TAMK University of Applied Sciences
Environmental Engineering

Final thesis

Helene Salminen

# SUSTAINABLE VILLAGES IN NORTHERN CONDITIONS: REVIEW ON SANITATION ALTERNATIVES IN RURAL AREAS

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| Supervisor | Senior Lecturer Eeva-Liisa Viskari |
| Commissioned by | Sustainable Villages in Northern Conditions project/ Outi Palttala |

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# ABSTRACT

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| Helene Salminen | Sustainable Villages in Northern Conditions: Review on sanitation alternatives in rural areas |
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| Keywords | Sustainable sanitation, wastewater treatment, rural areas, ecovillages |

The aim of this thesis was to find out and compare sustainable decentralised wastewater treatment systems in selected ecovillages and countries in Northern Europe: Sweden, Denmark, Northern Germany, and Finland. Social, technical, legal, and financial issues are covered. The thesis was commissioned by an on-going project, “Sustainable Villages in Northern Conditions: Models for rural construction - comparative follow up study”, and it should act as possible reference material for that project.

The information for the thesis was gathered by reviewing existing research projects and publications on the topic, both in printed and non-print form. Also a small questionnaire was conducted concerning existing sustainable communities in order to obtain information possibly not exhibited in existing research publications.

As an outcome of the research process, this thesis contains a cross-sectional view to the different issues related with sustainable wastewater management issues, such as which social aspects should be taken into consideration in the planning phase, what kind of options there are for water source, toilets and the on-site wastewater treatment plants, how legislation is guiding or perhaps restricting the use of such decentralised solutions, and what kind of economic issues are related. The thesis also contains discussion on the similarities and differences between the studied countries, and on which pieces of knowledge from abroad could be applicable in the conditions of Finland.

As a major part of this work is formed by a review on existing reports and writings, it is highly recommendable to study the reference material when more particular information on the covered issues is required.

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# TIIVISTELMÄ

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| Helene Salminen | Kestävä kylä pohjoisissa olosuhteissa: katsaus haja-asutusalueiden jätevesien käsittelyratkaisuihin |
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Tämän opinnäytetyön tavoitteena oli selvittää ja vertailla kestäviä jätevesien käsittelymalleja Pohjois-Euroopassa, kohdemaina Ruotsi, Tanska, Pohjois-Saksa ja Suomi sekä ekokylät näissä maissa. Käsitellyt aiheet kattavat kestävään jätevesihuoltoon liittyviä sosiaalisia, teknisiä, lainsäädännöllisiä sekä taloudellisia seikkoja. Työn tilaajana toimi parhaillaan meneillään oleva projekti ”Kestävät kylät pohjoisissa olosuhteissa: Malleja maaseudun rakentamiselle – vertaileva seurantatutkimus”, ja työn olisi tarkoitus tuottaa lähdemateriaalia projektin käyttöön.

Materiaali opinnäytetyötä varten kerättiin arvioimalla olemassa olevia tutkimusprojekteja ja julkaisuja. Lisäksi suoritettiin kysely ekokylien asukkaille tarkoituksena kerätä tietoja joita tutkimusjulkaisuissa ei välttämättä esiinny.

Tutkimustyön tuloksena tämä opinnäytetyö sisältää poikkileikkauksen kestävään jätevesihuoltoon liittyvistä asioista. Näitä ovat muun muassa suunnitteluvaiheessa huomioon otettavat sosiaaliset näkökohdat; vesihuollon, käymäläratkaisujen sekä paikallisen jätevesihuollon tekniset vaihtoehdot; lainsäädännön suuntaukset tai mahdolliset rajoitteet hajautettuja ratkaisuja kohtaan sekä taloudelliset näkökohdat. Työ sisältää myös pohdintaa kohdemaiden ratkaisujen sekä vaihtoehtojen samankaltaisuuksista ja eroista sekä ajatuksia siitä, mitkä vaihtoehdot voisivat olla toimivia Suomen olosuhteissa.

Koska tämä opinnäytetyö on huomattavalta osin kirjallisuustarkastelu, kiinnostuneen lukijan on hyvin suositeltavaa tutustua lähdemateriaaliin tarvittaessa yksityiskohtaisempaa tietoa joistain aihealueista.

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# FOREWORD

This thesis was written at the Tampere University of Applied Sciences for the project "Sustainable Villages in Northern Conditions: Models for rural construction - comparative follow up study".

I would like to thank my thesis supervisor Eeva-Liisa Viskari for all her time and support during the thesis process. A warm thank you also to the lecturers of Enve and the staff of Tamk for making studying there a pleasure.

Secondly I would like to thank Outi Palttala for providing the topic of this thesis and for valuable information and helpful instructions on the way. I hope this thesis work can offer her and the project needed information.

Last I would like to thank my family and friends who gave their support in various ways during this thesis project and the whole course of my studies. Special thanks go to Toni Järvinen who worked in cooperation with me, as our thesis topics were from the same field: thank you for all the hours spent together combating challenging issues. Equally special thanks go to my brother Jaakko for irreplaceable and devoted help and support during the proofreading phase.

A thank you and a smile to all who were patient during the process.

Tampere, June 2008

Helene "Lumi" Salminen

# LIST OF CONCEPTS AND ABBREVIATIONS

**Fractions of household wastewaters**

| | |
|---|---|
| Yellow water | Urine, (water) |
| Blackwater | Faeces, other solid toilet wastes, water |
| Greywater | Household wastewaters excluding yellow and blackwaters; wastewater from the kitchen, washing, etc. |

**Commonly measured properties of wastewaters**

| | |
|---|---|
| $BOD_7$ | Biological Oxygen Demand of a water sample during a 7-day analyzing period. Measured in [mg/l]. |
| $BOD_5$ | Biological Oxygen Demand of a water sample during a 5-day analyzing period. Measured in [mg/l]. |
| N/Tot-N | Total nitrogen, both particle bound and free. Measured in [mg/l]. |
| P/Tot-P | Total phosphorus, both particle bound and free. Measured in [mg/l]. |

**Abbreviations**

| | |
|---|---|
| PE | Population equivalent/Person equivalent, the average household wastewater load for one person during one day (usually BOD, phosphorus and nitrogen) |
| WC | Water closet, also mentioned as conventional toilet in this thesis; toilet where water is used for flushing the excreta |
| DT | Dry toilet; toilet where water is not used for transportation of the excreta |

# TABLE OF CONTENTS

# 1. INTRODUCTION

The original objective of sanitation was to protect human health and keep diseases under control by providing a hygienic and safe living environment for humans. After the connections that exist in the environment between ecosystems became clear environmental aspects, such as the decontamination of wastewaters, were added to the goals of decent wastewater treatment systems. Today it is clear that also ecological aspects need to be taken into account. These aspects deal with the recovery and recirculation of nutrients and the minimization of energy consumption e.g. in the construction and operation of wastewater treatment systems. Reducing the amount of generated waste material in general is also an important issue. A more ecologically sustainable approach to wastewater management should also positively influence related environmental aspects.

In Northern Europe the standards of living are such that many people have the possibility of affecting their way of life in relation to the environment and ecological issues. As wastewater treatment systems are required for every household, the option of obtaining a sustainable one should be made as attractive as possible. There are many examples of designs of decentralized wastewater treatment in the Northern European countries of Sweden, Denmark and northern Germany. There are also some communities utilizing these options in Finland, but not to the extent as in the other countries studied in this thesis, and the experiences and knowledge in these issues is relatively limited at the moment. The primary aim of this thesis is to gather and summarize solutions used in wastewater treatment systems that could be applicable in Finnish conditions.

There are various aspects related to sustainable wastewater treatment ranging from the users´ opinions and viewpoints to different possible technical solutions, matters of legislation, and financing. This study aims to cover a selection of these issues and especially to find solutions that have been successful in Northern European conditions. The two methods used in this thesis are a survey of available literature on the above mentioned areas and a questionnaire form on wastewater treatment facilities that was sent to a number of ecological villages in Sweden, Denmark and northern Germany.

## 2. METHODS

The first part of this thesis is a literature review drawing together a number of studies on planned and existing options for sustainable wastewater treatment in rural areas. Different aspects related to sustainable wastewater treatment are covered from social, technical and financial issues to current regulations and legislation. Libraries, internet sources and scientific databases were searched for material in addition to using personal discussions and information as a basis for research.

Regarding the literature review, section 3 explains the basic concepts related to sustainable wastewater treatment in rural areas in northern conditions. Section 4 concentrates on social issues connected to the planning of wastewater systems while section 5 introduces a variety of techniques that have been studied and used in the field. Sections 6 and 7 discuss the legal and economic issues connected with wastewater treatment system implementation.

For the second part of this thesis a questionnaire was prepared and sent to selected ecological villages (from here on: ecovillages) in Sweden, Denmark and northern Germany. The purpose of the questionnaire was to gather information that is not easily found in published form and also to find out about possible research projects on individual ecovillages on the one hand and inhabitants' perceptions on wastewater treatment systems in use in their particular ecovillages on the other. The questionnaires were sent to 27 ecovillages in Sweden, Denmark and northern Germany. Responses were obtained from 5 villages. The questionnaire form can be found in Appendix 1 and was prepared in co-operation with Toni Järvinen, who is writing a thesis on energy issues in ecovillages. In this thesis section 8 summarizes the results of the questionnaire survey with regard to wastewater treatment in ecovillages.

