

B 7 SUSWAT  
Sustainable Water Supply  
in the  
Baltic Sea Islands

**Idea Catalogues**

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### PREFACE

A plan for sustainable water supply can be a very useful instrument, both for the future management of the water supply and for the local authorities responsible for the overall planning and management of the society.

Up-to-now a sector planning process for water supply has been normal procedure in a few B7 islands and the involvement of water supply planning in spatial planning has normally not been given high priority.

This is mainly caused by differences in legislation and traditions.

### Background

In Denmark, municipal sector planning for the water supply became a legal demand in 1985. Since 1995, this has changed to a broader legal concept with incorporation of water supply planning in the municipal spatial planning process (The Municipal Spatial Plan). Also counties have produced water plans, because the counties since 1985 have been responsible for the water resources. This has resulted in so-called Water Extraction Plans in all Danish counties, and integration of water extraction, water protection and water supply in the regional spatial plans (Regional Plans) with overall measures and guidelines for these subjects.

Based on these Danish experiences a Water Supply Plan for a municipality, a district or for a group of waterworks can typically have the following content:

#### A. Introduction

Typically giving information about the legal background of the plan, of the main issues of the plan, of the headlines in the plan and the expected usage of the plan. The planning period is often 12 – 15 years.

#### B. Existing Water Supply

With short descriptions of

- The supply structure in the area (works, water quantity etc). The water extraction and treatment plants (extraction wells, equipment etc).
- The supply system (size, quality and extension of pipelines, water towers, pressure zones, metering equipment etc).
- The capacity of the waterworks (of the wells, of the treatment plants, of the reservoirs etc).
- The level of security in water supply (delivery capacity compared to maximum consumption per hour and 24 hours, emergency supply possibilities etc).
- The quality of the drinking water (results of analyses etc).
- The headlines in the water extraction permission(s) (typically given by county or state) and conditions given in the permission(s).

### **C. Water extraction**

With descriptions of

- The (known or expected) water catchment area for each well field and information about the land use.
- The aquitards and aquifers (geology, hydro geology, water quality, vulnerability of the aquifers etc) – often information given by county or state and/or results of specific mapping and monitoring in the area.
- The quality of the raw water (results of analyses etc).
- The potential human based sources for pollution of the aquifers (farming, industries and installations, sewage pipelines, deserted wells, old soil pollution, landfills etc).

### **D. Relations to spatial planning and sector planning**

Mainly with descriptions of

- The planned spatial development in and around the supply area.
- The relations to sewage plans and sewage systems (leakage and percolation etc).
- The relations to surface waters (rivers, streams, lakes, wetlands etc).

### **E. The existing water demand**

With descriptions of

- The development in the water consumption over the last 5-15 years, if possible given for the different types of consumers (dwellings, industry, summer houses, institutions, farming etc) and for different parts of the supply area. The description is given for consumers connected to the common water supply system and consumers with own water supply (single plants).
- The development in the unity consumption for each category of consumer (dwellings, industry, summer houses, institutions, farming etc).
- The development in the losses in the supply system (counted or calculated).

### **F. Prognosis for the future water demand**

With descriptions of

- The basis for the prognosis, for instance forecasts for population and size of households, land use plans or development in industry, tourism etc.
- Expected, foreseen or just possible water saving measures (for instance: increased maintenance of the pipelines, installation of meters, reduction of supply pressure, changes in consumer habits through campaigns, taxes etc). Each measure can be described in detail and the assumed result in the planning period is stipulated.
- Expected development in unity water demand – for a household, a summer house, a farm, a hotel, an institution etc is predicted.
- This leads to a total prognosis and based on the input it can be presented as the expected water consumption for year 0, year +4-5, year +8-10 and year +12-15.

## **G. Overall goals/measures in the water management**

This chapter can describe the result of given political decisions regarding the water management in the future or just set up suggestions for goals and measures. Typical examples can be that the planning authority wants

- to guarantee the consumers the best possible security in water supply,
- to obtain an environmental sustainable water supply and management,
- to deliver clean and safe drinking water in the amounts needed by the consumer,
- to reduce unnecessary water consumption, and
- to reduce the demand for energy and the resources in the supply company.

Such measures can of course be more or less detailed.

## **H. Plan for future water supply and management**

This chapter describes the activities that are - or can be - actual or needed in the planning period to fulfil the overall goals.

- It will typically be a number of different activities regarding for instance
- the structure of the supply system, renovation of pipelines and installations, new pipelines and pumping stations etc,
- the establishing of new extraction wells and the eventually closing of existing wells,
- the protection of the water recovery areas and,
- the monitoring programmes for water levels and for raw water quality etc.

## **I. Prioritised action plan and time schedule**

Here is - in schematic form – given the different recommended activities under Chapter H shown in sequence in time.

The action plan ought to be very concrete for the first part of the planning period (4-5 years) and less detailed for the rest of the period.

## **J. Future revisions of the plan**

It might be a good idea to incorporate a procedure and time plan for future revisions of the plan.

In Denmark the local authorities are obliged to make an inspection of the spatial plans (including the sector planning) at least once in each electoral period (4 years) and to revise the plan if needed.

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## 1.2 IDEAS FOR PUBLIC INVOLVEMENT IN THE PLANNING PROCESS

### PREFACE

A dialogue with different stakeholders, private individuals, and organisations is usually necessary for good planning. This dialogue may be formalised by law or take place through more informal handling of particularly problematic matters. The reason for starting an informal dialogue may vary, and the design may vary according to the specific topic. To achieve a good dialogue, it is crucial to reach the right target group.

### General

For most of the islands in B7 it is in reality impossible to solve water supply problems by importing water from the mainland. The islands have to rely on the water resources of the island itself. It is therefore crucial to protect the resources for the supply of drinking water, and this is a problem for all the islands. The protection may apply to both qualitative and quantitative aspects.

If the protection of water resources is to be effective, it is essential that it should be understood and accepted by as many people as possible. Active participation by the individuals and organisations concerned means a better chance of understanding any restrictions that may be needed or measures that have to be taken.

Good knowledge of local water resources can often be found among people living and working within the area. This knowledge may be of great significance and it should be utilised.

### Current legislation

Status Report 1998, table 4.1, page 25, shows the state of affairs on the B7 islands as regards different types of plans and the statutory requirements for public involvement in the planning process.

In Sweden there are several laws that give the public the opportunity to participate in any planning that affects water resources, namely:

- In physical planning, in accordance with the Planning and Building Act.
- In the introduction of water protection areas in accordance with the Environmental Code.
- In the utilisation of water supplies above a certain size in accordance with the Environmental Code..

### Planning and Building Act

The rules on the procedure for drawing up plans are in Sweden regulated in considerable detail in the Planning and Building Act. One of the most important objectives of the Act is that everyone affected by the plan should be guaranteed a real influence on the design of the plan. This is ensured through consultation and display. Consultation and display are used for both structure plans and local plans. Consultation means that anyone can submit views on the proposed plan, either in writing or at a public meeting. However, a consultation meeting is held only if the plan is significant for a large number of people. The views expressed are compiled and considered in a report. According to the law, all affected individuals and organisations should be given an opportunity for consultation.

The proposed plan should be on public display for at least three weeks (local plan) or at least two months (structure plan). The display must be announced on the municipal notice board and published in the local newspaper. Those who wish to submit their views during the display period should do so in writing.

In certain cases of local planning, a simple planning procedure may be used if the proposal is of limited significance and of no general interest and if it is compatible with the structure plan and the country administration's statement

after scrutiny of this plan. Simple planning procedure means that the municipal authorities consult the affected parties on just one occasion.

### **Introduction of water protection areas**

With the support of the Environmental Code, the county administration or the municipal authority can designate an area as a water protection area to protect a source of surface water or groundwater. Notification must be given of special instructions on protective actions, restrictions, and cautionary measures. The protection rules may mean that the landowner is entitled to compensation for encroachment.

There are no formal requirements as to how and to what extent people should be informed when a proposal for protection regulations is drawn up. Information to the property owners affected by the regulations is mostly included as part of the work of drawing up the proposal.

Before a decision about protection regulations is taken, all the affected stakeholders are invited to submit statements. The requirement that stakeholders should be asked to state their views is connected with aspects of property law regarding these matters; it is supposed to ensure that stakeholders read the documents and formulate a response.

Information is often announced to the general public after a protection area has been established by means of signs set up along the boundary of the area.

### **Utilisation of water supplies**

Setting up a water supply, whether surface water or ground water, to provide water for more than two households, requires a permit in accordance with the Environmental Code.

Consultation must take place at an early stage, and not just with the authorities but also with affected members of the public. The law does not stipulate what form consultation should take; it can vary from case to case. In the continued handling of the matter, the compulsory consultation is governed by the Environmental Code and varies depending on the size of the activity or the risk of disturbance.

The matter must always be announced and be available to the general public so that people may express their views.

A meeting with the affected parties is held in major or controversial cases.

### **Increased public involvement**

The stated requirements in the legislation are minimum levels for the potential for public involvement in various planning contexts. The opportunities for participation by the general public, through consultation and other means, as required by legislation, have been formulated partly in order to ensure the rule of law.

The requirements for formalisation may in many cases be an obstacle to public involvement. To develop public participation, it is deemed that a more active approach is needed. Increased involvement and an increased understanding of the importance of our water resources are essential. One way to achieve this is a better dialogue in different planning situations, and the use of other occasions for public involvement.

There should be many more occasions when it could be appropriate to have public participation, and they should be more varied than those provided for by current legislation. Such occasions could be:

- When there is a need to capture local or unique knowledge
- When local involvement is needed, to increase understanding
- When it is important to change habits or patterns.

The target group for participation, the “general public” can be a highly varied group depending on the occasion and the purpose. It can be anything from the entire population who have to be reached in a major information campaign, to a limited group such as schoolchildren, who are the target of a limited campaign, or a small, restricted

area with a shared problem. If a dialogue is to be possible, the target group should not be too big. Otherwise the dialogue has to be carried on over a long period, or special representatives, organisations, associations, political parties, companies, and the like have to represent the public in contacts with the authority.

## **Ideas**

Below are some ideas as to when increased participation may be appropriate. The first two ideas, which are presented in some detail, represent projects implemented by Gotland Municipality.

The ideas may be viewed as suggestions as to occasions when increased information may be considered, examples of how local involvement can be achieved, which groups may be targeted, and the experiences that have been gained.

### **Hangvar – a small, well-demarcated area**

Hangvar is a small area with private settlements, about 50 properties, some farms, and a school. Water and sewage supply are based on private solutions for each property. The shared water supply in the area is threatened, and for some properties the drinking water has been condemned (bacterial pollution). The sources of pollution in the area are sewage emissions and the agricultural use of manure. The geological potential to purify the pollution is limited in much of the area.

The problem is how to ensure the common supply of water so that an acceptable long-term water supply can be obtained.

#### Working method

- Introductory meeting. All the residents in the area were invited to a meeting where they were informed about the background and how future work was planned. The aim of the meeting was to give an opportunity to meet and inform the residents and thus increase their awareness, and to shed light on the common problem.
- Survey and analysis of all sources of pollution in the area. The results were compiled in a special report.
- Concluding meeting. All the residents in the area received a report and were invited to a meeting where they were informed about the results and conclusions of the work. The aim of the meeting was of course to communicate the results and conclusions, but above all to create an understanding of the problem and ensure a local momentum in the continued work by forming a working group.

#### Experiences

The target group in this case was all the residents in the area, which meant that everyone felt equally involved and informed. Meetings should be held locally; the authority must go to the public. It is important to remember that just because people live within a limited area, it is far from certain that they know each other well, and there may be different opinions within the group.

To ensure that discussions arise, it is generally easier the smaller the groups are. It is good to have a coffee break so that the meeting is broken up into smaller groups, which gives an opportunity for discussion and asking slightly more “personal” questions.

### **The Water Plan – a major structure plan**

When Gotland Municipality was going to draw up a water plan, a method was chosen that involved consultation over and above the statutory level. The start of the actual planning work consisted of an early consultative hearing, which brought together a large number of the affected people. The aim was to ascertain people’s knowledge and expectations before the planning began, as well as the demands and needs concerning future water matters.

#### Working method

- Selection. The target group may be said to consist of all residents of Gotland, so a selection was made of

over 40 representatives who were invited to the early consultations. The representatives consisted of small private companies, larger companies, the military, relevant associations such as the Society for the Conservation of Nature, other affected authorities, organisations such as the Federation of Swedish Farmers and the local research station. The political parties were not invited for consultation in this part of the process.

- The early consultations were held privately with each representative for about 45 minutes. The municipal participants were the working group for planning, the immediate superior, and a secretary. A total of 27 of 41 representatives accepted the invitation to participate. The viewpoints expressed were compiled to provide background material for continued work with planning.
- Follow-up. All those who took part in the early consultations received the proposed water plan for comments on the two occasions when the plan was circulated for comments. This means that the normal comments procedure was expanded.

### Comments

Holding consultations with affected representatives at an early stage in planning work gives an opportunity to capture available knowledge and viewpoints. At the same time, it is an opportunity for the authority to spread knowledge about the coming planning work, which should increase the chances of the product having a wider spread and better support.

Since water issues concern everyone in society, a large number of representatives were invited. There should be a continuation of the earlier consultation, in that the participants have a chance to state their views of the plan when there is a finished proposal.

### **Focused campaigns**

Information can be spread by advertisements in newspapers or by mail to a selected group. A campaign of this kind can either have a message of a fairly general character or it may contain a concrete message, such as the importance of using water sparingly.

To achieve a dialogue with the general public, the campaign should be specially focused and limited. This enables feedback to the participating public and hence a dialogue. All those who take part in some form of campaign need a confirmation of their participation and the actions they have taken.

### **Open house**

One possibility for direct contact with the public, to really show them what water supply means, is to invite them to come on a study visit by arranging an open house. This kind of arrangement should be recurrent. It can suitably be supplemented with an exhibition, lecture, or the like to convey the desired information. It should be held in conjunction with some other event, a market or the like, and be held locally in order to attract more visitors.

### **Computer media**

With computers becoming increasingly common among private persons, there are greater opportunities for more widespread communication. With a greater quantity of information, above all as geographical information on maps, it can be made more accessible to the general public.

Opportunities for public participation should thus be increased, and it should moreover be both simpler and more common than is the case today. An idea for the future, a vision, can be a constantly ongoing dialogue between the authority and the locally affected public.

## **Conclusions**

There are many opportunities and occasions to allow the public to take part in different planning questions. The obligations stated in the legislation are only minimum levels. Achieving increased involvement by the public requires resources, and this must be balanced against the gains envisaged for the future. Even with broad involvement it is not certain that the set objectives can be attained.

If it is to be possible to achieve greater insight and understanding about the importance of protecting our water supply, however, it is necessary to find new and more forms to make room for greater public participation. This applies both to large overall plans and to plans for small, limited areas.

It is not possible to draw up any exact or defined list of the organisations, associations, and the like that are suitable for participation. This must be decided from case to case on the basis of the problem and the geographical scope.

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## **1. 3 INTEGRATION OF WATER SUPPLY IN THE PLANNING PROCESS FOR A SMALL SOCIETY**

### **PREFACE**

One of challenges in the spatial planning process is to integrate issues concerning water supply. To succeed you must have some basic facts for example about water consumption and access to water supply. How many and what kind of facts you need depends on the extent of the plan. A plan gives a possibility to issue rules for different activities in order to protect water resources and prevent pollution..

### **Task**

The task is to find different possibilities to integrate water supply in the spatial planning. The water resources are so important for the every day life in all communities that you have to pay attention to the resources in all planning processes. This contribution to the idea catalogue regarding the problems about integration the water tasks in the planning process is done from a view of a small municipality.

### **Background**

Föglö is a small municipality in the county of Åland. The municipality is situated South East of the mainland of Åland. The distance from Mariehamn City is 30 kilometres. Connection to the mainland is by ferry, which have 30 minutes sailing time.

The total area of the municipality is 950 square kilometres distributed in 132 square kilometre land and 818 square kilometre water. There are about 600 inhabitants in the municipality.

Föglö municipality maintains total municipal administration. Water tasks are handled by the technical sector in the municipality. The municipality has one waterworks, which supports the capital village on the island. The waterworks take the raw water from a groundwater source. In the municipality no ground water resources are

protected by law. The same goes for surface water catchment areas. Water supply in the other villages in the municipality is handled by private wells for each household.

At the moment Föglö is preparing a municipal Summary Plan to be ready in year 2000.

Map over Åland and the municipality of Föglö.

## **Legislation on Åland**

The spatial planning in Åland is regulated by the Building Act and the Act for Municipal Summary Planning. According to those acts the municipality takes care of its own spatial planning. The Government of Åland has the overall responsibility. Åland has its own Water act, which was taken in effect the first of January 1997. Environmental panel gives permission authority for different water task.

