

For treatment of the pre-precipitated mixed wastewater, a sand filter bed (described in alternative 3) is recommended.

Flexibility and user aspects

The chemical dosage is made according to a programmed time schedule, which can easily be adjusted by a service technician to meet new circumstances. The pipe system, septic tank and filter bed are not flexible, and have to be built for maximum load from the beginning.

It is very important that the chemical container is changed when empty. If flows or habits of the family change, chemical dosage has to be adjusted. Experience show that this system requires regular service by a professional and a service agreement should therefore be made before the system is taken into use.

Handling of end products

The waste product from this system is chemically precipitated primary sludge. In total, about the double volume is produced, compared to the same system without chemical treatment. The sludge has a high water content, but the amount of phosphorous is high (approximately 5 % of dry matter).

The phosphorous-rich sludge can be used in agriculture. As it contains faecal matter, and hence pathogens, it needs treatment, e.g. storage or composting, before use. It is uncertain if any farmer is interested in spreading this product from mixed sewage on his fields, since it is not as clean as urine or blackwater regarding e.g. heavy metals and remains of detergents. Moreover, it is only rich in phosphorous and not in other nutrients.

Possibility of fulfilling the requirements

Reliability	Toilet: the system is conventional and well-tried. Chemical precipitation: New technique, few installations made. The product has been tested and evaluated in a Swedish research project with good results*. The large septic tank and filter bed act as buffer. Therefore, operation disturbances in the pre-treatment can be tolerated without risking the treatment results. Treatment: if septic tank is not large enough and not emptied when needed, there is a risk of floating sludge clogging the filter bed.
Economy	Investments: approx. 6000 € Maintenance: approx. 300 € per year
Responsibility and control	Samples can be taken on effluent from the filter bed. Sampling can also be made on sludge, to decide if the precipitation is functioning as planned.
Sanitary aspects	Small risk on-site. Treatment in sand filter beds is a more effective method than e.g. sewage treatment plants. With pre-precipitation and a polishing ditch, the pathogen removal is enhanced further. Risks in connection to handling of the sludge are the same as for ordinary sludge from septic tanks.
Reduction and recycling	High reduction and potential for nutrient recycling. The removal of BOD and nitrogen is dependent on the quality of the filter bed, while most phosphorous is removed in the septic tank. Reduction achieved in this system is 95% of phosphorous, 50% of nitrogen and 95% of BOD. A major part of P in the wastewater can be recycled back to agriculture.

*Bra Små Avlopp – Small wastewater treatment systems. Project run by Stockholm Water 1999- 2002.

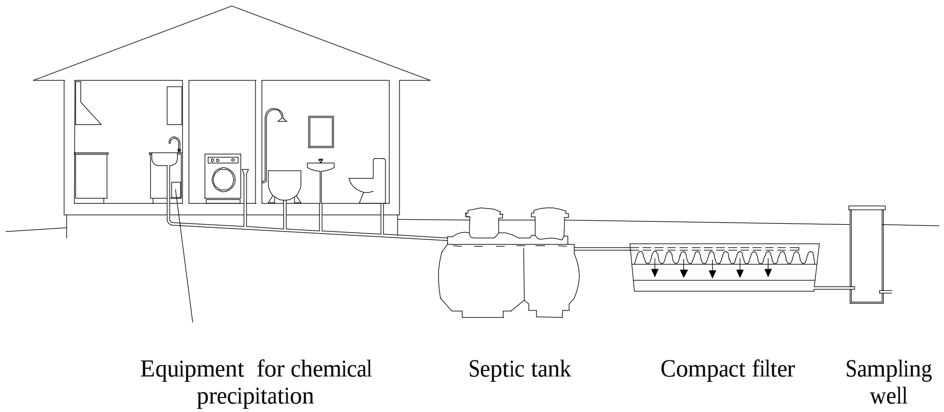


Figure 18. Schematic description of the system for alternative 4.

Figure 19. Equipment for chemical precipitation installed within the house.

Comparison between the solutions – the decision in Barva Park

The four solutions described above all fulfil the Terms of Requirement. In order to select one final solution, all positive and negative aspects of the different systems are gone through. Below, these aspects as well as the views of the housing company are presented.

Alternative 1: Dry urine diversion and sealed (compact) filter.

+	-
• Robust technique • Very efficient in terms of nutrient and pathogen removal. • High nutrient recycling potential. • Direct feedback to user prevent misuse of the system	• Handling of faeces must be done in a rational way, if not residents will disapprove. • Need user participation for taking care of the faecal matter.