Finally, section 9 summarizes the results of all the previous sections and offers some suggestions for improvement. This is followed by a short conclusion.

A major part of this thesis aims to present in condensed form different aspects connected with wastewater treatment solutions in rural areas for northern conditions. It would prove most useful for the interested reader to study the material referenced in this thesis in order to gain broader and more detailed information on the planning and construction of local wastewater treatment solutions.

# 3. BASIC CONCEPTS

## 3.1. Sanitation – conventional, environmental and/or ecological

The term sanitation refers to facilities and services used for the safe disposal of human urine and faeces /27/. It can also be defined as the "control of physical factors in the human environment that could harm development, health, or survival" /18/. Both of these definitions can be seen to highlight the importance of proper treatment of household wastewaters as part of successful sanitation. This thesis differentiates between three kinds of sanitation; conventional, environmental and ecological.

Conventional sanitation utilising flushing toilets considers human excreta merely as waste that needs to be disposed of. Flush toilets and sewage systems quickly separate the producer from the waste, transporting it away from the producers until it is disposed of, sometimes even straight into waterways. The main objective of conventional sanitation is to take care of good hygiene and prevent the spreading of diseases by removing waste from the immediate vicinity of population centres; treatment is not implied.

Opposite to conventional sanitation, sanitation that acknowledges the problems human excreta causes in the environment can be called environmental sanitation. The possible environmental problems related to sanitation are pollution and eutrophication as well as the spreading of pathogens and diseases, not to mention odours or other unpleasant encounters with the waste. These problems are prevented most often "end-of-pipe" by centralised treatment of the wastewaters collected from households. This causes a large volume of diluted wastewater that needs treatment.

Ecological or ecologically sustainable sanitation takes into consideration three aspects; the protection of human health by preventing the spreading of diseases, the protection of the environment by reducing the amounts of nutrients and other harmful pollutants discharged, and the returning of the nutrient cycle back into a closed-loop system by recycling the nutrients to where they are needed. /24, 14/

## 3.2. Fractions of household wastewater

"--- *we mix and dilute wastes that our bodily systems have spent the whole of evolution separating and concentrating*." Sandy Halliday, Sustainable Construction /6/

The typical household wastewater is a mixture of grey and blackwaters. Blackwater contains everything that is disposed into the toilet: urine (yellow water) and faeces together with paper and other solid wastes diluted with water. The yearly production rate of excreta for an individual is approximately 500 litres of urine and 50 litres of faeces. Greywater accounts for water used in the kitchen, for washing and for other household needs. The amount of greywater produced per person varies a lot due to different water consumption habits but can be estimated to be between 20 000 to 100 000 litres annually. /13/

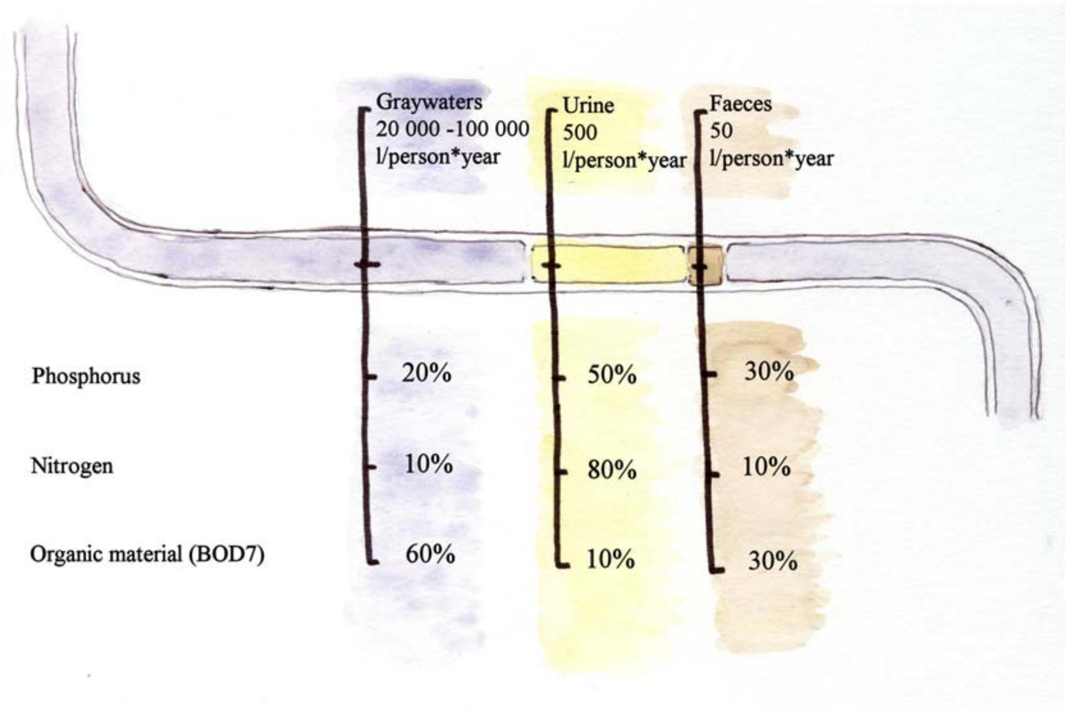


**Figure 1.** Dispersion of the nutrients P and N as well as organic matter between the different fractions of wastewater. (Figure produced from data in sources /13/ and /1/)

When led to a wastewater treatment plant through a sewage system, blackwater is usually mixed and thus diluted with greywater. Looking at the different characteristics of the components of wastewater, this mixing hardly makes any sense (see Figure 1). Urine contains most of the soluble nutrients, of which nitrogen (N), phosphorus (P) and potassium (K) are the most important when considering eutrophication/nutrient recovery, and is in itself almost completely free of pathogens. The nutrient content of the urine produced during one year by an adult person is about 5,6 kg nitrogen, 0,5 kg phosphorus and 1,0kg potassium. This amount of nutrients is enough to produce an amount of grain with sufficient nutritional value needed for one person for a year. Solid faeces contain mostly organic matter and particulate nutrients but also most of the pathogenic material in human excreta. Greywater contains a minimal amount of nitrogen, phosphorus and potassium, but a considerable proportion of organic matter. When all these are mixed together they form a bulk wastewater which is pathogenic, rich in nutrients and organic matter, and which requires a multiface treatment process to get rid of all the harmful substances. However, if the different components of wastewater are collected separately, the treatment processes can be simpler and lighter and the end products more readily utilizable. /13, 11/

## 3.3. Sustainable construction

The terms *sustainable* and the concept of *sustainability* are used in this study primarily to refer to ecological sustainability. However, as housing and housing related issues are strongly connected to economic and social aspects, also economic and social sustainability should be taken into account with the same level of importance. There are, of course, various issues connected with ecologically sustainable building. This study will concentrate on issues related to water and sanitation management. In addition, waste management issues will also be discussed where appropriate.

For many, the prevailing image of ecological sanitation seems to be complicated technology and high costs. However, the concept of ecological sanitation calls for solutions that have a low demand for energy and are based on natural processes. Simplicity of usage and maintenance and a long lifetime should cover up for the installation costs. /24/

Peter Graham states four laws for ecologically sustainable building in *Building Ecology: First principles for a sustainable built environment* /5/. They are referred below in the context of sanitation issues:

Law 1: “Consume resources no faster than the rate at which nature can replenish them” – An ecologically sustainable wastewater treatment system should be manufactured, operated and maintained with minimal, efficient energy and resource use, and renewable or recyclable resources should be utilized as much as possible.

Law 2: “Create systems that consume maximum energy-quality” – Where energy use is necessary, energy efficiency of the system should be ensured. Also the amount of waste should be minimized, since waste represents unused energy and may cause possibly unnecessary harmful environmental impacts. Also a functioning sustainable wastewater treatment system minimizes the amount of waste and mixed wastewater produced.

Law 3: “Create only by-products that are nutrients or raw materials for resource production” – Sustainable wastewater treatment systems can contribute to this law, if and when the nutrients in human excreta can be returned to circulation, and the amount of polluting substances is thus minimized.

Law 4: “Enhance biological and functional adaptability and diversity” – The planning phase of sustainable wastewater treatment systems should take into account the whole life cycle of the different parts of the process and emphasise long-term environmental aspects. A good sustainable treatment process not only protects water ecosystems from environmental pollution but also enables the natural fertilizing of terrestrial ecosystems, thus easing them from the burdens of chemical fertilizers.

**Figure 2.** Sustainable construction is based on life-cycle thinking, taking into account energy efficiency, waste minimization and material reuse as well as the protection of ecosystems. (photo: Outi Palttala)

## 3.4. Rural areas, northern conditions

This study aims to find solutions for sanitation issues in rural areas subject to northern conditions. *Rural areas* are here defined as areas in which households cannot easily be connected to a centralised wastewater treatment plant but rather have a need for a decentralised option. *Northern conditions* are used here to refer to environmental conditions (geographic, climatic, etc.) in the northern parts of Europe, mainly concentrating on the Nordic countries (especially Finland, Sweden and Denmark) and northern Germany.