## **Ideas about integrating the water supply in the planning process**

Following items could be important to think about in the municipal planning process:

To get a specification of how the water resources are distributed in the municipality you should do a complete mapping of the groundwater occurrence in the municipality. In that way you could estimate which areas have a great importance for the future water supply and therefore must be protected by the planning process.

In the plan you should also have specifications of the water consumption in the municipality. What the quality of the water is? How big the consumption is in the different regions? The estimated future consumption depending on the development of the municipality?

You could introduce a conception about "wet and dry houses" in the planning process.

A "wet house" means a building with water closet while a "dry house" has a dry toilet system either inside or outside the house. According to the municipal summary plan should only "dry houses" be accepted in an area, which you do not want to exploit hard, for example an islands and along sensitive shores.

Drilling for groundwater should be regulated in the plan so that the municipality gives permission for the measure. There is also a need for a register of the drilled wells.

There is often agriculture in a rural district. The agriculture can have a negative effect on the groundwater and on potential surface water resources. Therefore it is motivated to make rules for using fertilizers and pesticides for agriculture. Those regulations could consist off demands on for example, protected areas to ditches, drains, important raw water wells alternatively raw water lakes and so on.

You must also consider an alternative to build a complete system of water supply pipelines in the municipality and compare to the alternative of smaller local waterworks in order to secure the water supply for the inhabitants.

The municipality plans for future settlements, so that suitable land areas are reserved as dwelling areas according to the water supply. This concerns also industrial activity as companies, tourist commerce and so on.

Different solutions on waist water treatment in order to protect raw water, used for water supply should be clear in a sustainable plan.

## **Conclusions**

To sum up it is very important to pay attention to the water supply in the municipality planning process. Water supply is depending on how much you exploit land for different purposes. By that the municipality should introduce different parameters in the plan like water extraction, water consumption, waterworks supply capability and so on to secure the future water supply in the municipality.

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# IDEA CATALOGUE 2

## SUSTAINABLE WATER RESOURCES IN ISLANDS

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#### **2.3 ARTIFICIAL INFILTRATION OF SURFACE WATER 2.17**

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## 2.1. HOW TO FIND THE BEST AQUIFER/RESOURCES

### PREFACE

Geological and hydrogeological knowledge is needed to enable localisation of the best water resources. Both field investigations and studies of literature are normally necessary to acquire the necessary knowledge.

There are several different investigation methods, which may need to be carried out in the field to obtain the necessary knowledge. The methods can be compared with different equipment depending on the objective of the investigations.

### Data analysis required to find the best aquifer/resources

Geological factors (related chiefly to geologic formations and their water-bearing properties) and hydrogeologic factors (related to the movement of water in the formations) must be known in some detail to properly design groundwater investigations. These data are normally developed in a field investigation using methods described in this idea catalogue. The geologic framework of a site includes the lithology, texture, structure, mineralogy, and distribution of the unconsolidated and consolidated earth materials through which groundwater flows. The hydraulic properties of these earth materials depend upon the geologic framework. Elements of the geologic framework and the site hydrogeology that should be considered in groundwater investigations include:

- the spatial location and configuration of the uppermost aquifer and its hydraulic properties (e.g., horizontal and vertical hydraulic conductivity's, depth and location of groundwater surface, seasonal fluctuations of groundwater surface elevation);
- hydraulic gradient within the geologic materials.

### Interpretation of existing geologic information

Frequently, the hydrogeologist must make preliminary hydrogeologic interpretations based on information from the literature. This type of information is used to design the type of groundwater investigations program i.e., the construction and location of sampling points.

There are regions where a knowledge of the **surface geology** is critical to understanding groundwater and contaminant migration, and hence the proper placement of wells. Sometimes the interpretation work is already done and sometimes it is left to the resources of the investigating hydrogeologist.

Three **characteristics of bedrock** are most influential with respect to groundwater movement and hence the success of a groundwater investigation, the porosity, the hydraulic conductivity and the structure.

Not all limestone's and dolomites, that outcrops on islands Saaremaa, Hiiumaa, Gotland, Öland are prone to developing solution-enlarged fractures. If the fracture orientation and density are sufficiently developed, a rock can behave like a relatively uniform porous medium like Balka and Nexoe Sandstone in Bornholm. However, it is much more common for rocks to have fracture systems which create anisotropic, heterogeneous conditions.

**Anthropogenic influences** have profoundly affected the nature and quality of groundwater. This is particularly true in urbanised and industrial areas where intense human activity may have occurred over some period of time.

Understanding a site prior to initiating any subsurface investigations involves not just a geological research project, but a research project focused on man's activities. There are a number of sources of information, which can help direct a researcher to provide information about past uses of a particular piece of land.

The basic information on the groundwater conditions is possible to obtain from different **hydrogeological maps**. The hydrogeological maps of Saaremaa (Perens 1981) and Hiiumaa (Perens 1977) at the scale of 1:200 000 compiled at the Geological Survey of Estonia (EGK) can be used in planning work where groundwater conditions must be considered and will thus facilitate the co-ordination of groundwater prospecting and protection, the localisation of urban and recreation areas, industries, dumping places, etc.

The same information and estimated exploitation potential of groundwater are presented at the hydrogeological maps of Gotland county (Karlqvist et al. 1982) and Öland (Müllern & Pousette 1981) compiled by the Geological Survey of Sweden (SGU) at a scale of 1:250 000.

## Downhole geophysical measurements

One of the most common subsurface investigation techniques is that of sampling soil and rock at discrete intervals as a boring is advanced. This method provides gross information on subsurface lithology but sand lenses, fractures, or other subtle changes in geology, which can affect hydraulic conductivity, can easily go undetected. Though continuous sampling or coring can improve the description of geologic conditions, it is very costly and time consuming, and material description is somewhat subjective. Furthermore, 100 % sample recovery is rarely achieved.

A number of downhole logging techniques are available for determining the characteristics of soil, rock, or fluid along the length of a borehole or a well. These methods provide continuous, high-resolution in situ measurements that are often more representative of hydrogeologic conditions than samples obtained from boring. An adequate assessment of subsurface conditions will often require that multiple logs be used since each log responds to a different property of the soil, rock, or fluid.

A description of the most commonly used logs on Saaremaa and Hiiumaa is given below (Table 1).

Table 1. General characteristics and use of downhole geophysical logs on Saaremaa and Hiiumaa

Downhole Log	Parameter Measured	Casing		Satu-rated		Unsaturation	
		Un-cased	Steel	Satu-rated	Unsaturation		
<b>Gamma</b>	Density	yes	yes	yes	yes		
<b>Resistivity</b>	Electrical resistivity	yes	no	yes	no		
<b>Temperature</b>	Temperature		yes	no	yes	no	
<b>Fluid conductivity</b>	Electrical conductivity			yes	no	yes	no
<b>Flow</b>	Fluid flow	yes	no	yes	no		
<b>Caliper</b>	Hole diameter	yes	yes	yes	yes		

Downhole logging measurements can be correlated to the known geologic strata in one hole and then can be used to identify and correlate geologic strata in other holes without sampling. Thin layers and subtleties, not readily detected in soil or core samples, can often be resolved by logging. Logging can significantly improve the ability to accurately characterise and correlate strata between borings by providing high-resolution data independent of subjective interpretations of soil and rock type.

A number of soil and rock properties can be measured in situ. Values for soil and rock porosity, density, seismic velocity, can be obtained. Even more important is the ability to identify the uniformity or lack of uniformity of subsurface conditions. Downhole measurements can be used to identify permeable zones, such as sand lenses in glacial tills, weathered zones, and fractures or solution cavities in rock. The same measurements are also effective for identifying impermeable zones, such as aquitards, and assessing their continuity and integrity. Using

downhole techniques, it is possible to obtain geologic information and well construction details.

**A temperature log** is a continuous record of the temperature of the borehole fluid immediately surrounding the sensor as it is lowered within an open borehole. The temperature log will often indicate a zone of groundwater flow within the uncased portion of a borehole. Flow is indicated when an increase or decrease in water temperature occurs. Changes in temperature can also be used to monitor leaks in casing where damage or corrosion has occurred.

There are many ways of measuring **fluid flow** within a borehole. The most commonly used method is the use of an impeller type flow meter that provides counts per second. The count rate can usually be calibrated to provide results in l/minute.

**A fluid conductivity** log provides a measurement of the specific conductance of the borehole fluids. The method can indicate a zone of saline groundwater.

## Surface geophysical methods

The first and also the most important task of most site investigations is the **evaluation of natural hydrogeologic conditions**. A description of overall hydrogeologic conditions and identification of any hydrogeologic anomalies is usually required.

The first step in any site investigation is to obtain appropriate background literature, maps, and aerial photos so that geophysical surveys and other site work can be planned.

To improve the accuracy of site characterisation, adopting a broader integrated systems approach is recommended. Geophysics is just one of many technologies that can be readily incorporated into a site investigation program. Airborne and/or surface geophysical methods are generally used as initial reconnaissance tools to cover an area in a quick search for best aquifers. Surface geophysical methods can then be employed for a detailed assessment of site conditions.

After potential problem areas have been identified, the drilling locations for boring and monitoring wells can be selected with a higher degree of confidence to provide representative samples. Analyses of soil and water samples from properly located borings or wells, will then provide the necessary quantitative measurements of subsurface parameters. Downhole geophysical methods can be applied to define details of conditions with depth.

Table 2. Surface geophysical methods for evaluation of natural hydrogeological conditions carried out on Saaremaa and Hiiumaa

<b>Method</b>	<b>General Application</b>	<b>Continuous measurements</b>	<b>Depth of penetration</b>	
<b>Resistivity</b>		Soundings or profiling and mapping	No	No limit
<b>Seismic refraction</b>		Profiling and mapping soil and rock	No	No limit
<b>Seismic reflection</b>		Profiling and mapping soil and rock	No	to 300 m
<b>Gravity</b>	Profiling and mapping soil and rock	No	No limit	
<b>Magnetic Micro-magnetic</b>		Profiling and mapping soil and rock	Yes	No limit

Because the results of geophysical work usually result in identification of anomalous conditions, geophysics should generally be done first so that anomalous areas can be identified for drilling and sampling.

However, if borings or wells have already been installed, geophysical surveys can still deliver increased accuracy. The location and data from existing boreholes and wells can be assessed using geophysical methods, thus providing a means of evaluating the validity of data already acquired.

## Drilling methods

Drilling and sampling for groundwater investigations utilise much of the same technology used in conventional drilling and geotechnical exploration. The method of drilling or sampling is often site-specific, depending upon the type of logging or testing to be done.

**Borehole logs** are the written reports prepared by the field geologist or engineer and the drilling contractor. These reports are prepared on site as the boring is advanced. They provide a record of the drilling, sampling, and well construction procedures, and they are often the sole record of the significant occurrences that occurred during field work.

## Methods and procedures for defining aquifer parameters

The storage and movement of groundwater through soil and rock obey certain physical laws. These laws are represented mathematically and are used to quantitatively describe the behaviour of groundwater within a particular hydrogeologic setting. Certain physical parameters, such as hydraulic conductivity, storage coefficient and aquifer thickness, must be determined in order to solve the mathematical relationships describing groundwater behaviour. Determination or measurement of these parameters is a primary purpose of many field investigations. Once defined, the parameters can be utilised with the appropriate mathematical relationships or equations to calculate such items as groundwater flow rate and direction, aquifer yield, or the behaviour of chemicals transported in groundwater.

Bulk density, water content, porosity, hydraulic conductivity and permeability, groundwater velocity, specific storage, specific yield and transmissivity are the most important hydrogeologic parameters.

Ideally, all aquifer parameters should be measured in the field under the anticipated groundwater conditions. However, some of the parameters can be measured reasonably well in the laboratory on representative samples of unconsolidated geologic material and then be applied to the field situation.

A term related to hydraulic conductivity which is commonly used in aquifer evaluations, is **transmissivity**. Transmissivity, like hydraulic conductivity, is useful for calculating groundwater flow rates and recharge capacities of wells. Transmissivity is defined as the average of all horizontal hydraulic conductivity's at various depths multiplied by the vertical saturated thickness of the aquifer.

Besides traditional aquifer pumping tests, **the impeller method (flowmeter logging)** has been widely used in studying the filtration characteristics of carbonate bedrock of Saaremaa and Hiiumaa (Perens et al. 1994). According to the logging data about half of water in these wells is provided by the upper portion of cross/section with a thickness of 15 m and average transmissivity of 400 m<sup>2</sup>/d (Figure 1).

Decreasing of waterbearing zones and hydraulic conductivity in deeper layers of Saaremaa and Hiiumaa is very similar to Gotland.

Consider this, it will be not rational to drill deep wells in coastal areas.

**A pumping test** is the most commonly used procedure for determining aquifer transmissivity, specific storage and/or specific yield. Pumping tests are also useful in examining boundary effects from recharge zones (lakes and rivers) and low conductivity boundaries.

The ultimate objective of hydrogeological investigations is **to obtain a sample of the water** that is as representative of the actual groundwater quality as possible. This objective should be kept in mind through out the groundwater investigations, because everything that is done, from the installation of the wells through the sampling

and analysis of the groundwater, will affect the reliability and interpretation of the data collected. In order to meet the statistical analysis requirements the well network and sampling program must be carefully planned.

Saline groundwater is a serious problem for coastal municipalities in all islands of Baltic Sea (Aastrup et. al. 1995). It will be useful to present content of chlorides and another chemical components as maps (Figure 2).

Figure 2. Distribution of Cl<sup>-</sup> concentrations in groundwater of the Silurian (S) aquifer system (mg/l) on island Saaremaa.

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## 2.2 MODEL FOR RESOURCE ESTIMATES

### PREFACE

An essential condition if groundwater resources are to be considered in planning contexts is that we know how big the resource is. A knowledge of groundwater is needed both in conjunction with overall planning work and in different kinds of physical planning within small, well-demarcated areas. One of the tools for handling this knowledge consists of calculation models, of which there are several different examples on the market. It is important that the model has properties, which make it as simple as possible, so that it can be used “locally” and not just by experts.

The Geological Survey of Sweden (SGU) has written this work. Presented here is a simple calculation model, which has been developed to meet the needs of “non-experts”. The model can be used to estimate groundwater resources for a whole island or parts of it.

## Background

The basis for water supply on Gotland, whether public or private, is groundwater extracted from the bedrock via rock-drilled wells.

The Ministry of Agriculture's Commission on Water Planning has previously asked SGU to design a model for calculating groundwater formation on Gotland (1). This calculation was carried out using the finite element method. The input data consisted of previously collected details of groundwater levels and calculations of the hydraulic properties of the bedrock, based on data from wells.

## Objective and presuppositions

Groundwater must give a safe and sustainable supply of drinking water and contribute to a good living environment for plants and animals in lakes and watercourses.

The objective of the present work is to formulate a tool for assessing the size of groundwater resources for structure plans with regard to long-term sustainable utilisation of groundwater occurrences for different purposes.

A model is of course a simplified description of reality. The hydrogeological reality is often highly complex. The more realistic a description one wants, the greater are the requirements for the information about groundwater systems. Normally we do not have the desirable amounts of information; instead, our descriptions, forecasts, and consequence analyses must be made on the basis of simplified assumptions.

The approach also presupposes that groundwater reservoirs have sufficient storage capacity so that the entire net precipitation can be stored in them. This is not always the case, as can be exemplified by the situation on Gotland, where it happens periodically that large areas are covered with water so that the effective precipitation cannot be stored in the fissure/pore systems of the bedrock. A large proportion of the effective precipitation thus runs off without having formed groundwater. This also occurs in the Balka-Sandstone reservoir in the southern part of Bornholm.

Using the method for assessing the size of groundwater resources based on the assumption that all the effective precipitation forms groundwater, there is a risk of overestimating the size of groundwater occurrences.

Another way to assess the size of groundwater resources is to consider *the size of the groundwater reservoirs* in relation to *periods with little or no groundwater formation* and *the consumption need*.

Normally there is little effective precipitation during the summer months. From this it follows that there is little formation of new groundwater, which leads to receding groundwater levels. In periods like this, the only available water supply in principle is the amounts of freshwater stored in groundwater reservoirs. Important factors for assessing the amount of water, which can be extracted for water supply, are thus the occurrence and length of periods with a falling groundwater level which is simultaneously under the mean level. Time series with data on groundwater levels are therefore an essential basis for assessing the size of groundwater resources.

The extractable volume of water (effective porosity) in crystalline bedrock is normally less than 0.1% of the total volume of rock. In sedimentary limestone it is larger, approx. 0.2–0.5% (4). Where karst weathering occurs, one may reckon with significantly higher effective porosity.

In groundwater reservoirs in non-cohesive soils the effective porosity is between 1% and 20% depending on the soil type (5). This means that the storage potential in groundwater reservoirs in the soil layers can be up to 100 times greater than in groundwater reservoirs in bedrock.