The housing company considered urine diversion with dry handling of faeces as less suitable based on the belief that users would see the system as not modern and comfortable enough. Also, houses should be constructed with a concrete slab. The construction of a special service space below the house was seen as complicated and a limitation in house planning and design.

Alternative 2: Urine diversion with vacuum and sealed (compact) filter

+	-
• Flexibility in house planning and design. • High reduction of nutrients and pathogens • High recycling potential	• Little experience of the technique • Investment costs are higher than for the other alternatives. • Three fractions to handle

The housing company found this solution interesting, but since there are three fractions to collect and experiences from the technique are limited, the solution was disqualified. However, vacuum technique could be a valuable option for system no 3, if topography and house plan made collecting liquids by gravity difficult.

Alternative 3: Wet urine diversion and sealed sandfilter

+	-
• A well-tested technique • Good potential for recycling of nutrients • Several different manufacturers of toilets on the market	• Urine-relieved wastewater contains pathogens, thus urging sealed and high efficient purification. Precaution for hygienic security raises costs. • If not used correctly, reduction and recycling potential is lower.

Urine diversion in water closets was the alternative that the housing company found most interesting. The double flush toilets were considered modern and comfortable enough and the system quite simple since there are only two fractions (urine and sludge) to manage. Important for choosing this system (before e.g. no 4) was that urine is accepted in agriculture. Entrepreneurs and fields for fertilising could be found locally.

Alternative 4: Chemical precipitation and sealed sandfilter

+	-
• Simple and similar to conventional systems • High reduction of phosphorous and a high potential for phosphorous recycling	• Rather new technique, but it has been tested with good results. • Uncertainties if post-precipitation limits life of the sandfilter.

The possibility of recycling chemical sludge is not certain in the munici-pality where Barva Park is located. Therefore, the housing company did not find this technique interesting.

	Alt 1 **Urine diversion with dry handling of faeces**	**Alt 2** **Urine diversion with a vacuum toilet**	**Alt 3** **Urine diversion in water closet**	**Alt 4** **Chemical precipitation of mixed wastewater**
Reliability	+++	0	+++	++
Flexibility	+	+++	++	++
Economy	+++	+	++	++
Reduction	+++	+++	++	++
Recycling	+++	+++	++	++?
Sanitary aspects	+++	+++	++	++
Responsibility and control	++	+	++	++
Conclusion	Very high reduction and recycling potential Cheap Complicated in the specific house construction	Very high reduction and recycling potential Three fraction to handle Higher investment costs non proven technique	High recycling potential Well-tested End products (urine) accepted in agriculture Relatively cheap	High reduction Only potential for recycling of phosphorous Uncertain if sludge is accepted by farmers

Afterword

The open wastewater planning process for the new housing area in Barva Park led to the decision of using a treatment system with urine diversion in water closets and treatment of urine-relieved wastewater in a sealed sand filter bed (alternative 3). Four different treatment solutions were found to fulfil the Terms of Requirement, and the final choice was made by the principal, in this case the housing company.

However, after two years the treatment system still has not been designed nor constructed. The housing company changed owners and the new owners had a different view on how the systems should be organised. One of the most important demands from the original owners was that the systems should be possible to construct individually for each household. The new owners preferred a collective wastewater treatment system, in order to obtain co-ordination benefits. The new principal found that total economy for exploitation should gain from constructing a centralised wastewater systems since expensive infrastructure like roads, drinking water pipes, electricity cables, etc, nevertheless had to be invested before house selling could start.

When this booklet is written the final solution for the wastewater system in Barva is still not decided. Information given to us by the permission authority says that the Terms of Requirement described in the booklet should be used also for ruling further investigation and decisions.

One learning from the described planning case is that there are many different views on how the wastewater treatment can and should be constructed in a specific case. This clearly illustrates the importance of starting planning with an open mind and giving the process a high degree of transparency, something that is facilitated when using the Open wastewater planning method.

More information

There is a lot more to know about wastewater planning, legislation and treatment systems than is presented in this booklet. Below, some sources for more information are listed. This list is not intended to be complete in any way, but can serve as a starting point for further reading.