So called *ecovillages* were used in this study as a model for sustainable rural areas, and earlier research on them formed a large portion of the material studied here. An ecovillage is a community where the inhabitants strive to maintain and protect the environment and ecological cycles and to find a balance between consumption needs and habits. It is emphasized, however, that the options presented in this thesis can be used for single households as well as for larger, cooperative rural dwellings such as ecovillages. Some of the solutions presented can also be applied in close vicinity to more densely populated areas.

In Finland, there are approximately 1 million inhabitants (~20% of the whole population) constantly living in households without a connection to sewer systems and centralised wastewater treatment. This is equal to approximately 350 000 permanent households that depend on a local solution for treating domestic wastewaters. In addition there are about 450 000 secondary residences in rural areas that are mainly inhabited during vacation periods, which often lack proper wastewater treatment. /22/

When assessing the future perspectives of water resources in Finnish communities, the Finnish Environment Institute states the wastewaters of rural areas as a significant potential risk if the wastewater treatment plants are poorly situated, inadequately maintained or in bad condition. These aspects might lead to long-term problems in groundwater resources. The problem is also that groundwater resources are rather clean and normally do not need any treatment. Due to this there are often no purification processes available at the water intake plants utilizing groundwater even if a problem with water quality would occur. Therefore the proper design, use and maintenance of wastewater treatment systems in rural areas can have a major impact on human health as well as the environment. /7,10/

# 4. SOCIALLY SUSTAINABLE WASTEWATER TREATMENT

The whole planning process behind sustainable wastewater treatment systems should be based on local circumstances and the inhabitants of the existing or future housing area. Only the thorough knowledge and motivation of the users as well as the proper suitability of the system into its surroundings can ensure a fully functional wastewater treatment process.

The level of user commitment should be realistically estimated in the planning phases. Technical solutions, even when they lead to better treatment results, require time and care from users. The use and maintenance of wastewater treatment systems should be made easily understandable. Possible problems and how to deal with them should be pointed out. Depending on the inhabitants, the chosen system should be accessible to a broad range of users; the young, the old, the disabled, etc. Knowledge on how to use and maintain the systems is vital for functioning sustainable wastewater treatment. /14/

The extent to which ownership and management responsibilities are assigned to particular individuals or shared by the community as a whole also depends on the chosen system. It is important to define already in the planning phases which responsibilities related to the use and maintenance of the wastewater treatment are the duty of individuals and households and which fall under the shared obligation of the whole community. /14,3/

Good instructions for a planning process of a sustainable wastewater treatment solution, taking also social issues into account, can be found in Ridderstolpe's *Sustainable wastewater treatment for a new housing area – How to find the right solutions* /14/.

# 5. TECHNICAL SOLUTIONS FOR DECENTRALISED WASTEWATER TREATMENT

The following subsections present some technical solutions for the different parts of decentralized household wastewater treatment. Wastewater treatment planning is always case-sensitive, however, and requires proper knowledge of the site and its conditions as well as the requirements of the residents in order to be fully functional. The subsections below are in the order in which the covered topic usually appears in a household water and wastewater system, from freshwater source via toilet facilities to finally the treatment phase and end products.

## 5.1. Freshwater source

Households have two options for their water source. They can either be connected to a central water supply or they can use a local source for water. The benefit from using a central water supply is usually the continuously good hygienic quality of the water. Connecting households in rural areas to central water supplies can result in long distribution distances. This leads to small water volumes in the pipes, which in turn causes stagnation and the degrading of water quality.

A local water source, usually a well, is recommendable if the distance to a centralized water supply is long. The benefit from using groundwater is in most cases the minimal need for purification before use. As a disadvantage groundwater sources are vulnerable to contamination and are often very difficult and slow to decontaminate. Preventing household wastewaters from leaking into groundwater resources and contaminating them is a major reason for their proper treatment.

If a local solution for the water source is chosen, the formation of a cooperative water association is recommended. A larger cooperation with shared maintenance, control and repair costs can be more easily sustainable from an economic point of view. /11/

## 5.2. Sanitation options

The conventional flush toilet or water closet (WC) is the single most water-consuming appliance in a household. By separating excreta from other wastewater, wastewater consumption can be decreased by up to 70–80% /11/. Perhaps the most important and beneficial issue when considering options for ecological sanitation in rural areas, be it villages or single houses, is the use of urine diverting toilets. The separation of urine lowers the nutrient load of the wastewater considerably (see section 3), relieving pressure from the treatment process and enabling the recycling of the nutrients to agriculture. A selection of different water utilising and dry toilets is demonstrated in the following text.

The available options are naturally different depending on whether the system is to be set up in an existing building or if the decisions are made in the planning phase of a new construction project. In some old houses there might be space and dimensioning restrictions that simply prohibit the construction of dry toilet systems, since they require a rather large amount of space below the toilet seat and also the facilities for emptying the containers. In these cases other options should perhaps be considered, bearing in mind the beneficial aspects of using urine diverting systems.

### 5.2.1. Toilets with water flush (WCs)

Non-diverting options, i.e. conventional flush toilets, can be considered in some cases where the further wastewater treatment is handled efficiently enough for example with willow treatment facilities. In this case, the septic tank or a separate collection basin should be dimensioned to be able to collect the sludge that can be separated from the blackwater. The remaining wastewater is then led further into the treatment process.

The use of non-diverting, mixing toilets should be well justified and the proper treatment for such a case defined. Does it fulfil the targets of ecological sanitation or only those of environmental or contemporary ones? Can the nutrients be efficiently recycled (e.g. with a willow treatment system during willow growth and harvesting for energy use)? In most cases, it is always easier to separate *before* mixing.

### 5.2.2. Urine diversion combined with water flushing systems

Urine diverting toilets with a low-water flushing system for faeces and solid matter can be operated either separately from greywater collection or together with it. In the latter case, blackwater can also be collected into a sludge pre-composting tank, where dewatering and composting takes place. /13/

If a system using water as a transportation agent is chosen, the water used for the toilet could preferably be household greywater or harvested rainwater in order to avoid the use of freshwater for these secondary purposes. These options require two piping systems, which may increase the costs in the construction phase and often prevent their use in existing constructions. The requirements for the quality of the “secondary waters” used should be high enough in order to avoid pathogens and the degradation of piping and equipment. /12/

Small amounts of water may be used in the flushing of urine in these diverting options, however it has been noticed that this might cause clogging in the pipelines (due to scaling, affected by the calcium in water). Solutions for avoiding the use of water in flushing are being studied. /8/

### 5.2.3. Dry toilets (DTs)

Examples of plain dry toilets could be earlier found in use in large numbers as the main toilet concept in rural areas. In these toilets, urine and faeces are simply collected together without using water as a transportation agent. Therefore DTs are an excellent way to decrease water consumption.

Traditional dry toilets allow faeces and urine to combine in the same chamber. This is not the best option, as pure urine is contaminated by the pathogens of faeces, when it could be separated and used almost as such. Another problem with mixing urine and faeces is the chemical reactions between these two causing foul odors which may lower the comfort of use.

Dry toilets require a lot of care from their users, but award them with soil improvement products for use in the garden, on fields or otherwise. The construction of a dry toilet system also needs enough space and a way to access the maintenance, and is often more easily installed in a new household. /3,14/

### 5.2.4. Urine diversion with dry handling of faeces

The use of a urine-diverting toilet with dry collection of faeces and other solid toilet waste is recommendable for users seeking a high level of nutrient and organic matter recovery and a lowered strain on the wastewater treatment system. When properly stored, the separated urine can be used directly or when diluted with water for agricultural purposes (see section 5.6.1.) and the solid toilet wastes can be composted and used further for soil improvement (see section 5.6.2.).

The facilities for dry toilets are simple and can also be matched with a similar toilet seat as urine diverting water flush systems (see Figure 3). Dry toilets require more work and therefore more motivation from users during the emptying, storage and processing (e.g. composting) phases. With the right dimensioning of the systems maintenance intervals should be tolerable and the size of the facilities sufficient. When constructed and maintained correctly there are no odour problems. Sometimes, however, odour problems may be an indicator of block-ups or other problems in the system. /14, 3, 9/

**Figure 3.** Example of a urine-diverting dry toilet seat. The urine is diverted to the front of the seat (right) and faeces with toilet paper falls freely without water from the back (left). (photo: Outi Palttala)

### 5.2.5 Vacuum toilets

Another option for a toilet system is the vacuum toilet. Vacuum toilets are similar to those used in ships, trains and airplanes. Excreta are transported to the wastewater treatment via a sewer system kept in under-pressurized conditions by a pumping system. The main benefit of a vacuum toilet is the reduction in water use. A major disadvantage at the moment are high costs of installation, and one uncertainty lies in the case where the system fails as the technique is somewhat more complicated than for example with DTs. /13/

## 5.3. Options for wastewater treatment

In order to reach sustainability, functionality as well as comfort for users it is reasonable to choose options that are uncomplicated, simple to maintain and repair and which have a long lifespan. Novel technological solutions might be as good when comparing performance results, but if there are complications they might not be easy to repair by the users themselves, or they may require a continuous source of electricity or added chemicals that could diminish the ecological value of the system.