In coastal areas there is always a risk of saltwater penetrating into the groundwater. This risk falls with increasing distance from the shore, and at a distance of just 0.5–1 km it is deemed to be small. In cases where salty groundwater is found at greater distances from the coast, it derives from groundwater with elevated levels of chloride or from human activities (salting roads, landfills). To minimise the risk of obtaining salty groundwater when extracting from rock-drilled wells, the recession of the groundwater level should not exceed 20 m. Residual saltwater could be a problem also far away from the coast.

If the thickness of the soil cover is less than 1 m, it is generally assumed to be of no significance for groundwater. On the other hand, if the soil cover is more than 1 m, it plays an important role as a compensation reservoir for further infiltration to groundwater reservoirs in the bedrock. Information about soil composition and distribution is therefore a prerequisite for work with the model. The extra contribution from the soil layers normally occurs as leakage to the underlying groundwater reservoir in the bedrock. The size of the leakage depends, among other

things, on the vertical permeability of the underlying rock.

## Calculations and estimates

Generally speaking, the available quantity of groundwater per unit of area in places where the bedrock is exposed or is covered by only a thin layer of soil may be described as:

$$n_{eb} \cdot A \cdot \Delta s = V$$

where  $n_{eb}$  = effective porosity of the bedrock (%)

$A^{eb}$  = area of the groundwater reservoir (m<sup>2</sup>)

$\Delta s$  = maximum permitted recession of the groundwater reservoir (m)

$V$  = amount of groundwater (m<sup>3</sup>)

The effective porosity of the bedrock is calculated/estimated on the basis of analysis of data in the SGU Archive on Wells and on any information in the literature or reports from investigations.

In areas where the soil cover is deemed to influence groundwater formation and storage, the corresponding calculation is done using the following equation:

$$n_{eb} \cdot A \cdot \Delta s + n_{ej} \cdot A \cdot h = V$$

where  $n_{ej}$  = effective porosity of the soil layers (%)

$h^{ej}$  = recession of the groundwater level in the soil layers (m)

The values of the effective porosity in the soil layers can be found in the literature.

*Figure 1. Groundwater level measured in metres below the surface for the period 1990–1997 and mean values for the period 1970–1996. \_\_\_\_\_ month mean value ●● measured level*

The diagram in figure 1 describes the variation in the groundwater level over a period and the mean monthly level for the whole observation period. One can see from the diagram how the current level relates to the mean level. For example, groundwater levels were higher than the mean level during autumn and winter 1990–91 and in the same seasons in 1994–95. Throughout 1996 and the first half of 1997 the levels were below the mean level. If the groundwater level falls and in addition lies under the mean level, one may say that there is a “shortage situation” since the only source of water supply is to be extracted from the water in the reservoir. Using a diagram of the above type makes it possible to determine the length and frequency of “shortage situations”, see table 1.

*Table 1. Number of days when the groundwater level is sinking and simultaneously lower than the mean level.*

Year	1990	1991	1992	1993	1994	1995	1996	1997
Number of days	150	50	115	90	0	75	135	75

On the basis of the above, it is possible to calculate or estimate how large a supply of groundwater is and how long it will last, at a certain consumption, in periods of low effective precipitation (dry periods = consumption solely of stored groundwater).

## Calculation example from Östhammar Municipality (8)

The model has been tested in some municipalities with crystalline bedrock, including Östhammar, which is on the coast about 100 km north of Stockholm.

The figures for water consumption are assumed on the basis of a good future standard for water and sewage

supply, for example, with techniques that are economical on water.

*Table 2. Number of people/hectare for whom the water supply is sufficient in dry periods of different lengths, permanent residence (for permanent residence a water consumption of 180 l/person\*day is estimated)*

Groundwater supply, m <sup>3</sup> /ha	40 days	80 days	120 days	160 days
20	3	2	1	1
60	8	4	4	2
519	72	36	24	18
557	77	39	26	19

## Comments

The model presented here is based on simplified assumptions about the hydrogeological reality. The model is generally valid for open, surface groundwater reservoirs and can be applied to any geographical area. The model has been used to assess the size and potential duration of groundwater resources in coastal areas and archipelagos (6,7,8).

The input data in the model consist of information on geological conditions, chiefly soil composition and distribution, groundwater levels in the form of observation series, archival statistics on wells (well capacity), effective precipitation, and the effective porosity of the groundwater reservoir.

In combination with hydrogeological experience it is deemed that, despite the degree of simplification, the model is still a useful tool for assessing the size and duration of groundwater resources.

When assessing the potential duration of a groundwater reservoir, one must also take into account the other values that can be influenced by large consumption. The withdrawal from surface reservoirs, for example, can affect spring mires or other wetlands of great natural value. However, permanent recession of the groundwater surface, to enable building, is more often the cause of damage than relatively temporary drops in the groundwater level. Permanent lowering of the water table can cause bad groundwater quality.

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## **2.3 ARTIFICIAL INFILTRATION OF SURFACE WATER**

### **PREFACE**

Dry summers prevail on Öland and other islands in B7, when no new groundwater is formed and consumption is higher because of tourism. Artificial infiltration is one way to maintain a water supply on a sufficient scale and of good quality. This requires good ground conditions, which must be thoroughly investigated, and a supply of surface water. The surface water mostly requires pre-treatment, which can be done in different ways, but it is important to make it as simple and reliable as possible and to try to limit the use of chemicals.

### **A brief introduction**

Owing to its cleanness, nice taste and even temperature, groundwater was originally the main source of drinking water. As the urban areas grow, the water consumption increased, and as a result, the groundwater resources became insufficient. Therefore there was a gradual changeover to increased use of surface water.

At the end of the 19:th century a new technique, called artificial infiltration, was developed, for the purpose of increasing the groundwater supply.

At best, it is possible to use surface water for artificial infiltration with no previous treatment. Normally, a reduction of suspended and organic material of the water is necessary to reach an acceptable length of drifting times in the infiltration basins and to minimise the risk of clogging up of the infiltration area. Commonly, this reduction is effected by micro filtering and / or by rapid filtering. In some cases the previous treatment also has to include chemical precipitation to additional reduction of the content of fine particles and organic matter (COD-Mn) of the water.

### **The cleaning process**

As the infiltrated surface water is moving through the ground, suspended particles of the water are separated. Furthermore, humus and other dissolved organic substances, some of them giving the water bad taste and bad odour, are decomposed.

The presence of oxygen is necessary for this process to occur. Normally, the surface water, which is infiltrated into the ground, has an oxygen concentration of 8-10 mg/l, at most, depending on the water temperature. Theoretically, this oxygen concentration is big enough to reduce the content of organic matter (COD-Mn) of the infiltration water to 10-12 mg/l. If the content of oxygen in infiltration water is completely used up, there is a risk of creation of hydrogen sulphide. The contribution of oxygen from ground pores is normally small.

The decomposition process is chemically complicated, and it is depending on many factors, for example:

- the quality of the surface water
- the geological structure of the infiltration zone
- the hydrological conditions of the infiltration zone
- the fluctuations of the water level
- temperature matters
- the time spend for infiltrated water to move through the ground before reaching the groundwater zone
- the thickness of the unsaturated part of the ground

The time spent for the infiltrated water in the ground before reaching the groundwater zone should be as long as possible. The water quality is gradually improved, at least during the first two months spent in the ground.

The most obvious improvement concerning water taste, water smell and the reduction of humus of the water is supposed to occur in the infiltration bed, perhaps already in its upper zone. This is a fact because even as short as twenty-four hours of time spent for the water in the ground has proved to effect considerable improvements to the water quality. To bring about an even temperature of the water over a year, the time spent in the ground has to be at least one month. The Swedish national food administration has made rules, which demand taking of samples of groundwater and surface water at regular intervals, to control the water quality. According to these rules, the water has to spend at least two weeks in the ground, otherwise there is no legal right to name the water as groundwater.

## **The infiltration plant**

### **Previous treatment**

The surface water should be treated before it is infiltrated into the ground. Normally, a rapid filter is used. If the content of plankton of the water is considerably high, the water may be passed through a micro strainer before reaching the filter. If the COD-Mn or the content of fine particles (for example clay) is still high, in spite of using filter and micro strainer, then a chemical precipitation step should be introduced. Otherwise, there is a risk of oxygen deficit and also risk of clogging up in lower part of the infiltration zone. If high concentration of plankton and fine particles are occurring only in shorter periods, for example as a result of rapid snow melting or intensive rain, then it may be possible to stop the infiltration process during this periods, presupposed that the water supply of the ground is big enough to avoid interruptions in water distribution.

### **Construction of the infiltration plant**

Normally, the surface water is infiltrated into digged basins, which are filled with sand layer 1 metre thick. The picture below shows an outline of this:

An infiltration basin may be compared to a slow filter without bottom. 2-5 cubic metres of water per square metre is recommended to be infiltrated into the basins every twenty-four hours.

### **The infiltration process**

As the infiltrated water reaches the groundwater zone, the decomposition of organic substances of the water is proceeding. In this process there is also a precipitation of minerals. When the infiltration water is mixed with the natural groundwater in the ground, there is an additional increase of the content of minerals in the water. Besides the reduction of COD-Mn, micro-organisms and the improvements of taste and smell, the increased content of calcium and alkalinity also is of big importance to the final drinking water quality.

If the infiltration time is long enough there is also a levelling of the temperature fluctuations and variations of the infiltration water, which means that the temperature of the infiltrated water will only vary a few degrees from that of natural groundwater.

### **Planning**

When planning to build an infiltration plant is carried out, it is of big importance to closely investigate:

- The water-bearing qualities of the groundwater resource, for example by carry out water infiltration tests and pumping tests.
- The quality of the groundwater
- The quality of the surface water.

It is of uttermost importance to find out the concentrations of humus, algae and other suspended substances of the

surface water, and also to find out the variations of these parameters during different periods and due to different precipitation situations. The content of humus of the water is included in the parameter named COD-Mn. This parameter gives the amount of oxygen, which has to be consumed to work out a complete decomposition of all organic substances of the water. The amount of oxygen in water normally varies between 8-10 mg/l in summertime and between 13-15 mg/l during winter. That is, there is a risk of oxygen deficit in the infiltration basin and the ground zone below if the COD-Mn approaches 10 mg/l. The content of suspended substances has to be low in the water, which is infiltrated, otherwise there may be a rapid clogging up, and then repeated cleaning work has to be carried out to make the basin serviceable. Furthermore, if the clogging up occurs deeper than 2 m from the ground surface it will be difficult to restore the infiltration area. To prevent this to happen, previous treatment of the infiltration water is necessary to carry out.

## The quality of water

In the table below the alterations of the chemical composition of the surface water, when it is transformed to groundwater by means of artificial infiltration, is illustrated:

Chemical oxygen consumption	Surface water		Water taken from wells		
	Units	COD Mn	mg/l	5-10	1-2
Colour	Units	30	5		
Iron	Fe	mg/l	0,3	0,05	
Manganese	Mn	mg/l	0,05	0,02	
Calcium	Ca	mg/l	10	17	
Alkalinity	HCO <sub>3</sub>	mg/l	20	40	
Aggressive carbon dioxide	CO <sub>2</sub>	mg/l	3	15	
Conductivity	mS/m	15	20		

## Artificial infiltration in Öland

### Brief introduction

In the municipality of Borgholm, on the north part of Öland, infiltration of surface water was started about 10 years ago, because the groundwater supplies were decreasing, due to large water consumption mainly during the tourist season.

Today, artificial infiltration is carried out in two water supply areas on the island of Öland, namely Köpingsvik and Löttorp. These two supply areas account for about 90 % of the total municipal drinking water production in the municipality of Borgholm. The artificial infiltration is up to now successful in these areas, and the drinking water produced is of high quality and of a sufficient quantity. The running reliability of the plants is high. Water production zones are declared for both of those water supplies.

#### Köpingsvik

The groundwater resource of Köpingsvik is about 5 square kilometres, and the thickness of the sand layer is about 18 m. Surface water is taken from two brook- and channel systems, and the surface water is infiltrated into seven basins of the water resource. App. 1,2 million cubic metres of water are infiltrated every year during the period October until April. The charge on the infiltration basins is about 0,08 m/h.

The water is treated by passing through sand layers, 6 m thick, of the basins. It takes about 6 months for the water to get in contact with the natural groundwater, which is pumped up via 20 wells, for further treatment and distribution.

The basins should be cleaned up, and the sand layer should be renewed, every five years.

#### Löttorp

The groundwater resource of Löttorp is about 2,5 square kilometres, and the thickness of the sand layer is about 10 metres. The surface water is taken from Hornsjön, the only lake, which is found on Öland, and the water is infiltrated into two basins. Besides, a test project was started in May of 1999, in which the surface water is spread about a natural area, by a sprinkler plant, and infiltrated into the natural ground of the area. Thus, the water

treatment takes place in the natural ground.

A total quantity of 150000 cubic metres of surface water is infiltrated during the period from September until May. The charge on the basins is a good 0,1 m/h. Infiltration by sprinkler plant cannot yet be evaluated, because this test has been carried out only a short time.

The water is treated by passing through a sand layer, 60 cm thick, of the basins. It takes about 2 months for the infiltrated water to get in contact with the natural groundwater, which is pumped up via 7 wells, for further treatment and distribution.

The basins should be cleaned up, and the sand should be renewed, every 2 years. In recent years, an increasing concentration of COD- Mn has been noticed in the infiltration water, and therefore flotation tests are going to be carried out during the winter of 1999-2000.

### Shaping of an infiltration system

The basins of Köpingsvik and Löttorp both has a deep of about 1,5-2 m, and they are dugged out in the natural ground. After that, a layer of sand, about 60 cm thick, is laid to serve like a surface of a filter. The surface water is pumped into the basins via a pipe, which is cut on a height of about 1 metre above the basin. Thus, when the infiltration water falls into the basin, the concentration of oxygen of the water is increased.

The picture below shows an outline of a basin.

### Flotation

The concentration of COD- Mn of the infiltration water has gradually increased, especially in the infiltration plant of Löttorp. There are several methods to remove COD- Mn, for example by using a flotation process. This processing step is going to be introduced at the plant of Löttorp during the winter of 1999-2000, as a test project.

The flotation process means leading the water into a vessel, in which the water is mixed with a large amount of atomized air. The air forms a "mat" which lifts the pollution substances to the surface, from which they are removed. After that, the cleaned water is pumped to the infiltration area to be infiltrated into the ground. The aim is to use as small quantity of chemicals as possible in the flotation process. At best, there is no need to use chemicals at all, which means very low costs, as to both construction and running of the plant.

Since a long time, the flotation process is used in cleaning processes of waste water, and it has proved to work very well. Also, in the municipality of Borgholm, the flotation process is successfully used in softening of hard water.

### Conclusions

Infiltration carried out on the island of Öland is successful. Without contribution of water from infiltration, it would be impossible to successfully manage the water supply of the municipality of Borgholm in summertime. Thus, if the ground conditions etc. are right, artificial infiltration is a reliable and quite cheap method to increase the groundwater resources.

When planning to build an infiltration plant, it is important to carry out thorough investigations. When the plant is in use, it is also of great importance to take samples of the groundwater and the drinking water at regular intervals, to control the water quality.

Of course the infiltration plant should be legalised to make sure that the foreman of the plant has the control of the drinking water production.

In the table below are the alterations of the chemical composition of the surface water, when it is transformed to water taken from wells (groundwater) by means of artificial infiltration. The results in the table below are from Köpingsvik.

	Surface water	Water taken from wells	
Chemical oxygen consumption	COD Mn	Mg/l	7 3
Colour units	35	5	
Conductivity mS/m	59	70	
Bacterium hetero. 2x24 h, 20° C		/ml	1100 2
Bacterium hetero. 7x24 h, 20° C		/ml	4400 6
Bacterium coli, 35° C	/ml	380	<1
Escherichia coli /ml	5	<1	

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VAV Publication P71

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# IDEA CATALOGUE 3

## SUSTAINABLE PROTECTION OF WATER RESOURCES IN ISLANDS

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## PREFACE

Drinking water supply is exposed to many different kinds of threats:

- The threats are found in the entire water supply system, from the formation of the raw water until the drinking water reaches the consumer.
- The threats are of varying nature: Qualitative, technical and quantitative.
- The threats differ in their significance for water supply.

Reducing the threats by taking preventive measures is in many cases a constantly ongoing job. A good tool and foundation for this work is to carry out a risk analysis. It should comprise a description of the different threats, ranking them in order of seriousness, and propose appropriate measures.

### **The vulnerability of the drinking water**

The inhabitants of industrialised societies have become much vulnerable by being dependent on large scale systems which are difficult to survey, and which are easily damaged, either unintentionally or intentionally. The problem is obviously exemplified by the building up of our water supply systems. Households, hospitals, industries, agriculture etc. expect the municipal water supply system to deliver drinking water of high quality without any interruption. If the municipal water supply systems fails to deliver drinking water just for an hour, for example because of an accident, the result may be disastrous. For example falling off of industrial production and economical losses may follow.