Ecological sanitation in general

- EcoSanRes – closing the Loop on Sanitation. www.ecosanres.org

- International Ecological Engineering Society. www.iees.ch

- Ecosan – closing the loop. Proceedings of the 2nd international symposium on ecological sanitation, incorporating the 1st IWA specialist group conference on sustainable sanitation, 7 – 11th April, 2003, Lübeck, Germany.

Legislation

- Water Framework Directive: http://europa.eu.int/comm/environment/water/water-framework/index_en.html
- Urban Wastewater Directive: http://europa.eu.int/comm/environment/water/water-urbanwaste/index_en.html
- Bathing water quality: http://europa.eu.int/water/water-bathing/index_en.html

Planning process

- Ridderstolpe, P. (1999) Wastewater treatment in a small village – options for upgrading. SwedEnviro Report No.1999:1. Uppsala, Sweden: WRS. This report is available in English, Estonian, Latvian, Lithuanian, Polish and Russian and can be ordered from Coalition Clean Baltic: www.ccb.se

Treatment systems and equipment

- Ridderstolpe, P. (1999) Wastewater treatment in a small village – options for upgrading. SwedEnviro Report No.1999:1. Uppsala, Sweden: WRS. This report is available in English, Estonian, Latvian, Lithuanian, Polish and Russian and can be ordered from Coalition Clean Baltic: www.ccb.se
- Lennartsson, M. & Ridderstolpe, P. (2001) Guidelines for Using Urine and Blackwater Diversion Systems in Single-Family Homes. Uppsala: Coalition Clean Baltic. This booklet can be ordered from Coalition Clean Baltic: www.ccb.se
- Johansson, M. & Lennartsson, M. (1999) Sustainable wastewater treatment for single-family homes. Uppsala: Coalition Clean Baltic. This booklet can be ordered from Coalition Clean Baltic: www.ccb.se
- Market Survey- Extremely Low Flush Toilets (2001) SwedEnviro report no. 2001: x. Uppsala: WRS. This booklet can be ordered from Coalition Clean Baltic: www.ccb.se
- Ecotechnology for Wastewater Treatment – Functioning facilities in the Baltic Sea region (1997) Book with overview of 15 different innovative approaches to wastewater treatment. It can be ordered from Coalition Clean Baltic: www.ccb.se
- Del Porto, D. & Steinfield, C. (1999) The Composting Toilet System Book. Concord, Massachusetts, USA: The Center for Ecological Pollution Prevention.

SUSTAINABLE WASTEWATER TREATMENT FOR A NEW HOUSING AREA

How to find the right solution

By Peter Ridderstolpe, WRS Uppsala AB, Sweden.
A company in the SwedEnviro Consulting Group.

In this report, the method of open wastewater planning is applied to the specific case of the establishment of a new housing area, located in the countryside near Lake Mälaren, Sweden. The planning method places focus on the goals of the treatment and aims to achieve a wastewater treatment system that is environmentally sound, hygienic, cost-efficient and long-term sustainable.

Four treatment solutions are found to be feasible for the housing area and are described more in detail:

1) Urine diversion with dry handling of faeces, and treatment of greywater in a compact filter;
2) Urine diversion with vacuum toilet and treatment of greywater in a compact filter;
3) Urine diversion in water closet and treatment of urine-relieved wastewater in a sealed sand filter;
4) Mixed wastewater treatment with chemical precipitation, biological treatment in a sand filter and polishing in wetland/ditch.

The report serves as a guide through the entire planning process, from the formulation of the planning prerequisites and the setting of environmental targets and designing criteria to the evaluation of different solutions and the final decision.

Coalition Clean Baltic

In Helsinki, February 1990, non-governmental environmental organisations from nine countries of the Baltic Sea region united and established Coalition Clean Baltic (CCB) in order to co-operate on activities for protection of the Baltic Sea environment. CCB is a politically independent, non-profit association. Currently CCB unites 27 member organisations from the Baltic countries. CCB gathers, produces and distributes information on environmental solutions for the Baltic Sea region. CCB co-operation projects provide assistance to the member organisations in their efforts to restore the Baltic Sea. Sustainable management of wastewater is a priority area for CCB.

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SWEDENVIRO consulting group

SwedEnviro Consulting Group is an association formed by Swedish environmental consulting companies working with water and soil management, waste and wastewater treatment for sustainable use of natural resources. The companies in SwedEnviro are: EcoManagement SE, Vattenresurs AB, VERNA Ekologi AB and WRS Uppsala AB. SwedEnviro's work focuses on sustainable development with an optimal use of resources.

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