Wastewater treatment systems can be dimensioned a bit differently and might have different operational demands depending on whether the wastewaters led to the system are grey or blackwater. In the following subsections, pre-treatment in septic tanks followed by the options of land filtration systems, constructed wetland systems and treatments utilizing willow coppice are shortly presented.

### 5.3.1. Pre-treatment in a septic tank

The wastewaters coming from a household should first be lead into a septic tank or series of tanks (usually 2-3). The purpose of the septic tank is to separate suspended solids and particles that are lighter than water from the wastewater fraction. The tank should be dimensioned so that the retention time for the water in the tank is at least two days in order for the settling to be sufficient. The solids (organic material, heavy metals, faeces and toilet waste if these are part of the wastewater fraction) are settled to the bottom of the tank, whereas oils, fats and substances bound to these are separated to the surface of the sedimentation tank. The cleanest water fraction is therefore in the middle, between the surface and bottom, and can be directed forward with a T-pipe connection at that level. Figure 4 contains a basic process flow chart of a septic tank system.

Research has shown that septic tanks could extract up to 70% of the solid material in a wastewater flow, which eases the burden of the following wastewater treatment option and possibly also lengthens its lifetime. As the solid and other materials are caught into the septic tank it should be emptied as often as necessary, at least once a year. This is dependant on the size of the tank and also the amount of consecutive tanks. The sludge emptied from a septic tank can also be reused, for example after composting.

After the septic tank the wastewaters are led further on with distribution wells and pipes and the process is continued depending on the chosen primary treatment system, some of which are presented in the following. /1, 12/

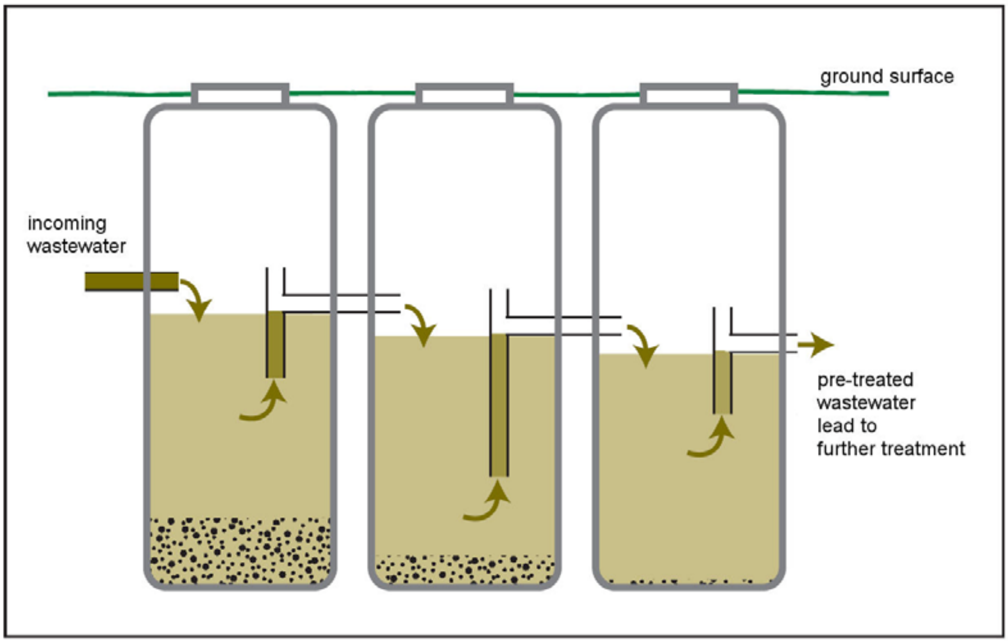


**Figure 4.** Process flow chart of a septic tank system with three tanks in succession. (Figure modified from source /1/)

### 5.3.2. Filtration systems

Wastewater treatment done by filtration is an old, wide spread and usually rather reliable system. There are various ways to organize the filtration “cycle”, always depending on the conditions of the site. Land filtration should be differentiated from leaching beds, where after settling in the septic tank wastewaters are allowed to slowly leach into the surrounding soils. The leaching beds, even though easy to manage, put the groundwater resources into a more vulnerable position since the speed and depth of filtration cannot be controlled. In land filtration, the filtration beds should be isolated from the surroundings, and the treated wastewater lead to the environment only at the point where treatment success can be assured.

If the natural conditions of the site are suitable regarding soil properties and distance to groundwater resources, a natural soil filter system is appropriate. The principle is that soil acts as a bio-geo-chemical reactor having multiple simultaneous treatment functions for different particles of the wastewater: the suspended solids are filtered and adsorbed, organic matter mineralized, phosphorus is flocculated and precipitated into minerals, pathogens are handled by beneficial microbes. When the existing soil conditions are not suitable for use as a filter bed, an open sand filter bed is recommendable.

Filtration systems can be designed with vertical or horizontal flow directions, or a combination of these both. Both systems have their benefits, and the largest restriction for the choice of which to use might be the size of the area available. The systems are usually based on gravity flow, but if the conditions of the terrain so require a pump may be added to maintain the flow throughout the system.

Filtration beds can be combined with ponds or small-scale wetlands into which the treated water is led for “polishing”. /3 ,25/

### 5.3.3. Root-zone treatment systems

Filtration systems can also be combined with plants, utilizing the root-zone of the plants as a participant in the treatment process. These are called root-zone treatment systems (or: root zone (vegetation) purification plants), and sometimes in literature they are clustered under constructed wetlands, called wetlands with a subsurface water flow (SWF) (see section 5.4.4.).

A root-zone treatment system needs an area of at least 50m2 per household /12/. The plants used in the treatment process should be such as are naturally used to wet conditions, growing e.g. in lakesides or by ponds or moors and which can be found in the region. Along with the plants, also bacteria, algae and water fauna utilize the pollutants in the water as their source of nutrition simultaneously purifying the water. Usually the root-system of the plants used and micro-organisms living in symbiosis with them should be appropriate in the way that they take care of the oxygen demand of the plant. Problems with using systems functioning with plants in northern conditions arise in the wintertime, when the plants naturally can not “operate”. Therefore treatment systems that function with plain soil or sand filtering may be beneficial enough, and the additional vegetation may not be necessary, but can nevertheless provide added value to the system. Root-zone treatment systems do not support nitrification, and also have a limited ability to remove phosphorus. They are well suitable for the removal of organic material, and are thus appropriate for household greywater treatment, combined with a separating toilet. /25, 2/

### 5.3.4. Constructed wetlands

Vertical flow constructed wetlands have been shown to have the ability of reaching high demand treatment results. Research shows that vertical flow constructed wetlands would have a good rate of organic matter removal and the nitrifying abilities have been found to be effective even during cold winters. On the other hand phosphorus removal has been found to be quite limited. This suggests that a constructed wetland of this type could be used effectively for greywater treatment, but would better be coupled with a separating (dry) toilet. The process flow chart of a constructed wetland can be seen in Figure 5.

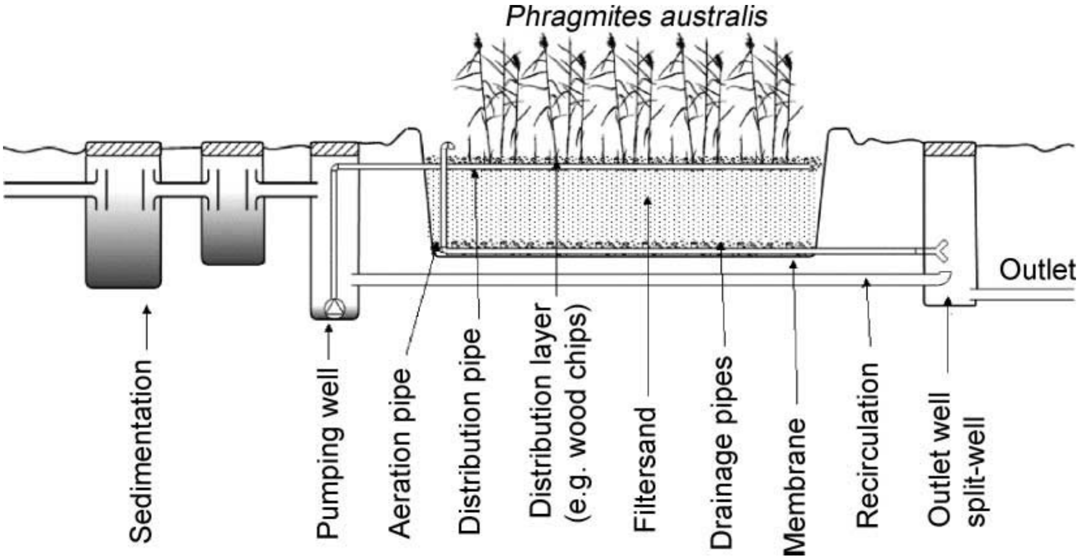


**Figure 5.** Process flow chart for a constructed wetland with vertical water flow. The wastewater is pre-treated in a septic tank (on the left, "sedimentation"), and then led through a pump-controlled distribution system to the constructed wetland. The treated effluent is collected with drainage pipes, and in this model part of it can be recirculated back to the pumping well. /4/

Typically used plants for treatment are different reeds, most often *Phragmites Australis* and *Iris pseudacorus.* The characteristics of the wetland plants should contain at least the following: temperature requirements of 12-23°C, rapid growth via rhizomes, pH ranges from 2 to 8, maximum salinity tolerance 45g/l, and low value as a food source for most birds and animals. Constructed wetlands are either with Free Water Surface (FWS), operating in the depth of 0,1-0,45 m from the surface, or with Subsurface Water Flow (SWF), which operate in the depth of 0,45-

1,0m from the surface. The latter are sometimes also called root zone systems, which are described in the section 5.4.3./4 ,2/

Rather detailed instructions for the construction, use and maintenance for vertical flow constructed wetlands can be found in *Danish guidelines for small-scale constructed wetland systems for onsite treatment of domestic sewage* by Brix, H. and Arias, C.A /4/.These guidelines are designed for Danish conditions and could be applicable also in Finland.