Other probable problems may be serious trouble in running hospitals and nursing homes, occurring stoppage in the waste water pipes, conflicts, spreading of rumours and panic feelings among municipal citizens (SOU 1995). Generally, it is of uttermost importance to bring about a more safe water supply system. The question of effect a more safe water supply is as important as any in islands, where import of water from the mainland is very expensive and therefore normally only a theoretical solution.

### **Threats against the water supply system**

*Threats against the water resource* include leakage of oil products caused by vehicle accidents, for example petrol truck accidents on roads and excavator accidents in gravel pits in connection with water supply areas. Oil leakage can also occur for example if a petroleum tank of a farm or a house is damaged. Other threats are discharge of outlet and industrial waste water to areas which are connected with the water resource.

The use of fertilisers and pesticides in agriculture is a threat toward water resources, because of the risk of spreading nitrates and pesticides into the groundwater or the surface water. An illustrative example of such an accident occurred in the springtime of 1987, when the municipal groundwater supply of Gårdby (municipality of Mörbylånga, Öland) was made unfit for several months, because the groundwater of the well was polluted by fertilising substance. How could this happen? A later investigation actually showed that the fertilising substance, spread on agriculture fields nearby before the frost in the ground had broken up, had mixed with the melting snow, followed a stream and, finally, the substance had infiltrated into the well, which was adjacent to the stream. (Nilsson 1998). Furthermore, investigations have revealed very small contents of pesticides in some Swedish groundwater resources (Rosling 1998).

In later years, more attention are given to different kinds of diffuse discharges, including for example car exhausts,

which are contaminating water resources in a very slow rate. In a short run, this pollution may be regarded as insignificant. Yet, in the long run, this kind of pollution may be a serious threat against the drinking water quality.

The **threats against** the pipe system include damages on pipes, for example caused by corrosion, ground settling or by heavy traffic. There are always a small leakage from water pipes, but at regular intervals also larger leaks are formed, causing the supplying of water to the supplied area to fall or even cease. If having bad luck, the searching for the leak and the subsequent repair work will take rather a long time. Only in the summer of 1998, two big leak accidents were reported in the municipal water supply system of Mörbylånga, Öland. In both of these occasions, the drinking water supplying of a major foodstuff industry was seriously threatened (Nilsson 1998).

When a big pipe leaks, the pressure inside the pipe falls. As a result, outlet water may be drawn into the drinking water pipe, because drinking water pipes and outlet pipes normally are drawn next to each other in the ground, and because a drinking water pipe is never completely watertight (Livsmedelsverket 1993).

The size of the water pipes of islands are often chosen to fit the maximum water consumption, which often occurs during the holiday season in summertime. During winter, when the consumption of water is much lower, drinking water may be standing still in pipe ends for long periods. As a result, pathogenic bacteria may have the opportunity to grow and multiply in the pipe, and an outburst of illness among the water consumers may follow. Such accidents occurred at six different times in Sweden 1980-1989 (Livsmedelsverket 1993), but no such incidents are known from the island of Öland.

**Threats against waterworks** includes falling off of electrical power, for example as a result of stroke of lighting or tree falling on power line. Lack of electricity makes it impossible for the water plant pumping the water from the water resource into the pipes. Also, fire, thunderstorm and flooding sometimes cause damage on the computer controlled steering and adjustment machinery of the plant. Furthermore, sabotage may be a threat, for example by causing physical damage on vital parts of the plant or by destroying the water quality by adding pathogenic bacteria to the drinking water (Stenström 1994).

Outbursts of waterborne diseases in Sweden are also caused by unintentionally incorrect dosing of chemicals, for example chlorine. No accident of this type is known from Öland.

### **Which threats are most dangerous?**

Of course the importance of different kinds of threats against the drinking water varies in each specific case. A research study carried out on the island of Öland 1998 showed that the most severe threat against the municipal water supply system actually was that of falling out of electrical power (Nilsson 1998). Other big threats, the study concluded, was forming of large pipe leaks, and severe drought, causing shortage of water. Also, leakage of oil products, caused by petrol truck accidents, was generally found to be a big threat, but the importance of this threat varied in different water resource areas.

### **Improving the water supply security - a general account**

Improving the drinking water security means taking measures which deals with the water supply system itself, for example technical improvements, but it also includes making the consumers less susceptible to interruptions in the drinking water supplying (ÖCB 1990).

To *improve the water supply safety regarding the water resource areas* it is of uttermost importance to declare the water resource area as a *water protection area*, and dictate regulations aiming to restrict and control different kinds of activities in the area, for example making of gravel pits, use of pesticides and oil products, and industrial activities.

It is important to arrange a reserve water supply, which can be easily and quickly put in use. Having a small reserve water supply, though insufficient as to supply capacity, is considerably better than having no reserve water

supply at all (Livsmedelsverket 1993). The reserve water supply should be tested at regular intervals. Big water consumers, for example hospitals and some industries, should be recommended to arrange their own water reserves.

Realistic practice should be carried out at regular intervals, for example by training the municipal staff how to act and take measures in case of an (imagined) petrol truck accident. To reduce the risk of polluting a water resource as a result of road accidents, barriers could be arranged, preventing vehicles from driving off road. Also, covering vulnerable ditches with a dense layer of clay can help to prevent, or at least delay, leaked oil from quickly infiltrate into the ground. Accurate planning of sanitation work is necessary. Of course this plan has to be worked out before the accident actually occurs.

**Water supply safety regarding the water works** includes having access to reserve energy, in case of falling out of electrical power. Fire alarm, fire extinguisher, lightning conductor, and maybe also a flooding alarm, is necessary equipment of a plant. If the computer controlled steering system of the plant becomes disabled, there should be a possibility to run the waterworks manually.

**The pipe system.** By systematically and regularly carry out leak survey and mending work, the losses of water from distribution could be reduced, and seen over a long time this may also reduce the probability of larger leaks to occur.

In the municipality of Mörbylånga, about 10 million Swedish crowns has been spent on leak survey over a period of twenty years. As a result of that, the loss of water in the municipal water distribution system has been reduced from 25-30 % in 1983 to about 10 % in 1998 (Nilsson 1998). An amount of about 100 000 cubic metres of drinking water is saved each year, owing to this work.

## **Risk analysis and action plans**

Before taking measures aimed to improve the water supply security, a risk analysis should be worked out. In this analysis, the problems and risks are identified, and relevant measures to improve the situation are proposed.

The risk analysis should include (Vägverket 1998):

- Identification of risks. This means identifying activities that can be regarded as risks, so called risk objects, and also identify consumers which are threatened, so called risk objects. For example, oil transportation may be identified as risk object, and a water resource may be regarded as a protection object.
- Risk analysis, including estimations of the probabilities of different types of accidents to occur, estimations of consequences from different kinds of accidents, and calculations of the risks.
- Risk valuation, which means valuing, considering and comparing the benefits of different alternative measures aimed to reduce the risks. This valuation may very well be done as a cost-benefit analysis.

The risk analysis may also include (ÖCB 1990):

- Mapping of priority water needs and priority water consumers
- Scenarios, in which the priority needs are compared to the ability of the water supply system to meet this needs.

## **Calculating the probability in risk analysis - an example**

Leakage of oil products, as a result from road accidents, is a threat against water resources. Protection measures along roads in vulnerable water resources are often very expensive, and therefore, from an economical point of view, it is important that the taken measures are carried out in an effective way that maximise the benefits from

them. The following example shows a way to calculate the probability of an oil transportation accident causing leakage of oil products to the ground. This calculation of probability may be an important part of the information basis, helping to consider choices and priorities of different types of measures, aimed to improve the safety of the water supply system. The example at the next side is partly taken from *Vägverket* (1998):

The municipal groundwater resource shown in the picture above is situated in a sub aquatic boulder ridge, which is partly covered by a layer of clay. This water resource is situated in a rural area, and is crossed by two roads, with different traffic flows, speed limits and standards. According to traffic flow, the road no.1 may be divided into two parts: North and south of the crossing of road no.2.

Road information:

Road information	Road no 1, south of crossing road no 2		Road no 1, north of crossing road no 2	
	Road no 2			
Sort of road	road with two lanes		road with two lanes	road with two lanes
Road width (metres)	11		11	6
Length of road in contact with groundwater resource (km)	1,6	0,4	2,4	
Length of road in contact with surface water resource (km)		1,7	-	-
Pavement	Bituminous	Bituminous	Gravel	
Speed limit (kilometres/hour)	90		90	70
Number of heavy vehicles per every 24 h, average	960	890	110	
Distance from road to groundwater well (kms)	0,8-1,3	1,0-1,3	0,5-1,0	

Now, we want to calculate the probability for an oil transportation accident to occur at the road no.1, south of crossing road no.2, and with oil leakage of oil products as a result.

### Calculation:

The probability that an accident including heavy vehicles and oil transportation's will occur depends on a couple of factors, for example traffic intensity, conditions of roads, speed limits and frequency of oil transportation's and heavy vehicles on the road.

The probability can be calculated with the help of this formula:

N = number of transportation's of petroleum products + heavy vehicles, average per every twenty-four hours

Q= Accident quota (number of accidents/million vehicle kilometres)

L= Length of road affected by threat

F= Number of vehicles /accident. Standard values are used.

F= 1,5 (built up areas)

F= 1,8 (rural areas)

Calculating the probability for an accident to occur at the road no.1, south of the crossing of road no.2, and with

leakage of oil products as a result, gives:

A: Accident including heavy vehicle:

L= 1,6 kilometres

N=ÅDT=960 heavy vehicles every twenty-four hours

Q=0,35 (Value taken from table, *Vägverket (1998)*)

F=1,5

$$P = N \times Q \times L \times 365 \times F \times 10^{-6} = 960 \times 0,35 \times 1,6 \times 365 \times 1,5 \times 10^{-6} = 0,29$$

This means, that an accident including heavy vehicle is expected to occur approximately once every three years on the road no 1, south of crossing road no 2.

B: Accident including vehicle carrying a cargo of perilous (risky) goods:

L=1,6 kilometres

N=ÅDT x 0,03\* = 960 x 0,03\* = 28,8 transportations every twenty-four hours

Q=0,35 (value taken from table, *Vägverket (1998)*)

F= 1,5

$$P = N \times Q \times L \times 365 \times F \times 10^{-6} = 28,8 \times 0,35 \times 1,6 \times 365 \times 1,5 \times 10^{-6} = 0,01$$

This means, that an accident including heavy vehicle is expected to occur approximately once every hundred years on the road no 1, south of the crossing of road no 2.

\*A standard value is used. If the number of transportation's of vehicles carrying perilous goods is not known, you can estimate this number roughly by calculating this way: number of heavy vehicles x 0,03.

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## **3.2 GUIDELINES FOR WATER PROTECTION ZONES**

### **PREFACE**

It is important that our water resources should be given legal protection by the establishment of water protection areas. This applies both to current sources of water supply and to planned sources for the future. If the protection is to become a reality, a functioning organisation is also needed to follow up and ensure compliance with the regulations. The protection of water resources must be given high priority to prevent activities with a negative effect on water protection from being established.

### **General**

The declaration of groundwater protection zones (used or not used) serves the sustainable water supply. Normally use of protection zones is not allowed or it is restricted if it may cause damages to or affect the groundwater or surface waters in the protection zones. In this way a good groundwater quality shall be maintained on a long-term basis in order to ensure the potable water production and to limit the water treatment to the necessary extent.

The public administrations on all islands hold the legal mandate for land expropriation related to water protection zones. The precondition for making use of the right to expropriation of land or of regulations of land use to control the pollution from farming, for instance, is that the area shall be declared as “water protection area/zone” or as on Bornholm the regulations have to be based on an approved so-called “Action Plan” for the area. If the regulations cause considerable obstructions for land use, the law says that the landowner has the right to receive financial compensation.

The water protection regulations for public areas are on principle the same as for private areas, but often it is easier to implement the regulations in public areas. In Denmark an agreement prohibiting the use of pesticides in public areas has recently been established on national level. On Bornholm the County has stopped the use of pesticides in areas owned or administrated by the County more than two years ago.

On Gotland and Öland a permission to use pesticides in water protection areas is necessary. The permission is issued by the environmental health department of the municipality.

So far none of the islands mentions agreements concerning land use in groundwater catchment areas. But Bornholm expects them to come in a few years on the basis of new regulations and planning tools.

Nitrogen and/or phosphorus are mentioned as a problem on most of the islands. Regulations regarding discharges of nitrogen from agriculture have been decided. So it is not allowed, for instance, to spread manure on frozen land and the amount of manure per area unit is regulated.

## **Calculation and declaration of groundwater protection zones**

The calculation of groundwater protection zones is based on water flow velocity, water flow direction and how the groundwater is protected by upper soil layers taking into consideration the planned extraction quantity. On Rügen (and in whole Germany) there are usually shown 3 protection zones, sometimes there is existing a 4<sup>th</sup> zone:

Zone I: direct surrounding of well, at least 10 m in diameter, fenced in;

Zone II: narrow zone of protection, less than 50 days of groundwater flow time.

In case of very large distances between surface and aquifer, zone II can be reduced.

Zone III: covers the whole groundwater catchment area of the water supply plant;

Zone IV: covers the whole surface catchment area.

When using shore filtrate a detention time of 50 days in the aquifer shall be ensured. In case of artificial groundwater enrichment, the enrichment area shall be specified as a zone II area at least.

The exact delimitation of protection zones II and III often deviates from the calculation and is determined by real estate boundaries. In this way compensation claims of landowners can be established much better.

Most of the protection zones on Rügen have been determined in the period 1970 - 1985 (in the former GDR by expropriation) and are effective according to the Land Water Act. They shall be accepted by the landowners without any compensation. The determination of new protection zones is, however, very time-consuming since there shall be carried on long and often controversial negotiations with the landowners, especially with farmers. No general recommendations can be given as the relevant national law is to be applied.

## **Prohibitive rules and restrictions of use**

To the “old protection zones” on Rügen (those from the GDR times) there are usually applied the general guidelines for water protection zones. On the other hand, for each “new water protection zone” there is to be issued its own decree.

Prohibitive rules and restrictions of use shall take into consideration the respective local conditions such as

- How is the groundwater protected by upper soil layers;
- Existent pollution;
- Possible development of pollution by farming, building, etc.;
- Measures on renewal areas.

But: The groundwater protection is of great importance. In case of competitive claims to land use the drinking water supply shall be given highest priority.

## Examples for prohibitive rules and restrictions of use

Legend: p = prohibited (administration can make exceptions)  
 r = restricted (possible with conditions)  
 a = allowed

Use	Zone II	Zone III
<u>Farming</u> – silos – March) or not as required – Utilisation of pesticides – (cattle, shed) – p p-r p p-r r-a r (a) p a p	Establishment of new plants for animals – Establishment of silos – Storage of pesticides – Pesticides spreading by plane – Break-up of long-term grassland	Establishment of soil Manuring at the wrong time (1 Oct. - 1 Storage of mineral fertiliser – Individual breeding of animals p p p p p p p p p p-r
<u>Dangerous matters</u> – – p p	Storage, transfer of dangerous matters for water (e. g. oil, pesticides) Erection of plants for storage and transfer of dangerous matters p, only in admitted plants	r
<u>Sewage, sewage plants, sewers</u> – sewage plants – seepage from roofs into the underground	Erection, extension of sewage plants – Waste water seepage into the underground/soil – Laying of waste water pipelines	Erection of single house R a i n w a t e r p p p p-r p p r-a p r-a r
<u>Traffic</u> – Sports grounds –	Construction of new roads, widening of streets – Golf sites	Camping sites – mostly p p p p r r r p
<u>Other kinds of use</u> – extension of buildings – p r-a p-r p-r	Quarrying of gravel, sand, clay – New building areas – Petrol stations	Drillings – Erection and p p p p p p-r

For decisions to be taken or approvals to be given in relation to protection zone III the authority are given more or less wide discretionary powers. For (politically) important projects a hydrogeological expert's opinion referring to the respective site is normally asked. Therefore it can happen that in one case a large building project within protection zone III is approved, in another case such a project is rejected because of an unprotected aquifer.

## Experiences from implementation of protection zone rules

In Rügen (and on most of the other islands) the agriculture is the most important land user.

Practical application of restrictions and prohibitive rules (use of mineral fertiliser, utilisation of pesticides) for agriculture can hardly be controlled.

In Rügen all agricultural enterprises and those who spread liquid manure were handed over up-dated maps showing the water protection zones. All enterprises were instructed in relevant prohibitive rules. Therefore the prohibition of using liquid manure within protection zone II is mostly complied with. For two years has been carried through a project on the mainland: Instruction of agricultural enterprises situated in drinking water protection zones. Goal: Make the farmers aware of necessity of groundwater protection.

The erection of new buildings in drinking water protection zones proved to be a field of conflicts. The building of new houses or the extension of existent ones within zone II are, for instance, not allowed. The prohibition is justified with the possible endangering of groundwater by additional waste water production, new carports for motor vehicles and sealing of new soil areas. The water protection authority is entitled to allow individual exceptions

from this prohibition.

To facilitate the decision-making in such problematic cases, the problem discussion within a working group proved to be a good remedy. The working group holds its meetings usually every two months. The following institutions belong to it: the water protection authority of the county district, the state environmental office, health care office, Association of water suppliers of Rügen, hydrogeological institute. This working group is often faced with such problems as seepage of purified wastewater from single households situated in drinking water protection zone III. If it is in sight that this problem concerns only an isolated case and the aquifer is well protected, the application will be approved.

No drinking water protection zones are defined for single wells provided for private water supply (single houses, small hotels, farms). Sewage plants to be erected at the same plot of land must be situated minimum 25 m away from the well.

### **Unsettled problems**

In Rügen there are existing plans of wetland nature restoration. For many years most of the wetland (mainly grassland) has been isolated from the open sea or the inner coastal waters by dikes. Some dikes could be removed so these surfaces would be flooded (inundated) by brackish water from time to time (about 15 - 20 days per year). In that case brackish water would cause a problem when it comes near to such wells that are situated next to the flooded areas. The worst that could happen is that brackish water would infiltrate the aquifer and thus damage it (chloride penetration).

At the moment we do not know anything about what will happen, what the consequences are.

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## **3.3 MONITORING AND CLEANING UP POLLUTED SOIL**

### **PREFACE**

Some soil-pollution's can pose a threat towards the groundwater and thereby towards the drinking water supply. This theme seeks in a short form to describe, what to do with such pollution.

The theme has the following headlines:

- \* Risk analysis
- \* Cleaning-up
- \* Monitoring

## **Risk-analysis**

### *Goals*

In this context the goal of a risk-analysis is to make a decision, whether pollution is a risk towards the groundwater or not. One should consider whether it's risks towards drinking water supply or it's risks towards groundwater as such, that should be avoided.

### *Methods*

A variety of systems exist to calculate a risk from a polluted site. However the chemistry and physics in soil is very complicated. Therefore most risk-analysis computer models are uncertain, partly due to lack of precise knowledge of the behaviour of the chemical compounds in the soil.

Shortly, it is important to consider whether pollution has reached the groundwater, whether the pollution is able to reach a water-extraction borehole, whether the pollution will be decomposed by nature and whether the pollution can threat other items than the groundwater.

It is therefore important to gather a wide range of information e.g. about permeability and porosity of the soil, groundwater level, groundwater flow-speed and groundwater chemistry.

The groundwater chemistry can give important knowledge about the potential of natural degradation of the various kinds of pollution. Wide ranges of chemical compounds are degradable under aerobe conditions, but a number of compounds (e.g. chlorinated solvents) preferable degrade under anaerobe conditions.

## **Cleaning-up**

There are a number of methods for cleaning up soil pollution:

- Excavation
- In-situ methods
- Pump and treat
- Natural degradation

### *Excavation*

If the polluted volume is minor and situated close to the surface, it is often most profitable to remove the pollution by excavating the polluted soil and transport it to a earth treatment plant or a special landfill designed for receiving polluted soil. Also the excavation often is necessary in removing a hot spot to avoid further pollution of the groundwater.

Before using this method it is important to consider if it actually is possible to remove the main part of the pollution (e.g. buildings and roads can be in the way). Further it should be considered how far the soil should be transported to a plant or landfill. A long transportation distance is often not environmentally safe.

Figure 1: Excavation

### *In situ methods*

There exist a lot of methods for cleaning up polluted soil (and groundwater) without removing the polluted earth. Often oxygen is introduced (in form of atmospheric air, or as pure oxygen) to stimulate the biological activity in the soil and thereby speed up the degradation of the polluting compounds (figure 2). Other methods extracts air from the soil by introducing a vacuum in a filtered well, thereby sucking out the volatile compounds (figure 3).

In the recent years, methods have been developed where the soil is heated by means of steam or electricity. Minor heating can stimulate the biological activity; thorough heating strips the volatile compounds effectively.

Figure 2: Example of in-situ method – airsparging.

Figure 3: Example of in-situ method – Vacuumextraction.

### *Pump and treat*

In a few cases, it can be necessary to extract the polluted water from a borehole (figure 4). In this way you can fixate the groundwater pollution and prevent further migration of the water-pollution. On the other hand it is practically never possibly to remove a groundwater pollution in this way. The predicted pump-time often is in the scale of 10-100's of years.

Figure 4: Pump and treat

### *Natural degradation*

A large number of polluting compounds turn out to become degraded by the natural micro fauna in the soil and groundwater. A number of bacteria's is able to feed on the various types of organic compounds.

This is part of the explanation, why heavy pollution's with gasoline and fuel oil have closed very few drinking water wells. In Denmark very few fans of groundwater pollution have exceeded app. 200 meters.

Leaving the pollution to nature demands that you follow the state of the pollution very closely. This often requires a large number of monitoring wells and therefore it can be rather expensive to use the natural degradation as cleaning method.

## **Monitoring**

While deciding on a monitoring programme, you have to consider a number of problems:

### *Where to place the monitoring wells*

The monitoring wells could be placed as shown in figure 5.

Figure 5: Principle in placing monitoring wells.

### *What is the purpose of the monitoring?*

To follow the evolution of the groundwater-pollution?

To warn you whether the pollution will threat a water supply?

Something else?

*Which chemical compounds to analyse:*

Which compounds are possible present in the pollution?

Which compounds can possible find the way to the groundwater?

Which compounds can be dissolved in the groundwater?

Which compounds can be a threat towards drinking water supply?

*How often is it necessary to sample:*

How fast does the groundwater move?

How fast does the pollution progress in the groundwater?

How effective are the dissolution and/or the natural degradation?

How poisonous is the pollution?

It is difficult to give general guidelines regarding the frequency of the monitoring, but it's often once or twice a year.

It is very important to decide when to stop the monitoring, while the chemical analysis is expensive. Often the monitoring goes on and on without anyone considering the results of the monitoring.

*Sampling*

It is very important to design the monitoring wells in a proper way, to avoid false pollution from e.g. surface water, drains etc.

Of course, it is very important to place the filter of the borehole in the right depth interval.

Then it is important to choose a proper method of bringing the water from the filter and to the surface. Here you should avoid stripping of the volatile part of the pollution by using the smallest possible pump, and by filling the sampling bottle fully from the bottom up. You should be sure, that the sampling bottle is designed to be tight, also with respect to gasses.

The water sample should not be taken until you are sure that the water in the filter has been replaced fully. The best way to be sure that you sample water from the formation, and not oxygenated water in the filter, is to measure the conductivity of the water on-line. The conductivity should be stable before you take the sample.

## **Case-Stories**

In the following a number of examples are given, to give an idea of real-world problems.

*Excavation and following biological cleaning of the soil:*

From Hiiumaa, there is an example, where oil-polluted soil was removed by excavation. Afterwards the soil was biological cleaned by composting. In this way the pollution is decomposed into harmless components (namely carbon dioxide and water) by micro organisms.

The oil-contaminated soils was excavated and transported to a special landfill. Here the contaminated soil was mixed with bulking agents and organic amendments, such as wood chips, bark and horse dung to enhance the porosity of the mixture. Maximum degradation efficiency was achieved by maintaining moisture and oxygen content, pH, temperature and carbon to nitrogen ratio. The compost was placed in long piles and periodically mixed with mobile equipment. The oil content was reduced by 10 to 15 times during one year of composting.

In Bornholm a similar method was used by a foundation financed by the oil companies dedicated to make cleaning-up at sites with former sale of gasoline and petrol. Cleaning-up actions were made at 54 localities. Here the polluted soil was excavated and mixed with horse dung. The result was very good, as in Hiiumaa.

### **Example of natural degradation**

In Bornholm there is a number of old public landfills, where practically anything has been dumped. This includes daily waste from households, waste from the hospitals, chemical waste etc. Most often, these landfills were placed in old gravel pits, in the central part of the island. In these areas, we today have large interests of groundwater protection. We were therefore very concerned about the landfills.

In 1996 and 1997 we carried out initial investigations of the landfills. Inside several of the landfills there were found a pollution of the groundwater with BTEX and petrol/oil. In 1999, we carried out thorough investigations of the 4 largest of those landfills. The aim of the investigations was to see, if natural degradation is active, and if it is effective in removing the pollution, so that the pollution will not reach drinking water extraction wells downstream the landfills. The county hired a consultant to carry out the investigations. The consultant used the "Geoprobe" system, where an iron rod is hydraulically pressed into the soil. At the bottom of the rod there is a filter, where it is possible to take a water sample, whenever one wishes to do so. It is possible to leave a plastic filter for future groundwater sampling. In this way, a lot of groundwater samples was taken. A rather detailed picture of the groundwater pollution around the landfills was in this way achieved.

The samples were analysed for redox-active components (NH<sub>4</sub><sup>+</sup>, NO<sub>3</sub><sup>-</sup>, Fe, SO<sub>4</sub><sup>2-</sup>, O<sub>2</sub>, conductivity, pH, temperature and redox-potential). In this way, the redox-state of the groundwater was mapped. The redox-state of the groundwater (mainly the content of O<sub>2</sub> and NO<sub>3</sub><sup>-</sup>) determines the potential for microbiological decomposition of the pollution. Further, the samples were analysed with a field-gaschromatograf for organic components (oil, chlorinated solvents, etc.).

The investigation showed that the natural degradation was active in all of the landfills. Inside the landfills there is a zone where all available oxygen is consumed, but just outside the landfills there is enough oxygen to keep the aerobic microbiological processes running. In the oxygen free zone, there is on the other hand a potential for anaerobic degradation of the chlorinated solvents (Trichlor, Perchlor etc.). Moreover the investigations has shown that the natural degradation in the landfills in this case is effective in removing the polluting components, long before they reach drinking water extraction wells.

The method of natural degradation however depends on a thorough monitoring of the groundwater downstream the landfills, to warn if the chemistry of the groundwater changes. For the moment, the county samples once a year.

### **Excavation of a heavy metal polluted soil**

On a minor property in one of the small rural towns in Bornholm, the county has made a cleaning-up due to pollution of the soil with heavy metals (Pb, Cd, Zn and Ni.). Earlier there was a painter's workshop. Probably the painter lacquered cars too. The pollution was rather heavy with up to 50 times the limit with respect to lead (Pb). This implies that the people living on the property couldn't use the garden for vegetables and should be very careful avoiding the children eating soil while playing in the garden.

The soil on the property was removed to a depth of about ½ m (in places up to 1 m) and replaced with clean soil. At the same time the sewer was changed, co-financed by the owner. The county financed the cleaning-up.

In total 350 tonnes of polluted soil was removed from the property. The soil was placed on a special landfill dedicated to polluted soil.

The whole action lasted for about one month (from middle December to middle January). In the rest of the winter

and in the early spring the new soil should consolidate. In the spring there will be sowed grass and the garden will be rearranged.

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### **3.4 ENVIRONMENTAL SAFE FARMING**

#### **PREFACE**

Agriculture is the branch of industry with the greatest impact on water resources on most of the islands. The risk of the effects of agriculture depends on how intensive cultivation is and on local conditions.

The threats from agriculture mainly consist of leaching of the nutrients nitrogen and phosphorus and of pesticides. To reduce the threats and minimise the risk usually requires more than just one isolated action. A large number of measures are needed.

#### **Farming intensity**

Rügen and Bornholm are intensively farmed with agriculture on 61% of the total area. Hiiumaa, Saaremaa, Gotland and Øland have agriculture on 23-30% of the total area. Åland only has agriculture on 9% of the total area.

Bornholm has the most intensive agriculture. Especially is the pig production very high (figure 1.) In Bornholm, the input of fertilisers and pesticides is high and the farmers have to lower inputs according to national plans. In Hiiumaa and Saaremaa, the agriculture is rather extensive, and the inputs of fertilisers and pesticides are low.

Figure 1a. Data from “B7-Key facts”, County of Bornholm, 1996

Fig 1b. Same as fig 1a, but milk and number of pigs is converted to nitrogen.

In islands with extensive and less intensive farming local conditions - for instance soil type, climate (especially net precipitation), groundwater level and type of aquifer - means that local regulations of farming can be essential. In these islands too it is important not to increase inputs to agriculture in catchment areas for waterworks and

water protection areas.

### **Threats to groundwater from farming**

The major threats are pesticides and nutrients (nitrate and

phosphorus). The vulnerability of the groundwater depend on the amount of the input used, the way the input are used, farming practice (for instance crop rotation an time for (ploughing) and the ability for the underground to reduce nitrate and pesticides. In sandy soils and clay with macropores (which is the normal), the transport of pesticides and nitrate can be very quick. Phosphorus is the major problem in surface water.

The leaching of nitrate is growing exponential with the supply of fertiliser (figure 2):

Figure 2.

The leaching of nitrate depends of crop type. The number in the table 3 are index figure (bare soil = 100):

Bare soil	100
Winter cereals	80
Winter oil seed rape	75
Pasture (grazing and harvest)	60
Beets	60
Catch crops	50
Ryegrass	50
Undersowed spring cereals	40
Permanent pasture	20
Green fallow	16

Tabel 3.

The examples of “best practise” below are not stated in priority, because it is not possible to do that.

### **Best practice - reducing nutrients leakage from soils**

- spread nitrate fertiliser and manure on growing crops, this is the most important way to reduce nitrate leaching,
- avoid nitrogen fertiliser during autumn and winter, especially manure and slurry,
- better use of manure by nitrate analysis in soil and manure,
- split applications of fertilisers in spring,
- check machinery to ensure uniform application,
- avoid too much nutrients especially when using both slurry and fertiliser,
- most sensitive areas in extensive grassland management,

- establish wetlands and buffer zones along watercourses,
- healthy crops use nutrients more efficiently,
- optimum irrigation, (leaching is higher without or with too much),
- catch crops greatly reduce nitrate leaching, taking up about 40 kg nitrogen/ha in winter,
- adjust ploughing times for turning in stubble so that mineralisation coincides with crop requirement in spring,
- reduce soil treatment and avoid ploughing by direct sowing,
- increase size of green land especially in winter, using pasture and undersowing spring cereals with ryegrass, sown at 5-10 kg/ha,
- winter barley and winter oil seed rape are better cover crops than winter wheat because they establish soil cover earlier.

### Livestock farms

- sufficient slurry storage capacity so can spread at optimum times,
- reduction in use of nitrogen during autumn, especially slurry,
- maximum 50 m<sup>3</sup>/ha/year slurry application,
- adjust ploughing times for old grassland so that mineralisation coincides with crop uptake, (up to 90 kg N /ha mineralised from ploughed grassland),
- avoid ploughing out old permanent pasture,
- grow triticale (rye/wheat hybrid) instead of wheat as animal feed, (it grows more in autumn so reduces leaching),
- refine animal nutrition to optimise nitrate and phosphate utilisation, use animal feeds with low mineral contents,
- improve animal feed quality,
- use of nutrient balancing/minerals accounting,
- dairy washings can be stored with manure and spread or put in a lagoon (retention time 2-3 months),
- ending summer grazing earlier, reduces the amount of nitrate in soil at the end of the growing season.

### **Best practice - reduction in pesticide use**

- carefully planned crop rotations avoid build up of pests,
- use of resistant cultivars,
- mixes of varieties of cereal crops leading to lower fungicide use,
- healthy plants from correct fertiliser application, is less vulnerable to disease,

- enhancement of populations of beneficial organisms,
- monitoring of harmful species to develop control thresholds,
- careful selection of pesticide on criteria which include environmental impacts,
- seed dressings and raw application in preference to area wide treatment,
- use crop species with rapid soil covering habit and early leaf development,
- use of mechanical weeding techniques,
- use of flame weeders, pre-emergence and post harvest,
- row application against annual weeds,
- spot treatment of perennials where possible,
- reduce winter cereals (pre-emergence herbicides used in autumn causes most herbicide pollution of water, as rainfall, sediment run-off and leaching are high),
- spray pesticides at night and early morning when more likely to be still and high humidity.

### **Organic or ecological farming**

Organic or ecological farming is recognised as having less impact on environment. With no pesticides being used and no “artificial” fertilisers there is less risk to water quality. Investigations in Denmark have shown that nitrate leaching is lower in organic farming than comparable conventional farming.

### **Co-operation and compensation**

Normally national regulations of the use of fertilisers, manure, slurry and pesticides are insufficient to protect groundwater in catchment areas for waterworks. If sufficient or supplemental protection is needed local authorities and managers of waterworks has to co-operate with local farmers and often have to compensate for loss in yield.

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## 3.5 RECOMMENDATIONS FOR RAW WATER ANALYSES PROGRAMME

### PREFACE

If you want to know about water quality, then the water must be analysed. The purpose of the analysis decides how frequently samples should be taken and which parameters should be analysed.