### 5.3.5. Willow coppice treatment

One option for wastewater treatment are willow (*salix spp*.) treatment systems. Willow plantations based on evapotranspiration are effective for nutrient removal from wastewaters. Several studies show economical and environmental benefits both in the areas of nutrient cycling and energy use for willow wastewater treatment plants.

There are two possibilities for utilising willow plantations: the *summer option* which utilises willow wastewater treatment only in the summer months, and the *whole year option* in which wastewater is stored in storage ponds during the winter months when the willow treatment is not active. The willow treatment system can be either a so called zero-discharge system, where the treatment area is isolated from the ground and water is eliminated only through evaporation (see Figure 6), or an open system where water can also enter the soil below after treatment (see Figure 7). The latter is recommendable for areas where it is known that there is no groundwater in risk of contamination.

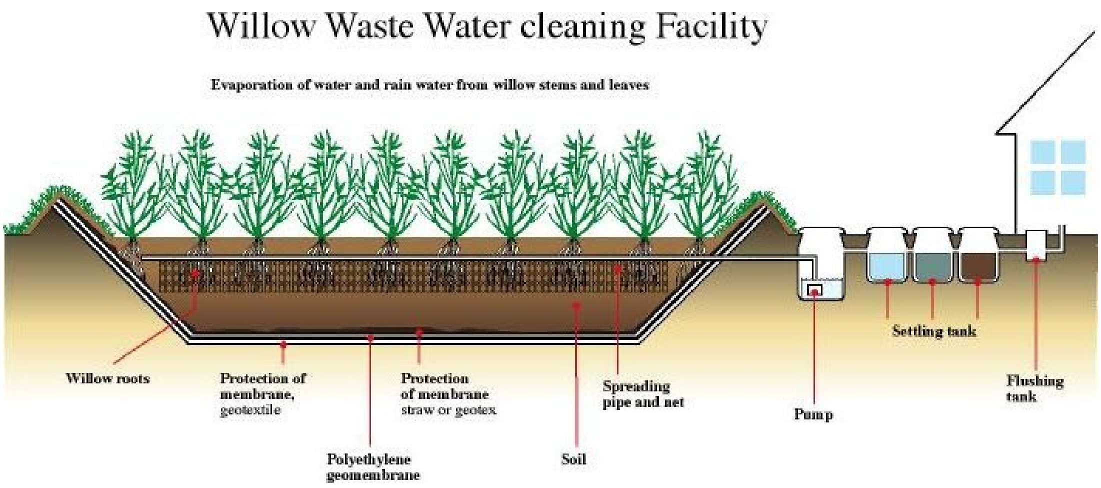


**Figure 6.** A willow treatment system with zero-discharge. The treatment area is isolated from its surroundings thus causing no leaching to the ground. Water is eliminated through evaporation. /17/

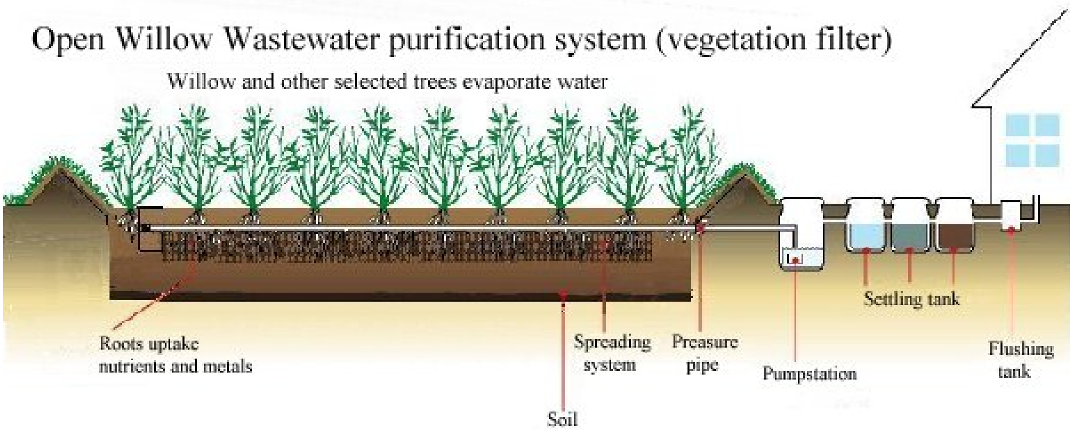


**Figure 7.** A process flow chart of an open willow treatment system where the remaining treated water either is evaporated by the willows or can also infiltrate to the surrounding soil. This option should be utilized in areas where there is no groundwater in risk of contamination. /17/

The wastewater, either blackwater or greywater (the latter may need additional nutrients in the early phases of treatment, to enhance willow growth) is led to the root zone of the willow plantations. The nutrients and heavy metals are gathered and stored in the stems and foliage of the willows and excess water is reduced by evapotranspiration. Reduction of the nutrients happens through the defoliation and harvesting of the willows.

In addition to nutrient and heavy metal removal from wastewaters, willow plantations can also otherwise be utilised as a resource for example as energy crops or material for small-scale building or garden use (e.g. wood chips) thus further balancing the ecological cycle.

Once implemented, willow plantations are rather simple to use and can be operated for at least 25-30 years, with harvesting of the willows happening every 2-5 years. Of course, as with all treatment systems it is important to determine already in the planning phase correct measures for the willow plantations as well as the large enough storage ponds for wintertime and possibly other facilities used during that phase. /2, 4, 17/

## 5.4. Other aspects related to wastewater treatment

Rainwater runoff is one aspect which needs consideration regardless to which treatment option is chosen. Excess amounts of rainwater may be harmful for certain systems, possibly causing dilution (e.g. willow treatment systems) or too rapid filtration (e.g. land filtration systems). Rainwater harvesting is very beneficial and the collected water may be used in gardens or even circulated as secondary water in the household (e.g. for toilets if a water flushing system is used). /12, 14/

As sustainable wastewater treatment systems are usually designed to imitate ecosystems, it is important to restrict the amount of “unnatural” substances flowing into the treatment. Substances that need to be restricted include heavy metals and their combinations, fats, oils and oxidizing substances, as well as toxic chemicals. It is recommendable to make the decision of using phosphate-free detergents, and to avoid very acid or alkaline ones. Reducing the amount of food scraps that ends up in sewage is also essential. /1/

## 5.5. Treatment and use of separated end products

If urine and faeces are separated from the rest of the household water, the nutrients they contain can be returned to the natural cycle. Both from environmental and economic viewpoints it is not reasonable to transport the end products for long distances, so they should either be further utilized on site or by farmers from the local community. Where the urine and/or composted faeces can not be utilized on site, co-operatives of local farmers or other interested parties should be searched already in the planning phase.

The spreading of the urine and composted faeces should be done to a large enough area. It has been calculated, that when using only urine for fertilizing purposes, an area of 200 m2 per person is required. For spreading of both urine and composted faeces the needed area would be 250 m2 per person. /12/

### 5.5.1. Use of urine

Ensuring a proper separation process is vital for obtaining pure and safe urine. Urine itself is almost pathogen free, but if allowed to be in contact with faeces it is under risk of contamination with/by bacteria, viruses and other pathogenic micro-organisms. These pathogens can be eliminated by a proper storage time and space. The death rate of pathogens is dependant on the temperature, pH level and the concentration of nitrogen in the urine mixture. A storage period of at least 6 months with the surrounding temperature being 20ºC is recommended to ensure hygienic safety before the application of urine to fields used for growing food or other crops. The storage of the urine should be organized in airtight containers to prevent the escaping of readily volatile nitrogen. The dimensions of the storage systems should be planned flexibly for possible increased user amounts. Further information of the hygienic aspects connected with the storage and general issues about application to fields, as well as other issues connected with urine separation can be found from the report *Urine separation – closing the nutrient cycle* by Mats Johansson /8/.