New sources of water have to be thoroughly investigated before they can be utilised.

Existing water sources must be subject to regular checks so that the quality delivered to the consumer can be guaranteed and any changes through time can be observed.

### General

Raw water for production of drinking water is not systematically analysed in all B7 islands. To follow the development in the groundwater and in the surface water used for drinking water, it is necessary to analyse the quality of the water systematically.

Figure. 1. - Natural water cycle and its affects

It is important to consider that:

- Water is mobile, based on the laws of the water cycle.
- Water is chemically active and an excellent solvent.
- Water moves slowly through the underground landscape, along different pathways, and with different transit times.

- Surface water is a mixture between water fractions (such as direct precipitation, surface runoff and groundwater), with different chemical history, and seasonal varying proportions.

To produce good quality drinking water the producer must know the chemical composition of the raw water. In this way, the producer is able to make an action, if and when it is necessary. In this context, it is important to state that precautionary action is better than repair. The water chemistry data etc. should be placed in a database, which should provide necessary data for decision-makers:

- Water resource policy development – to determine background conditions.
- Routine quality management - detects and defines contamination.
- Decide the method of water treatment, measure treatment effectiveness.

By analysing raw water components for a long period it is possible to predict the development of the water quality in the future. For doing this, the producer must e.g. know the geology, the precipitation and the land use in the vicinity of the water source. This can help to predict which kind of harmful components might occur in the water.

Below some possibilities for raw water analyses programme are given:

- a) Sampling frequency.
- b) Analyses of natural components.
- c) Analyses of organic matter, pesticides and industrial components.

### a) Sampling frequency.

I. For choosing a drinking water source the following analysis frequency could be used:

<b>Groundwater</b>	<b>Surface water</b>
2-4 times /year depending on the hydrogeological conditions.	8 - 12 times/year (2 years in sequence)

II. For an existing drinking water source the following analysis frequency of the raw water could be used:

<b>Components</b>	<b>Groundwater</b>		<b>Surface water</b>	
	<b>Town</b>	<b>Village</b>	<b>Small village &lt;1000 persons</b>	
Microbiological analysis	1x per month	1x per quarter	1x per year	1x per day
Toxic elements	1x per 3 years		1x per year	
Pollutants and organoleptical components			1x per year	1 x per month
Substances, which have influence on organoleptical values			1x per year	1x per month

If there appear problems with water quality, it is necessary to analyse more often according to a special investigation

programme.

**b) Analysis of natural components:**

**I.** For choosing the source of drinking water it is necessary at least to detect:

Chlorides, sulphates, iron, manganese, ammonium, nitrate, nitrites, oxygen demand, hardness, possible pollutants, pH and dry substances.

The water quality indicators must be determined by special investigation programme for micro- and macro-components. It depends on natural conditions and human impacts in the potential water extraction area.

**II.** For an existing drinking water source, it is necessary to detect:

Organoleptical values:

- Taste
- Smell
- Colour
- Turbidity

Substances that can have influence on organoleptical values:

- Chlorides
- Sulphates
- Hardness
- Possible pollutants
- pH
- Dry substances
- Iron
- Manganese.

A possible pollution related to human activity can be indicated by the presence of:

- Chloride
- Ammonium
- Nitrate
- Nitrites
- Oxygen demand value (usually permanganate oxygen demand)
- TOC (Total Organic Carbon)

### c) Analysis of organic matter, pesticides and industrial compounds.

**I.** For choosing a new source of drinking water you should, if possible, avoid areas where pollution have been demonstrated. If this is not possible you should try to design the water extraction in such a way that pollution is not likely to reach the extraction wells. If the groundwater is already polluted it is possible to clean the raw water e.g. by filtration through an active carbon filter or by treatment with ultraviolet light.

**II.** For existing drinking water sources the local authority must approve which kind of chemical compounds should be analysed.

The Danish EPA recommends that if you believe there is pollution in the water you can make a screening analysis, to detect a wide range of chemical compounds.

The Danish EPA has recommended that raw water should be analysed for the following polluting components.

#### 1) Pesticides:

Herbicides: 2,4 D; Atrazin; (Desethylatrazin, Desisopropylatrazin, Hydroxyatrazin); Bentazon; Cyanazin; Dichlobenil (2,6 Dichlorbenzamid (BAM)); Dichlorprop; Dinoseb; DNOC; Hexazinon; Isoproturon; MCPA; Mechlorprop; Metamitron; Pendimethalin; Simazin, Terbutylazin.

Insecticides: Dimethoat.

#### 2) industrial compounds

Aromates: Benzene, toluene, ethylbenzene, xylene, mineral oil.

Chlorinated solvents: Chloroform, tetrachlormethane, trichlorethylene, tetrachlorethylene, 1,1,1-trichlorethane.

Denmark has just started to analyse the MTBE (which is put into gasoline instead of lead (5-30 vol %), MTBE was introduced in Denmark in 1985). It is a rather unpleasant compound, which easily dissolves in water, and is very slowly decomposed in nature. There is a lot of discussion whether MTBE is a problem or not - time will show.

#### 3) Inorganic compounds:

Arsenium, Barium, Lead, Boron, Bromide, Cadmium, Zinc, Aluminium, Mercury, Fluoride, Chrome, Molybdenum, Nickel, Selenium, Cyanide.

### Conclusion

1. Raw water has to be analysed as any raw material. It is essential to know its chemical composition.
2. Precautionary principle. Time to time it is necessary to control all possible components that might influence the water quality in the area.
3. If it is possible, use water from areas without any significant human influence.

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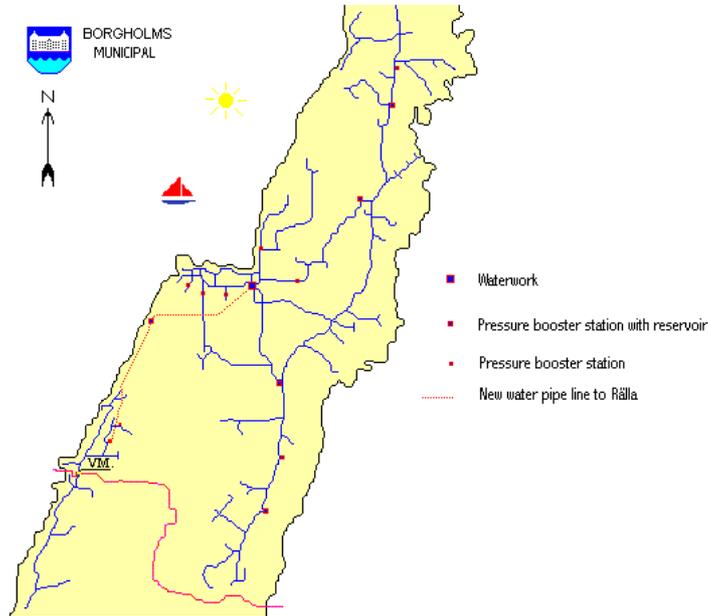
Persons who helped to write it: Hans Peter Birk Hansen (Bornholm) and Marianne Sädeme (Hiiumaa)

# IDEA CATALOGUE 4

## DIMENSIONING SUSTAINABLE WATER SUPPLY SYSTEMS IN ISLANDS

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<i>Author: Bror Johansson, Åland</i>	

## 4.1 WATER SUPPLY CAPABILITY AND PEAK LOAD DIMENSIONING IN TOURIST AREAS



**Table 1: Population and distributions net in the supply area**

**around Köpingsviks water plant.**

Household are calculated on 200 litres each and 3,5 person \* 365 d.

Official are figures that we know.

Vacation houses are calculated on 75 m<sup>3</sup>/year.

Farming is calculated on 200 litres/unit \* 365 d.

Camping are calculated on 300 litres/unit \* 60 d.

Industries are figures that we know.

Knowledge of this facts and approximate leakage in the water pipe line system are about 20%, the totally demand will be **1232450 m<sup>3</sup>**.

This calculation is based on figures that are recommended, but some is known consumption. We also know the max.day-consumption, that is **6900 m<sup>3</sup>**.

Knowing these figures, we can calculate on the max.day factor **fd** and max.hour factor **fh**.How you do that is described in Status Report 1998 of June 1999 on page 52.

Calculation for Köpingsviks water plant gives, **fd= 2** and **fh= 1,6**.

We can also easily get the Qmaxh =(Qmaxd/24\***fh**) 6900/ 24\***fh** = 287,5\*1,6 = **460 m<sup>3</sup>**.

The water pipe line system is built with several pressure booster stations, the largest of them with two chambers reservoirs, a large one for summertime, and a small for the winter. All our pumps are automatic frequency controlled, so that we have the most even distribution in the pipelines.

### Population and demand for the new water pipe line to Rälla.

In the village Rälla, situated 13 km south of Borgholm we had some problems with the water quality in some years. Therefore, we should now lay a new water pipe line to Rälla from the water plant in Köpingsvik.

What we have to think of then, is that in wintertime we have a consumption of 400 m<sup>3</sup>/d and in summer up to 1200 m<sup>3</sup>/d. Totally in a year about 180 000 m<sup>3</sup>. Those are the figures we have today.

However, we will connect a few other villages on the line, so the consumption will be higher in the future.

In this table, we can see the demand for the line to Rälla. Household are calculated on 200 litres each and 4,5 persons \* 365 d. Farming are calculated on 200 litres/unit \* 365 d.

	House-hold	m <sup>3</sup> /d	Farming	m <sup>3</sup> /d
Borgehage	190	171		
Strandtorp	45	41		
Halltorp	55	50	200	40
St Rör	150	135		
<b>Total</b>	440	397		
<b>fd 2.0 *</b>		794		
Rälla		1 200		
Mörbylånga		1000		
<b>Total</b>		3 034		

TABLE 2

The water pipe line to Rälla will be about 15 000 meter. It will be 6 700 m in the first part, to a pressure booster station with two reservoirs, 150 m<sup>3</sup> and 250 m<sup>3</sup>.

Pipe size will be 225 m/m and the pressure 0,6 MPa. We will have two pumps, one automatic frequency controlled and the second pump fixed. Those selections we also have in Köpingsvik and in the pressure booster station.

From the pressure booster station to the reservoir in Rälla is it 8 400 m. Pipe size is the same as in the first part, but the pressure will be 0,7 MPa, because Rälla is higher situated in relation to the pressure booster station.

Knowledge of the consumption of water in both systems, shall we look for the demand in Köpingsviks water plant when we increase with Rälla.

Köpingsvik we know that Q<sub>maxd</sub> is **6 900 m<sup>3</sup>**.

Rälla is calculate Q<sub>maxd</sub> **3 400 m<sup>3</sup>**.

Together it will be  $Q_{\max}$  **10 300 m<sup>3</sup>**.

$Q_{\text{medh}}$  will be  $10\,300/24 =$  **430 m<sup>3</sup>**.

$Q_{\text{maxh}}$  will be  $10\,300/24 * 1,6 =$  **690 m<sup>3</sup>**.

Knowing these figures, we can start looking for the solution in the water plant. For our help to do that, we use the table 8.14 in the status report of June 1999 page 67.

#### TABLE 3

The column Köpingsvik are the figures that we have today and here we see that the supply capability is enough, except the reservoir volume for clean water. However, when we add the figures for the new water pipe line to Rälla we get quite bad figures. It shows us what we have to do.

Now we put in the new figures in table 4 and then we can see that the figures will be better.

Water plant			Calculation	Köpingsvik	
			on basis of	New	
Consumer-pattern	Max.dayfactor	fd	x	2,0	
	Max.hourfactor	fh	x	1,7	
Supply-demand	Yearly consumption	1000 m <sup>3</sup> /y	x	1850	
	Max.day-consumption	m <sup>3</sup> /d		10137	
	Max.hour-consumption	m <sup>3</sup> /h		718	
	Pump capacity	m <sup>3</sup> /h		718	
	Extraction capacity	m <sup>3</sup> /h		441	
	Treatment capacity	m <sup>3</sup> /h		441	
	Total reservoir volume	m <sup>3</sup>		4131	
	Supply-capability	Water resources	1000 m <sup>3</sup> /y	x	3155
		Possible production	1000 m <sup>3</sup> /y		1931
Possible day production		m <sup>3</sup> /d		10580	
Delivery capacity		m <sup>3</sup> /h		811	
Pump capacity		m <sup>3</sup> /h	x	851	
Extraction capacity		m <sup>3</sup> /h	x	500	
Treatment capacity		m <sup>3</sup> /h	x	460	
Total reservoir volume		m <sup>3</sup>		4000	
Clean water reservoir		m <sup>3</sup>	x	4000	
High reservoir	m <sup>3</sup>	x	0		

## Solutions

Look at raw water capacity, the extraction. In our case, we have to do more wells.

Treatment capacity. Here we shall change pumps and convert the process, we shall softening the water. That we are going to do with, a new method that is build on flotation, and with this method will the filter capacity properly be better. If don't we have to put in some more filter.

Clean water pump capacity will not be a problem because we have two new pumps for Rälla.

We will build three more filter-wells in the area, each with a capacity of 36 – 55 m<sup>3</sup>/h.

The total raw water capacity will be **500 m<sup>3</sup>/h**, which satisfies our needs.

The four filter pumps we have gives 90 m<sup>3</sup>/h each so we change them to pumps that give us 115 m<sup>3</sup>/h, 4 \* 115 = **460 m<sup>3</sup>/h**. Our present process is dimensioned for 360 m<sup>3</sup>/h but it can easily be rebuilt.

As we can see in the table 4, we need to build a new clean water reservoir with a volume of 1.500 m<sup>3</sup> to satisfy the

demand. However, that will be an economical question. When this is done, we will have enough delivery capacity.

If you have any questions about this data, you are welcome to contact:

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## 4.2 DATABASE SYSTEMS AND SYSTEMS FOR MAPPING

There are lot of GIS software and database systems on the market. Most usable are:

ArcView  
MapInfo  
Microsoft Access  
Wilab LIMS etc.

They give us wide opportunities to organize database systems and systems for mapping. Our objective is suggest for small water supplies and islands some universal database and verification system with facilities connect them to digital maps.

Table 1 illustrates names of the GIS-systems that are in use in the B7 islands.

Island	GIS	Database Software
Bornholm	MicroStation, MapInfo	Vandgraf, GeoEnviron
Gotland	Map.Info	Access, Vabas/DUF
land	ArcView	-
R gen	GeoGIS	Geograt
A land	ArcView	Wilab LIMS
Saaremaa	-	-
Hiiumaa	-	-

Table 1

In most B7 islands database programs are used to organise water supply data connected to GIS software.

On Saaremaa and Hiiumaa there are not applied GIS-systems for water supply database and systems for mapping, but state officials intend to take in use MapInfo and Microsoft Access for county structures. Consequently, local authorities must take into consideration this fact.

Databases are needful to connect with map information. It is good to map polluted areas, point pollution sources and groundwater monitoring points. This gives a very clear picture of the water supply situation in the area.

The GIS and Database systems are relatively expensive why small municipalities are in difficulties to procure them. Saaremaa and Hiiumaa have now only few skilled staff able to handle those programs.

One of our issues is standardization of the structure of programs. Similarity gives us possibility to exchange data between B7 islands. For example:

- Water analyses,
- Co-ordinate system of wells location,
- Geological crosscut of boreholes,
- Name of water layers,
- Depth of wells,
- Pumping capacity,
- Water level in boreholes etc.

To take into consideration all information about GIS-systems (ArcView, MapInfo etc.) and from special software (GeoEnviron, UNIDISP etc.) I found out that small water supplies and islands municipalities might prefer the special programs (in Estonia is available NornInfo, UNIDISP etc.) for following reasons:

- less complicated
- less expensive
- do not require very high-level hardware
- it is possible to choose asuitable version according to domestic needs.

To successful use GIS-system and special software it is needed to

- prepare structure of needful data
- train employees.

## **Conclusion**

For sustainable and efficient water supply in the islands, we need good planning and management tools. GIS-systems are such a tool.

GIS-systems together with database software are giving the water suppliers and local authorities a good opportunity to collect and analyse technical data. Lot of attention must be paid at the structures of the programs.

Choose GIS-system that is:

- (at the beginning) quite simple to use

- train employees to handle it
- to take in use special software worked out for environmental information and management like GeoEnviron or the others
- software must be in wide range use – give opportunity to exchange information
- with possibilities to enlarge.

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## **4.3 RISK ANALYSES AND CONTINGENCY**

### **Background**

Everybody needs water to live. Drinking water is perhaps our most important foodstuff. But there are a lot of threats to the water-resources and to a sustainable water supply. The threats can be threats to the water-catchments, threats due to problems in the purification of the raw-water and threats in the distribution of the water. The use of

the raw-water and the purification and distribution of the water is important to have knowledge about and also the risks connected to that. When a situation arises that you could not foresee it is good to have plans how to do so-called contingency-plans.

The water supply must be safe. It is not necessarily, so that a low-price distribution is less safe than a high-price. That means that if the groundwater is of a very good quality the water supply can be both safe and cheap. Still it is so that the water-price in practice often is the factor that prevents choosing the safest method for water supply.

## **Examples of problems and risks**

### *Acidification*

The continuing acidification of the groundwater and lake-water is a potential risk. The risk on the B7 islands is not for the present so big. The limestone raises the pH in the groundwater in most of the islands and the lakes used as raw-water sources on Åland have at the present buffer-capacity against acid rains.

### *Eutrofication*

Outlets or leakage of nutrients from agriculture, wastewater risk to have a negative effect on the water used for water supply. High contents of nitrates in the groundwater are a problem you cannot easily solve. If you have an eutroficated lake that you use for water production it is complicated to reduce the content of organic substances. Eutrofication can also cause growth of toxic algae in the water and hygienic problems in the water-pipes if the purification of the water is poor.

### *Pesticides and other polluting substances*

Pesticides in the water-sources probably are an increasing problem. The time between the use of pesticides and the pollution of water-source is long so you cannot see all the future problems with the use of the pesticides during the last ten-year period. The situation regarding the heavy metals and the stable organic compounds in the water-sources is probable the same.

A risk not to be forgotten is the risk we have to live with, when we transport hazardous chemicals on our roads often close to the raw-water sources.

### *Shortage of water*

A too big outtake of water can cause lack of water or negative changes in the water quality such as to high salt-concentration in the groundwater.

### *Difficulties in the water treatment*

For the purification of the water a lot of chemicals such are used as precipitation-chemicals, pH-regulating chemicals and disinfecting-chemicals and methods. If the dosage of those chemicals is wrong, it can cause severe problems in the water supply

### *Problems in the distribution-systems*

Problems for the water-consumers can be caused by problems in distribution systems. Examples of such risks are:

- stops in the electricity-distribution
- breaks of the pipelines that distribute the water

- leakage of wastewater into the pipelines
- bacteria-growth in the pipelines.

## **Examples how to reduce risks**

### *Risks due to acid raw-water*

It is important to control pH of the water not only in distributed water, also in the incoming water to the waterworks. A more acid raw-water than you are used to will complicate the purification process. A consequence of acid raw-water can also be high contents of hazardous substances as heavy metals in the water.

If your raw-water is acid you can avoid problems by using lime in the water catchment-area. This can be better than using chemicals in the waterworks to raise the pH-value.

### *Risks due to eutroficated and polluted rawwater*

The best solution to solve the problems due to polluted raw-water is to prevent or stop pollution. The pollution related to outlets of wastewater can be solved by better wastewater-treatment or change the point of the outlet. Pollution from the agriculture, that can be outlets of nutrients and pesticides, can be decreased by establish protection-zones near to the water-catchment.

Sometimes when the raw-water is seriously polluted it can be necessary to look for new water catchments. If a new water-catchment is opened it is good to upset protection-plans with restrictions to management that can cause polluted raw-water. One problem is that those restrictions often cost a lot of money.

When you do a protection-plan, you have to inform about the restrictions. The information can be signs in the country. If there are transportation of oil and other chemicals on a road close to water-source restrictions of velocity and dense basins and ditches near the road are methods to reduce the risks for polluting raw-water.

If an accident, such as an oil-spill near a water-resource, happens it is good to have a plan for quick handling and clean the oil or other contaminating substances. Agreements with local people to act fast when an accident has happened can be a way to decrease the effects of the accident.

In Åland we have had problems, and still have a potential risk, caused by eutroficated lake water. In the lakes there have some times been an algae production where some of the algae have been toxic. The risks of rests of toxic substances in the drinking water from the biggest waterworks are now very small thanks to the new purification process in the waterworks.

### *Shortage of water*

A basic rule is to avoid taking out more water than what is formed. If you take water from a lake, you can easily know if you have taken too much but if you take groundwater it not so easy to know if you have taken too much. Therefore, it is always good using the water sparsely.

When planning new dwellings, cottages, industries and so on it is important to know the water supply situation. Perhaps it is not so easy to establish new management if the water supply will be very expensive due to shortage of water. In the archipelago of Åland we have such examples.

### *Risks in the water treatment*

Electricity is required for purification and pumping in the waterworks. Installation of reserve electric power supply can be a way to avoid problems. The reserve electric power station can also be mobile.

Alarm for fire is a way to reduce the risks for accidents with catastrophic consequences caused by for example a stroke of lightning. A better way to avoid fire due to strokes of lightning is to install a lightning conductor.

If the persons, who are responsible for the running of the waterworks, are not educated enough the water-treatment and quality of the drinking water can suffer. When, as in Åland, you often use lakes for the water supply you have to continuously educate the staff running the waterworks

#### *Risks in the distribution-system of the drinking water*

By continuing seeking of leakage of drinking water, you have good possibilities to prevent breaks in the pipelines that will disturb the water supply. That control also helps you to know which and when pipelines must be replaced.

Another way to secure the water supply is to build the pipelines so that it is possible to distribute water in more directions.

#### *Other risks*

When something unforeseen happens in the water supply, it is important to know who is responsible to solve the upcoming problem. If a risk-inventory has been made it will help.

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# IDEA CATALOGUE 5

## TECHNICAL SOLUTIONS IN SUSTAINABLE WATER SUPPLY IN ISLANDS

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## 5.1 SMALL SCALE WATER SUPPLY AND SINGLE WELL WATER SUPPLY

### Background

The area of Kõrgessaare community is 380 km<sup>2</sup> and the population is 1,540. Of the population, 800 live in a bigger settlement, the rest live dispersed all over the area of the community. Almost every household owns one or several wells (210 in total), of which about 50% are swallow wells. Since the wells are in the private ownership and since people have maintained the idea that groundwater is always supposed to be pure, there is a need for extensive information work to be done among the people to change their attitude. It is important that people are aware of the possible dangers concerning the quality of the water and interested in analysing the water in their wells.

Based on the existing analyses it can be said that the water in most of the wells meets the Estonian standard requirements for the drinking water. However, there are areas where the water contains too much iron, bacteriological contamination, the transparency of the water is below the allowed limit, or the COD is too high.

### How to get drinking water of high quality

Whether it is economically more feasible to connect the households of a certain area into water supply networks or supply them with water from single wells, depends on the quality of the groundwater of the area, the water consumption and the distance between the households.

One possibility to get pure drinking water is to drill a new well based on geological studies, since the existing wells are mostly founded on the nearest water-bearing layers without any previous studies or a plan, aiming only at the cheapest solution. The casing of the well in most cases is not proper either, which may cause bacteriological contamination.

In case of single wells we should mostly stick to the principle that the groundwater for technological needs should not be treated, when the quality of the drinking water is not important (e.g. for watering, flushing etc.).

Regarding the water treatment equipment to be installed, it is important to consider the following:

- easy to maintain and install
- energy efficiency
- low operating cost

There are definitely more problems with the quality of the water in shallow wells because they are open to all kinds of surface pollution. As most of the households with shallow wells lack the inside plumbing, the need for pure water is minimum. If this is the case, it's not reasonable to use the so-called flow-filter to treat the water. Of the filters on sale in Estonia, Katadyn Drip TRK system is more suitable for a single consumer.

The drip-filter TRK consists of two plastic containers; one of which is filled with untreated water, whereas the other collects the pure water dripping from the filter elements. This filter may be installed wherever you need it. The TRK provides clear, filtered and disinfected water. Naturally available water is thus made drinkable. The mineral and salt contents of the water remain unchanged. The hardness of the water is not changed and seawater not desalinated. Microorganisms causing diseases will be removed from the water: typhoid, dysentery, cholera, colibacillosis, amebiasis, bilarchiosis, giardiasis, etc.

## **Life span of filter element**

The life span depends on the degree of contamination of the water to be filtered. The filter element can be regenerated by simply brushing the dirty ceramic surface, although with every cleaning operation a thin layer of the ceramic is brushed off. However, in normal use, this cleaning process can be repeated up to 100 times before replacement becomes necessary.

Considering the conditions on Hiiumaa, it is the most reasonable to use oxidation and sand filtering in the supply systems with major pure water consumption. Depending on the nature of the contamination it is possible to use different fillings in the filters (activators, ion-exchangers or filter materials with specific characteristics). Of the systems on sale in Estonia, AKS VATTEN AB filter system is the most suitable for single-family houses.

To get rid of the bacteria in the water it is essential to effectively disinfect water. UV disinfection is the most suitable.

UV equipment disinfects water constantly without using chemicals that are heavy to handle. UV doesn't affect the smell or taste and there is no risk of overdosing.

It is also very easy to install and maintain, which makes it the most suitable in single households. The only thing to check is the dirt accumulating on the glass, decreasing the effect of disinfection. UV demands chemically pure water!

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## 5.2 IDEAS FOR LOW-COST WATER SUPPLY

### PREFACE

The present state of drinking water supply plants technological equipment on the B7 islands varies a lot. These differences are not only caused by different techniques but they are considerably influenced by the different historical developments in the respective countries. The Estonian islands Saaremaa and Hiiumaa have the greatest backlog demand concerning erection of drinking water supply plants complying with the European standards.

In this paper ways will be shown and technological aspects will be investigated which might help to reduce the costs of water supply and erection of water supply plants.

### **1. Preparation of a detailed water supply concept for whole supply area as a guide for the future development**

In order to efficiently and purposefully develop the water supply, every water supply company should have a clearly specified concept containing the following items:

- a profound analysis of groundwater resources in the form of hydrogeological expert's opinions with data about available water quantities
- findings of raw water resources analyses
- stock-taking of existing water supply plants with indication of state, technology, production capacity, capacity utilization rate, and possible problems
- water requirement analysis taking into consideration the building development
- comparison of different supply structures with indication of respective costs, advantages and disadvantages
- presentation of the optimum supply structure
- plan for step-by-step realization of necessary measures (specified acc. to urgency or indication of order of precedence).

Based on such a water supply concept and depending on the available funds the erection of water supply plants can systematically and efficiently be tackled. This way it is possible to take measures of main emphasis that will lead straight up to the optimum final solution. The important thing is not to realize the measures as quickly as possible but to avoid bad investments or uneconomical solutions. When in the end the whole concept will be fully realized, depends on the financial power of the respective supply company.

It should be noted that calculations of costs can not be based on investment costs only. The operational costs and ongoing maintenance charges must also be taken into consideration.

Furthermore it is important that the concept will regularly be revised since in the course of time alterations may become necessary due to changes of water requirement or new technologies.

## **2. Application of simple water treatment procedures, if possible, by means of well-tried commercial types of plants**

For correct drinking water production by treatment of the available raw water, only such procedures should be applied that are necessary for keeping to the quality parameters. If possible, such production equipment should be chosen that is available on site or the procurement and operation of which do not cause high costs.

In the majority of cases a treatment with pre-air mixer (for larger plants: oxidator) for oxygenation by air influx and sand filters is sufficient. By this procedure the raw water showing increased iron and manganese content only could be treated. It should be taken into consideration that this process is affected by an increased ammonium content. Establishing double filtration could raise the process efficiency.

The influx of pure oxygen can favourably affect the reaction process but it is not, as air, freely available on site, i. e. the use of pure oxygen causes extra costs for purchase and use of oxygen cylinders. Furthermore, serviceability of the plant depends on the oxygen supplier.

The use of activated carbon filters for treatment of badly polluted raw water is very efficient. However, it should be noted that such plants require a very large scope of maintenance work. High operational costs are caused by the necessary, regular activated carbon regeneration. Activated carbon regeneration process is done by cost-intensive large-scale plants with high energy demand. Construction and operation of activated carbon regeneration plants is economical only in case of working to capacity. That means that the respective demand shall be given. Often there have to be covered long transportation ways until the next regeneration plant.

Before building water treatment plants with activated carbon filters it should, therefore, be investigated carefully if there are existing more cost-effective alternatives. It should further be checked whether there – within an acceptable distance – are existing raw water resources of better quality that could be treated and transported with lower expenses. The establishment of network systems is advantageous.

In order to lower investment and operational costs, well-tried commercial type plants should be used, if possible. In the majority of cases, such plants are more cost-effective than plants especially projected for an individual case.

Before using a standard plant, it is necessary to get information on what plants are on the market. If necessary, independent specialised companies should be consulted. Normally, sellers dependent on producers only try to easily market their own products.

## **3. Use of the same kind of plants, if possible (same equipment, same make)**

By using the same kind of plants it is normally ensured that also equipment of the same kind, such as pumps, compressors and fittings, is used. When plants especially projected for an individual case shall be erected it should be taken care that the variety of equipment for the same purpose will not be too wide. The advantage hereof would be a cost-effective storekeeping of spare parts. Only a limited number of spare parts should then be stored and can be used for all plants. Another advantage is a bulk discount that is usually offered by the suppliers for the purchase of larger quantities or for regular customers and, thus, it is possible to reduce the costs considerably.

## **4. Establishing of connected systems dependent on the local conditions**

In feasibility studies of water supply plants, the operational costs are extremely important. High operational costs of waterworks are caused by high maintenance demand and power consumption. According to this and to the local conditions the costs could be lowered by reducing the number of waterworks and establishing connected systems. At the same time such networks guarantee a more stable supply.

In the long run the construction and operation of larger waterworks with transfer of reasonable length will be more

cost-effective than construction and operation of many small waterworks.

Connected systems with a low number of waterworks cannot be established in every supply area. On one hand the economic efficiency of such a system depends on the location of water resources and on the other hand on the settlement structure. It makes no sense to lay excessive drinking water lines for the supply of single houses. For this reason the water supply concept should contain a respective feasibility study.

## **5. Cost-saving operation of water supply plants**

If possible, water supply plants should be designed for the use of power at such times when it has a better price. In the majority of European countries, power bought in the nighttime has a lower price than power bought in the daytime. A solution could be the reservation of water storage capacity in high tanks, that are mainly filled during the night-time and used for covering a part of water requirement during the daytime. At the same time, when the high tank is designed as an opposite tank, it can be used for water supply compensation in smaller dimensioned nets during peak times. The economic efficiency of high tank installation depends on the size of the area to be supplied and on the technological design of the whole plant.

For the decision upon the pumps it shall be taken into account that they must be optimally designed for the respective case of use and that the working range lies within the pump's performance characteristics. Pump operation beyond the performance characteristics will cause considerable extra costs due to higher power consumption. Furthermore the pump rotor will be worn-out to a greater extent what will lead to a faster breakdown of the pump.

Speed controlled pumps that work infinitely variable without considerable energy losses in dependence on the respective demand are very efficient. On the European market there are offered complete speed controlled pump stations.

## **6. Set-up of an efficient automation system**

It is important that an automation system is set-up that corresponds to the requirements of plant operation from economic point of view. A respective investigation should therefore be part of the water supply concept.

It should be preliminary clarified what kind of data should be transferred where, with what purpose and what shall be operated on site or remotely controlled. It makes no sense to transfer as much data as possible that in the end do not directly influence the plant operation. An automation system with remote-control technique should consist of modules and must be extendable. So it will be possible to optimally adapt the system to the development of water supply plants. Since the development in the field of automation technology, especially concerning hardware and software, runs rapidly it makes no sense to built up a huge automation system and later on the corresponding water supply plants. That would result in a morally worn-out automation system that cannot meet the requirements after completion of water supply plants.

The use of such automation systems especially developed for the water supply is more cost-effective. Such systems can be bought at the European market for a better price than systems especially developed for individual cases or systems adapted from other fields of use.

## **Concluding remarks**

In the field of water supply, there exists a lot of cost reducing opportunities. In order to recognise most of the aspects a thorough verification of the concept is necessary. The more exact and detailed a concept is, the more visible become opportunities for cost reduction that in the end can systematically be realized.

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## **5.3 CLEANING PROCESSES FOR DRINKING WATER**

### **1. Things to consider when selecting a purification solution**

The extracted water usually has to be treated somehow before using. There are thousands of different purification installations in the market, however, the number of working principles used is quite limited. In order to determine which of the solutions is best for your needs you might want to consider the following:

- Which contaminants are actually in your water (and which ones might occasionally show up). The only way to know this for sure is to have your water tested.
- Which contaminants you are interested in to be removed.
- The cost of the solution you decide upon, both the initial and the ongoing costs. Look at the total amount you will spend over the next five to twenty years based on the amount of pure water you would like to be able to use.

To determine whether your water is susceptible to contamination by disease causing organisms, it should be tested for coliform bacteria. You should first disinfect the well and retest for coliform bacteria. If that test is again positive, then you should consider installing treatment to provide disinfection.

If your water is rust coloured, then the problem is probably high iron content. If the water is black instead, it could be either sulphur (which you would smell like rotten eggs), or manganese. All of these can be most easily treated with aeration and sand filtration.

A more difficult problem could be colloidal (very fine) clay in the water. If a glass of water stays very cloudy for more than an hour, then the particles causing the problem are very small, and a complicated filtration system would be necessary. A new well may be cheaper.