### 5.5.2. Use of faeces

There are a few ways of dealing with the faecal waste depending on the toilet system. In a dry toilet based system, the faeces and other solid matter from the toilet is collected and can be composted as such. With systems using water for the flushing of solid toilet wastes the resulting sludge needs dewatering simultaneously with the composting. The toilet wastes can also be mixed with kitchen or garden waste and these fractions can be composted together. /14/

The composting process can be enhanced by using earthworms to work on the breakdown of the organic material. This is called vermicomposting. With the right species this process can be very rapid and the products end up in rather small particles. The most common types of earthworms used for such a process are *Eisenia fetida* and *Eisenia andre.* The activity of the earthworms makes the important nutrients existing in faecal matter more soluble and readily available for plants and also enhances the microbiological activity within the solid waste fraction. In addition to dry composted waste, vermicomposting can also be applied with brown water sludge. /16/

The fully composted solid wastes can be used for soil fertility improvement in the garden or on agriculture land. An important thing here as well is to ensure the capacity of the collection and storage containers, also taking into consideration the possible increase of users. The composting time for the faeces should be long enough in order to ensure the safety of further use and the elimination of pathogens, a minimum time being between 1-2 years. /14/

# 6. LEGISLATION CONCERNING DECENTRALISED WASTEWATER TREATMENT

The following subsections contain information on legislation related to decentralised wastewater treatment in the four countries on which this study concentrates. The subsection on European Union (EU) legislation takes a look at different regulations relating to both wastewater treatment itself and also the further use of the possible end products of the process. The subsections covering legislation in specific countries aim to provide a general idea of specific legislation or regulations related only to wastewater treatment itself, since discussing acts or laws connected with the use of end products would have unnecessarily broadened the scope of this study.

## 6.1. The European Union

EU legislation contains two directives that are directly related to sewage treatment, i.e. the Water Framework Directive (2000/60/EC) and the Urban Wastewater Treatment Directive (98/15/EEC). The Water Framework Directive aims to maintain and improve the conditions of aquatic environments within the European Union, and obliges member states to prevent the further deterioration of surface and groundwaters. To deal with the pollution of surface and groundwaters, the Directive provides environmental quality standards and also technical standards and effluent values. The Urban Wastewater Treatment Directive also focuses on protecting surface and groundwater from harmful effects caused by wastewaters, but is specifically aimed at the wastewater discharges of larger population clusters with more than 2000 inhabitants. The Directive concentrates on pollution prevention and gives effluent concentration limits for biological oxygen demand (BOD), chemical oxygen demand (COD) and TSS (total suspended solids). Limit requirements for total phosphorus (total-P) and total nitrogen (total-N) are only set for sensitive areas subject to eutrophication. /3, 14/

Other environmental legislation can be found which could be indirectly related to sustainable wastewater management. These include the landfill directive (1999/31/EC on the landfill of waste), the nitrate directive (91/676/EEC on the protection of waters against pollution caused by nitrates from agricultural sources), the wastewater in agriculture directive (86/278/EEC on the protection of the environment, and in particular the soil, when sewage is used in agriculture) and the regulation on eco-labelling (EC Regulation No 1980/2000). The landfill directive is based on a waste hierarchy (reduce, reuse, recycle), promoting the reduction in amounts of biodegradable waste that is landfilled. The reclamation of sewage sludge or separated urine and faeces very much fulfils this part of the directive. The other two directives (the nitrate directive and the wastewater in agriculture directive) as well as the regulation on eco-labelling are ones regulating and possibly limiting the use of sewage sludge, separated urine and faeces in agricultural purposes. /3/

EU legislation is based on the principle that individual member states can also implement stricter national legislation. In general the environmental directives and regulations of the European Union allow member states to design legislation that would enable or demand urine and/or faeces separating sewage systems, but the legislation on the further use of these resources might cause problems in practice and needs proper interpretation and discussion. /3/

## 6.2. Finland

The most recent *Government Decree on Treating Domestic Wastewater in Areas*

*Outside Sewer Networks* (542/2003) in Finland has the objective of reducing domestic wastewater emissions and environmental pollution caused by them. It specifically takes into consideration national water protection objectives. The authorities guiding the implementation of the decree are the Finnish Ministry of the Environment and the Finnish Environment Institute (SYKE).

In general, the decree sets target values for the reduction of environmental loading caused by domestic wastewaters. The minimum reduction targets are given in percentage of the untreated wastewater. The reduction values can be seen in Table 1.

Table 1. Reduction demands for household wastewater emissions set by the Finnish wastewater act. *Reduced reduction demand applies to particular households and areas defined in the act. /9, **21/**

| **Type of emission** | **Organic material (BOD7)** | **Phosphorus (P)** | **Nitrogen (N)** |
|---|---|---|---|
| Reduction demand (%) | 90 | 85 | 40 |
| Emission to environment, maximum (g/person/day) | 5 | 0,33 | 8,4 |
| Reduced reduction demand (%) * | 80 | 70 | 30 |
| Reduced reduction demand for emission to nature (g/person/day) * | 10 | 0,66 | 9,8 |

The decree also requires that every property and dwelling has a report on their current wastewater treatment system which should enable the assessment of the environmental loading of wastewaters. The report is to be kept at the property in question and be presented to the authorities on request.

Attachment 1 of the decree contains general guidelines for what components a basic on-site wastewater treatment systems should have, but the information is rather brief and does not specify any construction dimensions. /9,21/

More detailed information and aid on understanding and implementing the decree can be found in Finnish in the publication *Käsikirja haja-asutusalueiden jätevesien käsittelystä Kiinteistönomistajille, kuntien viranomaisille, suunnittelijoilla ja alan opetuskäyttöön* /9/.

## 6.3. Sweden

The Swedish Environment Protection Agency (Naturvårdsverket) has produced a guideline for small-scale wastewater systems intended for domestic wastewater (NFS 2006:7). It is based on the decree on “environmentally harmful actions and protection of health” (1998:899, förordningen om miljöfarlig verksamhet och hälsoskydd) and on sections 2 and 26 of the Swedish Environmental Code (miljöbalken). According to the Finnish Environment Institute, the Swedish guideline was formulated on the basis of the Finnish wastewater decree. Similarities between the two are noticeable.

The guideline gives detailed information on the level of protection required for the protection of public health and the environment. There are two different levels of requirements, the normal and the high level, and the level of requirement has to be determined on a case-by-case basis. The guideline also somewhat promotes and highlights urine and faeces separation as it is mentioned that by the means of this separation (for example with a urine separating dry toilet) the amount of treatment required for wastewater can be reduced.

Attachment 1 of the guideline specifies the average emissions of household wastewater and also provides the requirements of reduction amounts (see Table 2). Attachment 2 includes similar information as the Finnish decree (see section 6.2) on the required report on the wastewater system of the household. /23/

**Table 2.** Reduction demands for different household wastewater emissions as defined by the Swedish wastewater act. * Requirements for areas which require a "high level" of treatment as defined in the act. ** Concentrations are calculated assuming that the wastewater amount per person per day is 170 l. /23/

| | Reduction % | Release amount, g/p, d | Maximum concentration in effluent, mg/l ** |
|---|---|---|---|
| BOD7 (Organic material) | 90 | 5 | 30 |
| Phosphorus (Tot-P) | 70 | 0,6 | 3 |
| *Phosphorus (Tot-P) | 90 | 0,2 | 1 |
| Nitrogen (Tot-N) | 50 | 7 | 40 |

## 6.4. Denmark

An ”Action Plan against Pollution of the Danish Aquatic Environment with Nutrients” was passed by the Danish parliament in 1987, with the objective of reducing the nitrogen and phosphorus loading of aquatic environments caused by agricultural, municipal and industrial discharges. In 1997 a separate amendment to the Environmental Protection Act, Act 325 on Wastewater Treatment in Rural Areas, was passed.

The requirements of Act 325 are rather high. There are four different treatment classes, depending on the receiving body of water into which the treated wastewaters are finally discharged. The removal of organic matter (BOD5) is required in all cases, be the place of discharge into freshwater or seawater. If the wastewater effluent is discharged into a lake or a watercourse that finally discharges into a lake, phosphorus removal is required (see treatment classes OP and SOP in Table 3). In cases where the effluent is discharged into a watercourse with a water quality objective for salmon fish, nitrification treatment is necessary (see treatment classes SOP and SO in Table 3).

**Table 3.** Treatment classes and their requirements for treatment (% removal) of wastewater in rural areas in Denmark. /4/

| Treatment class | BOD5 | Total-P | Nitrification |
|---|---|---|---|
| SOP | 95% | 90% | 90% |
| SO | 95% | - | 90% |
| OP | 90% | 90% | - |
| O | 90% | - | - |

The Danish Ministry of Environment and Energy has also produced official guidelines for different wastewater treatment systems. These include guidelines for soak-away or soil infiltration, root-zone systems (equivalent to horizontal subsurface flow constructed wetlands) and biological sandfilters. All the guidelines are written for a system size of up to 30 person equivalents (PE). Research on the original guidelines could not be conducted for this report as they exist only in the Danish. However, a separate report summarizes the guidelines for small-scale constructed wetland wastewater treatment systems (see reference X). These include guidelines for root-zone systems, vertical flow constructed wetlands and willow systems. The interested reader should definitely study this information as it summarises legislation and regulations, pre-construction studies of the site, pre-treatment demand, technical descriptions for designing and building the systems, and management demands related to the specific systems in use in Denmark. /4/

## 6.5. Germany

At least three legislative measures that are related to wastewater treatment were found from the act and ordinance collection of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit). These are the Federal Water Act (Wasserhaushaltsgesetz, WHG), the Wastewater Charges Act (Abwasserabgabegesetz, AbwAG) and the Wastewater Ordinance (Abwasserverordnung, AbwV).

Article 18 of the Federal Water Act states that disposal of wastewater should be done in a way in which “public interest is not impaired” and also that decentralized installations for the disposal of domestic wastewater can be in accordance with public interest. Specific articles also define the management objectives for surface water and groundwater, which include the avoidance of adverse changes in the ecological (surface water), quantitative (groundwater) and chemical (both) status of water resources.

Appendix 1 of the Wastewater Ordinance states requirements for wastewater at its point of discharge into nature. There are no specific requirements for rural areas, rather, the table sets limits for different amounts/volumes/magnitudes of discharge. However, the limits for the smallest size category (i.e. 1) are less than 60kg/d BOD5, which is a very large amount (the BOD5/7 is usually calculated in g/person per day). There may be some existing requirements for small-scale wastewaters, but these could not be located during the course of this study.

Federal legislation in Germany is restricted to producing framework provisions and therefore the acts and ordinances leave considerable legislative responsibilities for the separate states (Länder) within the Federal Republic. Therefore the regulations may vary noticeably from state to state. /19, 20/

# 7. THE FINANCING OF ALTERNATIVE WASTEWATER TREATMENT SYSTEMS

The economic resources available to users typically cause notable restrictions on the planning process of a (sustainable) wastewater treatment system. It can be argued that the costs of local, on-site treatment solutions should be comparable to the ones that follow from being connected to centralised wastewater treatment.

However, the costs should also be considered on a longer term, i.e. throughout the whole lifetime of a particular facility. The construction costs of a local wastewater treatment facility may be relatively high, but the initial investments in construction should pay themselves back on the long run. It is also always worth considering shared treatment systems as opposed to single-household systems, as significant benefits can be attained through shared costs. Other costs (and incomes) to be considered are related to different kinds of treatment systems. If urine, and possibly also faeces, are separated and used in agriculture, the costs of using artificial fertilizers should also diminish. Transportation costs should also be considered. When using water-saving appliances, costs for water and also wastewater should diminish. /14, 12/

Finally, governmental subsidies and such benefits should also be taken into consideration. The following two subsections discuss the availability of government subsidies for wastewater treatment systems in the countries studied for this thesis.

## 7.1. Subsidies aid for wastewater treatment issues in Finland

The Finnish State offers two kinds of subsidies for household water management. These are the *household wastewater subsidy* (talousjätevesiavustus) and the *water resource management subsidy* (vesihuoltoavustus). /26/

The household wastewater subsidy can be granted for the improvement of wastewater systems in residential buildings that are used all-year-round and are located outside the operational area of centralised water resource facilities. The subsidy is granted by the local municipality on the basis of social and economic consideration. /15/

The water resource management subsidy can be granted for a property owner or occupant when the property is used for permanent residence or for a commercial activity that implements similar water resource management. The project also has to be necessary from economic, human health, or environmental protection related reasons. The subsidy is granted by the regional environmental centre. It is granted on a case-by-case basis for several possible purposes, including the connecting of properties to water supply networks or the construction of a property's own water supply or wastewater treatment facilities. This subsidy is normally at most 30% of the costs of the project. /26/

However, it is stated on the web site of the environmental agency that in practice the granted water resource management subsidies have been very small or have not been granted at all due to the scarcity of available governmental funding. The question then is, how reliable funding source is it after all. /26/

## 7.2. Economic benefits in Sweden, Denmark and Germany

It was difficult to find any information on funding offered by local authorities or other organizations in Sweden, Denmark or Germany. Since it was noted that there is very little information available on this topic in literature, it was hoped that such information could be gathered via the questionnaire sent to selected ecovillages. However, partly due to the low amount of responses, this research channel did not act as a notably better information source (See section 8).

Funding or economic support can also be in the form of taxation or cost relief offered by local municipal authorities.

# 8. QUESTIONNAIRE

To supplement the above literary review a questionnaire was sent to 27 ecovillages in the countries studied here; Sweden, Denmark and (northern) Germany. The main purpose behind the questionnaire was on one hand to identify how wastewater treatment facilities are used on a practical level and on the other to supplement areas of the literary review for which information was not readily available, as for example in section 7.2.

The amount of responses to the set of questions sent to the ecovillages was rather small, the response rate being 18,5%. Nevertheless, the responses do provide some information on the issues from the point of view of the ‘ecovillager’. The questions concerning this study were related to the wastewater treatment facilities of the villages, their costs and possible subsidies received. The questionnaire is presented in Appendix 1. The villages who responded to the questionnaire can be seen roughly placed on a map in Figure 8.

Various ways of organizing wastewater treatment were present even among the limited set of respondents to the questionnaire. The following subsections discuss the information received from each ecovillage.

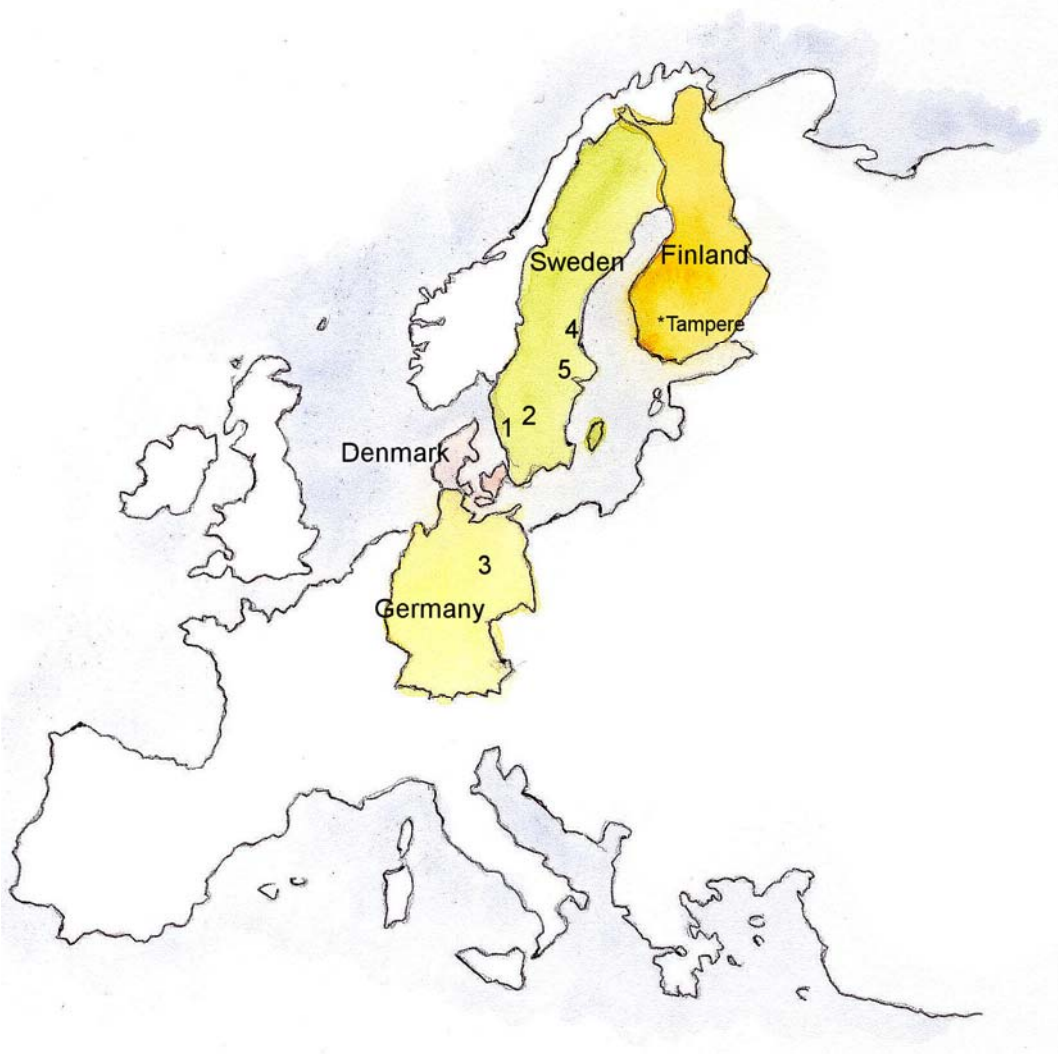


**Figure 8.** Map of Europe with the scope countries of this thesis highlighted. The numbers (in the same order of appearance as in the text) represent the villages who gave response to the questionnaire, very roughly situated on the map. Also Tampere, from where this research was conducted, is marked on the map. /HS/

## 8.1. Case 1: village in the Mark municipality, Sweden

The village in Case 1 houses 18 adults and 18 children of various ages in 6 private houses and one house with four rental apartments. The first houses were built in 1997. The building has been very free, and everyone could decide on their housing facilities according to their own taste and interests.

Wastewater treatment was organized individually by each of the village's households. Most of the households used urine-separating toilets combined with composting of faecal wastes. A local farmer used the collected urine as fertilizer.

The greywaters were treated in a gravel infiltration bed, except for one household which used a sand filter and the treated water from that was used for watering plants in a greenhouse. The functioning of the gravel infiltration beds was thought to be normal, but there were some assumptions on too large nutrient leakage to the environment. Difficulties with the sand filter bed were related to no design or information available for the construction, which had caused some mistakes.

When asked if any research connected with the wastewater treatment system had been performed in the village, the response was *"Unfortunately not, it would be good to know what's really happening!"*

According to the respondent, there had been no financial support for the village. To the question about any difficulties related with wastewater treatment, the respondent mentioned the mismatch between requirements of authorities (local council, organic agriculture certification bodies, etc.) for the storage of urine before use.

## 8.2. Case 2: village in the Jönköping municipality, Sweden

The second village is a community of 46 adults and 23 children in 24 apartments in semi-detached houses. The construction of the houses was started in 1993. In this village urine separating low flush toilets (3 l) were used. The urine was stored on-site and later utilized by local farmers as fertilizer. The remaining black waters from the toilets were treated by each household, using centrifugal separation of the solids and liquids ("Aquatron"). The solids (faeces and toilet paper) were lead to vermicomposts, of which each household had their own and the composted material was used in the community gardens. The separated liquids were combined with other household greywaters, and these were treated in a system consisting of a trickling filter ("Bioclere") followed by a constructed pond, a constructed stream and a natural wetland for ´polishing´ from which the effluent was discharged to a nearby stream. There was a community agreement on using low phosphorus detergents in order to minimize the impact of the greywaters on the environment. Problems had occurred with the construction and inadequate capacity of the Aquatron –systems. Discussion on connecting to municipal sewage treatment was going on in the village. This village used their own deep drilled (bored) wells as a source of freshwater.

There was no follow-up research going on at the moment, some students from a Swedish University had been interviewing the villagers some years ago but no results had been seen from that. Also a comparison research between the Bioclere greywater treatment used in the village and a nearby municipal treatment plant had been performed in 2001.

When asked about any financial support from outside, the answer was negative. Difficulties with the wastewater treatment system were related to the fact that the system was new to all involved people. In the planning phase it had been difficult to find any appropriate consultants to help with organising the system, from toilet to recipient.

## 8.3. Case 3: village in the Belzig region, Germany

The village in Case 3 is a community of 80 people; adults, children and youth. The village construction started in 1991. The respondent of this village briefly stated that they have a wastewater treatment system comprising of marsh plants and willows, working well since 16 years. There was also a spring on site used as a freshwater source.

The community had never received any subsidies from outside, which was stated as one reason for the slowness of the process. No on-going or finished research projects were mentioned, and neither any difficulties during the process.

## 8.4. Case 4: village in Nordanstigs municipality, Sweden

The fourth village is a community of five families, housed in two semi-detached houses and a one-family house. The first constructions took place in 1991.

The fourth respondent described their toilet systems to be urine separating, low-flush models. The separated urine was used in the gardens of the community. Faecal wastes were collected into containers which were changed monthly. They were left to dry and then composted. The greywaters were lead to a two chambered tank and from there to a large leaching bed (75m2 for five families) which according to the respondent functions well all-year-round. During 16 years of operation, the leaching bed has been thoroughly rinsed two (2) times, simultaneously emptying the separation tanks from which the wastewaters were taken to municipal treatment beds. This village also had their own bored well for freshwater intake.

There had been a few studies related to the wastewater treatment system in the village, and the respondent also mentioned that the municipal environmental chemists would take samples from the system when asked to do so.

There had been no direct financial support. The houses were built by the municipality originally on rental basis, until the residents purchased them. Bank loan had been taken to enable this. There were no costs from the municipality on water or wastewater. The community has its own borewell for freshwater and on-site infiltration for wastewater.

## 8.5. Case 5: village in Västerås municipality, Sweden

The fifth village studied consists of 26 residencies, with a total population of 117 inhabitants. The year of first constructions on site is 1990.

Information gained on the fifth village stated that there had been separation of urine, faeces and gray waters earlier, but since 2006 the village was connected to the municipal sewage system. This was because of *“cost and comfort reasons”*. There had been no follow-up projects on the systems used in the village, but the respondent gave a positive thought on the idea of having such.

To the respondents knowledge there had been no outside financial support to the community and the constructions. The difficulties that had arisen with the wastewater treatment system were on one hand cost and investment reasons: *“short lifelength of the sandbed for filtering the greywater”*, on the other hand reasons of comfort. Due to these reasons the decision for connecting to the local water and wastewater network had been done.

# 9. DISCUSSION AND CONCLUSIONS

Environmental sanitation is aimed to protect the environment from pollution and deterioration as well as the humans from diseases. In addition to these, ecological sanitation closes the nutrient-loop by returning significant resources back to the nature. Looking at available resources and knowledge, communities in Northern Europe are in a good position to implement ecological sanitation systems.

Sustainable construction should take into consideration ecological, economical and social aspects. These aspects contain the need for decreasing the use of non-renewing materials and energy, enhancing the recirculation of existing materials and thus reducing the amount of waste, ensuring energy efficiency and maintaining and enhancing ecological diversity. All of these aspects should be observed and implemented in the planning, construction and operating phases of a sustainable wastewater treatment system. As the legislative requirements in Finland for the wastewaters in rural areas have been recently adjusted and they call for some changes in many households, the time is appropriate for thinking also from all the sustainable points of view during the process.

There are various technical solutions to choose from, and it is important to make public knowledge out of the best functioning options. Some systems can be seen as more ecologically sustainable than the others, but issues regarding the construction and maintenance need to also be taken into consideration – a theoretically good system may turn harmful if used and maintained poorly. What is needed in this field is more readily available information on the simple, well-functioning sustainable options which would be in a good price-quality range. Consultants who have knowledge on the sustainable treatment systems and ability to find the right, localized solution are needed as well.

Legislation in the countries compared in this project are quite similar. This has to some measure been affected by the EU directives and regulations, implemented in each of the studied countries. The detailed guidelines for different (more sustainable) options for wastewater treatment (eg. constructed wetlands, willow treatment plants, etc.) that were found from the material produced by Danish environmental authorities were rather impressing in their details. This is perhaps something that could be done also in Finland – produce easy to access and informative guidelines for sustainable choices in wastewater handling and treatment. When the systems could be regularly monitored, more information on their functioning would be available and this could effect positively on the prejudices and fears of possible users and also authorities.

Local authorities could also provide economical benefits for households or communities making the choice for a sustainable wastewater treatment system. For example, if a community purchases only freshwater, and treats the wastewaters on its own premises, it is not very sensible to make them pay for outgoing wastewater as well. In general, sustainable choises of wastewater treatment systems for rural areas could be subsidised more as this would benefit the whole community or nation as e.g. reduced treatment costs, less risks of pollution, possible financial benefits from nutrient recovery and so on.

During the research it became evident, that better instructions and easy ways to perform follow-up research on the functioning of the systems are needed and also called for by the users. Research and measurements could be done either by the users or someone from outside the community; municipal authorities or specific private companies.

The most important issue is to spread the knowledge and promote long-term ecologically sustainable solutions. In order to have properly functioning wastewater treatment systems people should know the principles of their functioning and maintenance. The viewpoints, needs and wishes of future users should be taken into account with high regard in the planning phase of new systems. Well-functioning systems lead to positive attitudes of users, which again can help in spreading the word about sustainable options.

The promotion of sustainable sanitation and wastewater treatment systems demands for co-operation between experts of the field, local and national authorities and the common (would-be) users in order to gain wide-spread distribution.

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## Appendix 1: Questionnaire

To whom it may concern,

We are two students in the field of Environmental Engineering, from Tampere, Finland doing research for our final thesis projects. Both our theses are connected with sustainable villages in rural areas in northern conditions. Following are a few questions we would like to ask you in connection with your village.

1) How is the wastewater treatment organised in your village? How is it functioning, technically and in the opinion of the users? Are there any on-going or already finished follow-up research projects connected to the wastewater treatment in your village?

2) How is energy management organised in your village (heat and electricity)? How reliable is the system? Is there any back up electricity source if system fails for some reason? What kinds of measures have been taken in use to prevent any excess energy loss (heat and electricity)? Is there any on-going or already finished follow-up research projects connected to the energy management in your village?

3) In the planning or building phase of your village, did you get any financial support from any direction, e.g. the state / the region/ the municipality/ other organisation? Can you state, what proportion the possible outside support was from the total financing of the village project? Are there any ongoing financial supports for your village?

4) Were there any difficulties related to either the organising of wastewater treatment or energy management in your village? If so, how were they overcome?

We greatly appreciate your time spent on answering these questions. It would be great if you could answer before 09.05, so that we still have time to process the information. If there are any problems or further comments, please contact us in the address "enve.project@gmail.com".

With kind regards,
Helene Salminen & Toni Järvinen