If your tests showed high concentration of nitrates, chloride or other salts that filtration can not remove, reverse osmosis or distilling could be an option.

### **2. WATER PURIFICATION STRATEGIES**

**Desinfection** is the most common method for addressing the microbiological (esp. bacteriological) quality of the water. Chlorine is by far the most common type of desinfection.

**Aeration** is generally used for one of two purposes, either to remove volatile chemicals from the water, or to add

air to oxidize some chemicals. Cascade and forced air are the two major categories of aeration. In cascade aeration, the water falls down a series of steps. With forced air, a pump forces the air into the water. Since the introduced oxygen is a relatively weak oxidant, some contact time is generally required after air is introduced (up to 30 minutes, depending on the target chemicals).

In more complicated cases air could remain too weak an oxidant and additional oxidation with  $\text{KMnO}_4$  could be necessary.

**Water filters** are a complicated topic because there are many types of filtration strategies and combinations of strategies used. The basic concept behind nearly all filters, however, is fairly simple. The contaminants are physically prevented from moving through the filter either by screening them out with very small pores and/or, in the case of carbon filters, by trapping them within the filter matrix by attracting them to the surface of carbon particles (the process of adsorption). Viruses can not be physically removed by any filtration method.

A benefit of all home filters is that they are passive. That is they require no electricity to filter the water - normal home water pressure is used to push the water through the filter. The only routine maintenance required is periodic backwash or replacement of the filtration element. As long as the cost of the replacement filter elements is reasonable, the cost of owning a even a high-end water filter can be quite low if you look at the cost over several years and compare it with other solutions.

**Slow Sand Filtration** uses a very low application rate, which requires that the filters be quite large. The majority of the removal is accomplished by a layer of biological growth on the surface of the sand. The filters are not back washed, but the top layer of sand is occasionally (e.g. once a year) scraped and replaced. A substantial “ripening” period is required after placing the filters on line to allow the biological growth to form.

1-3 m deep bed of sand should be used. The sand should be roughly 0.3 mm (0.15-0.4) in diameter with a uniformity coefficient of roughly 2.0 (1.5-3.6).

These filters are seeing an increase in popularity, particularly in relatively small systems, due to their relatively low maintenance operation. They also make excellent candidates for “self help” projects, since their construction is relatively simple, and can sometimes be carried out by municipal employees. Two or three perforated pipes (perforations facing down) should be placed on the bottom to collect the filtered water. These can be piped together and reduced to a small diameter pipe that will pass through the wall of the filter as the discharge pipe. 0.5 m of gravel is placed around and over the collector pipes (coarse gravel at the bottom, and finer gravel as you go up). Next, 1 m of sand is placed. The discharge should be piped into a storage tank. There should be a valve on this pipe to limit the flow.

**Rapid Sand Filters** use a bed of granular material, the “media” (usually sand) to strain out particles. After the media has caught a certain amount of material, it starts to be clogged. To clean the filters, water is forced through the filter from the bottom (the opposite way) very quickly, and this water carries away all the removed particles. This process is called backwashing. One side effect of this lifting of the media is that the media is resorted during each backwash: the smallest particles go to the top, and the biggest particles fall to the bottom.

This is in a way unfortunate, because the filter would work better, if this were the other way around: coarse material on top taking out the big particles, so less material reaches the smaller particles and the filter would clog less slowly. To achieve this desired effect, 2 or more different materials are sometimes used. Most often, a coarse layer of anthracite (a light material, a type of coal) is added on top of the sand. The resulting “dual media” filter is much more efficient.

Sometimes, air can be forced through the filters, either before or during backwash to stir up the media and get it cleaner while using less water. The amount of water used to backwash the filters can be as much as 5% of the water produced by the filter plant, so minimizing the amount of water used and maximizing the time between backwashes is very important.

**Cartridge Filters:** There are many varieties of cartridge filters, from spun cotton and spun polymer to membrane filters. If there is a great deal of particulate matter in the water, it may be necessary to install a series of increasingly

fine filters. If a fine filter is used on very dirty water without a coarser filter ahead of it, it will tend to clog very quickly. Filters are generally classified by how fine a particle the filters will be removed. For instance “one micron absolute” means that all particles 1 micron or larger will definitely be stopped. This labelling is what you want to look for to stop Giardia and Cryptosporidium.

**Activated Carbon Filters:** Activated carbon is particles of carbon that have been treated to increase their surface area and increase their ability to adsorb a wide range of contaminants, it is particularly good at adsorbing organic compounds. The potential for adsorption of many different chemicals (pesticides, herbicides, chlorine, chlorine byproducts, etc.) and greater particulate filtration of parasitic cysts, asbestos, etc. is greater than most other purification process available. By using other specialized materials along with carbon, customized filters can be produced for specific applications or to achieve greater capacity ratings for certain contaminants like lead, mercury, etc.

**Ultra Violet Light** kills bacteria and deactivates viruses. Water passes through a clear chamber where it is exposed to Ultra Violet (UV) Light. It is typically used as a final purification stage on some filtration systems.

UV systems are very easy to use, which makes them ideal for private homes. The most serious limitation for home use is that fairly clean, clear water is needed, since dirt can mask the bacteria, making the unit ineffective. In order to ensure the proper operation of an UV unit, it must be cleaned regularly, and some sort of metering should be provided to indicate that the light is emitting the required intensity of radiation.

Ultra violet light systems are only practical for small systems due to the need for the microorganisms to be close to the radiation source. This treatment technique also has the drawback of not providing a residual in distribution, so an additional disinfectant, typically chlorine, would have to be added.

**Boiling:** Parasites that might be lurking in your water will be killed if the water is boiled long enough. Boiling will also drive out some of the volatile organic compounds that might also be in the water. This method works well to make water that is contaminated with living organisms safe to drink, but because of the inconvenience, it is not routinely used to purify drinking water except in emergencies.

**Distilling** will remove all inorganic chemicals. It works very slowly, and is expensive to operate because it uses so much energy. The device operates by boiling water and then catching and condensing the water vapour. Chemicals are left behind as the water boils off. These units will not remove volatile organic chemicals, since these will boil off with the water. Boiling the water will kill bacteria, but introduction of new bacteria during the process is possible.

Benefits - a good distillation unit produces very pure water. This is one of the few ways to remove nitrates, chloride, and other salts that filtration can not remove. Distillation also kills most parasites in the water.

Down side - Distillation takes time and uses electricity all the time the unit is operating. The high energy use makes distilling impractical for commercial use. Also beneficial minerals, calcium and magnesium, are removed along with the harmful contaminants.

Distilling is an option for getting pure water in special places.

**Reverse Osmosis** The average RO system is a unit consisting of a sediment/chlorine pre filter, the reverse-osmosis membrane, a storage tank, and an activated-carbon post filter. High water pressure is used to force water molecules through a membrane leaving the contaminants behind. Purified water is collected from the “clean” side of the membrane, and water containing the concentrated contaminants is flushed down the drain from the “contaminated” side.

Benefits - Reverse osmosis removes salt and most other inorganic material present in the water. For that reason, RO lends itself to use in places where the drinking water is brackish (salty), or contains nitrates that are difficult to remove by other methods. Microscopic parasites are removed by RO units. Though slower than a water filter,

RO systems can typically purify more water per day than distillers can.

Down side - Home sized RO units make only a few litres a day for drinking or cooking. Beneficial minerals like calcium and magnesium are removed along with the undesirable contaminants. RO systems are expensive and produce wastewater. Two to four litres of “waste” water are flushed down the drain for each litre of filtered water produced. A reverse-osmosis system usually makes sense only for people who have unacceptably high levels of dissolved inorganic contaminants in their drinking water that can not be removed effectively or economically by other methods. Water from shallow wells in agricultural areas that contains high nitrate levels is a good example of a situation where RO would make sense.

**Ion exchange** devices are used for treating specific water problems. Specialized ion exchange units can be purchased to replace the toxic ions with safer ions.

Water softening is a specific type of ion exchange system. Its sole function is to reduce the hardness of water by replacing calcium and magnesium ions with another ion, frequently sodium.

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## **5.4 RENOVATION OF PIPELINES**

### **Background**

Big assets are buried in the ground as water mains. sooner or later it will be necessary to renovate these pipelines. when and how is it optimal to renovate?

There are plenty of reasons to rehabilitate the waterpipes. some of those are bad water quality, corrosion in the pipewalls (inside or outside), decrease of the inner diameter and water leakages.

### **Knowledge about pipelines**

It is very important to know in which condition the existing water network is. It is very important to have information about the existing water supply system. Usually the local water supply system has been developed during a period of many years. The initial network has been extended as the population and water demands have grown. In case of most water supply systems, there is a problem with the lack of exact plans of all parts of the network. For renovation plans it is necessary to draw up the missing parts of the network maps first.

It is important to have a data bank, where past accidents and technical failures have been recorded and where new data are systematically added. This information makes it possible to identify the mains, which need renovation,

and to plan renovation works in long term.

It is necessary to observe the water consumption continuously. Deviations in the consumption pattern may indicate leaks or failures. If leaks are discovered early, it is possible to ensure supply of water without major interruptions.

### **Traditional method of renovation**

The most usual way to renovate is digging and installing of the new pipes by a traditional way. That is the most economical when there isn't any traffic or when it is cheap to dig. Every time before renovation it is necessary to estimate total costs of the project. The total cost consists of the following:

- 
- Digging costs
- Backfilling costs
- Installing costs of the pipeline
- Costs of connecting works to existing network
- Costs of traffic reorganisation
- Costs of old pipeline demolition
- Costs of supporting of the excavated soil
- Costs of pumping water from the excavated hole.

In the cities this traditional method is often very expensive and the most economical way could be to use “no dig” technology.

### **“No dig” method of renovation**

“No dig” method means that the old pipe is lined with a new pipe inside it. First thing before inspection and renovation works is cleaning the old pipes inside. It is possible to use lining with discrete or continuous pipe

Lining with continuous pipe is often used in the water pipes.

As continuous pipes are used:

- Polyethylene or polypropylene pipes. The continuous pipe is pulled into the old pipe. It is the simplest and cheapest method.
- Close-fit pipes by reduced diameter-pipe. Diameter is reduced by 10-15 % before lining with heat or mechanically.
- Close-fit pipes by U-shape. Pipes are given U-shape before lining. After lining the original shape of the pipe will be restored with steam and pressure.
- Inserted hoses. The hose is packed to the U-shape. After lining the original shape of the pipe will be

restored with water pressure.

Cement mortar lining is developed to prevent inside corrosion of pipes made of steel or cast iron. Cement mortar is applied to the water mains by a centrifugal spraying machine.

Pipes bursting method. In this method the existing pipes are crushed with a machine driven by air. After this process a continuous pipe will be installed. It is possible to increase the pipe diameter with this method.

## **Summary**

In order to ensure reliable supply of water with normal quality it is important to arrange monitoring of the technical state of the water system and to reconstruct the worn-out mains in time. If this process is carried out according to plans, consistently and economically, the consumer will not have anything to complain about.

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# IDEA CATALOGUE 6

## THE CONSUMER IN THE SUSTAINABLE WATER SUPPLY SYSTEM IN ISLANDS

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## 6.1 WATER SAVINGS AT CONSUMER LEVEL

### PREFACE

The amount of water used for any particular reason is often determined by habit. Showers, dish washing and cleaning activities often can be altered in small ways to save litres of water over time. Here are some tips that can save water.

#### **In the bathroom**

- Long, hot showers waste water and power, so keep your showers short. Install water efficient showerheads and aerators.
- Limit your showers to the time it takes to soap up, wash down and rinse off. Turn the shower off while soaping.
- If you want a long soak, a bath uses less water than a long shower. But don't overfill the bath.
- Use a tumbler instead of running tap when brushing teeth and shaving. This can save 10 or more litres per time.

#### **In the toilet**

- Install a dual flush toilet and use the half flush when needed.
- Use a half flush for flushing of liquid waste. Don't use toilets as a wastebasket, flush only when essential.
- A leaking toilet may not be seen nor heard but can waste thousands of litres of water in a year. Check your cistern by placing a few drops of food colouring in the tank. Without flushing, look for colouring in the toilet bowl. If the colouring begins to appear in the bowl without flushing, the cistern should be repaired immediately.
- Install a low capacity flushing cistern which uses only 3.5 to 4.5 litres per flush.
- Do not allow toilet cisterns to overflow.

#### **In the kitchen**

- Install constant flow regulators at your taps and fittings.
- When washing dishes by hand, wash in a filled basin, not with running water. This can save tens of litres per load.
- When using a dishwasher, choose machines with efficient water use ratings and wait until you have a full load.
- Don't rinse dishes before loading them into your dishwasher. Use the "Rinse & Hold" setting instead.
- Thaw frozen foods in the refrigerator, not under running water. This can save more than 10 litres per meal.
- Wash your fruit and vegetables in a kitchen sink half filled with water. If your washing takes around 3 to

5 minutes, you'll save 30 to 50 litres of water.

- Reuse water from washing of vegetables for watering plants.
- Prevent wasteful water leaks by replacing tap washers and fixing leaking pipes where necessary. A good way to detect hidden leaks is to read the water meter late at night and early the next morning to see if water has been running while everyone is asleep.

### **In the laundry room**

- Washing machines are major users of water. If you buy a new one, look for a low water use model. Front loaders use less water than top loaders, and don't forget to use the suds saver option for multiple loads.
- Use your automatic washing machine only for full loads. Every time you run your washing machine, you use about more than hundred litres of water.
- Wash clothes in a wash tub instead of under a running tap.

### **In the garden**

- Effective landscaping can save up to 50 per cent of the water you use in your garden. Group plants with similar watering needs.
- Deep soak garden once weekly rather than sprinkle lightly several times a week. This can save over 200 litres a week in the summer.
- Collect rainwater for watering plants.
- Water evening or morning to prevent rapid evaporation during heat of day.
- Use micro irrigation in garden beds to apply water directly to plants. Use directional nozzles to make sure all water goes on plants. Low-angle nozzles are best in windy, exposed locations.
- Use a good mulch and plenty of it. Mulches can prevent up to 73% evaporation loss and they are one of the cheapest and easiest ways to make the most of water in the garden. Spread it, at least, 75 mm thick to reduce evaporation, prevent weed growth and to help even out variations in soil temperature over the day and night.
- Use a trigger hose: This means that you are in control and water is not wasted when moving the hose around - but remember to turn off the tap when finished in case the hose springs a leak.
- Use a timer with your sprinkler to ensure you don't over-water. A forgotten sprinkler can waste over 1000 litres per hour.
- Choose a sprinkler that produces big drops rather than a fine mist, which is easily affected by the wind.

### **Outside around the home**

- Use a broom rather than a hose to remove leaves and debris from driveway, walk, patio, and pool decks. This can save 1000 litres of water per hour.
- Wash car with a bucket, sponge and a hose with a shut-off valve. This can save 200 litres or more per

wash.

Water use 4(litres)	Average Amount used each time (litres)	Average Amount used per year Family of
Bathtub (1/2 to 3/4 one bath per week full)	150	23400
Water-efficient Shower * 2 per day for 6 min. each	7 litres per min	84 litres per day 91980
Average Shower (old style) * 2 per day for 6 min. each	15 - 20 litres per min	180 litres per day 197100
Toilet (modern full flush) * 6 flushes per day	6 litres per flush	36 per day 52560
Toilet (modern half flush) * 6 flushes per day	3 litres per flush	18 per day 26280
Toilet (old single flush only) * 6 flushes per day	11 litres per flush	66 per day 96360
Dripping tap	22 litres per day	8300

Table 1. Amount of water used by different activities

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## 6.2 SUSTAINABLE WATER PRICE POLICY

### PREFACE

A sustainable water price policy must not favour large water consumption, but instead reward modest water consumption and reductions in consumption.

Water meters are a key factor in sustainable water price policy. When the consumer is able to see how much water she/he is using every day, and the water price is to some degree proportional to the metered water consumption, then the consumer is encouraged to cut away unnecessary use of water.

### Households

In the majority of the B7-islands, the consumer must pay a fixed annual price in addition to a m<sup>3</sup>-price. This is fair enough, because the waterworks has expenses not depending on the amount of water consumed. If however the fixed annual price gets too high, the motivation towards modest water consumption may fail.

It is interesting to compare the Status report's (1) information on water prices and consumption in the B7 islands:

The household water consumption per year is not directly related to the total price. In Bornholm where the total

water price is highest, the average water consumption is close to 50 m<sup>3</sup>/inh./year. But the consumption is also 50 m<sup>3</sup> or less in Åland, Saaremaa and Hiiumaa, where the total price is lowest, and there is no fixed price. Of course, local habits and household equipment is also important. The islands where a fixed price is used, there seems to be a relation between water consumption and the magnitude of the fixed price, see figure 1. This could indicate that the motivation to reduce water consumption is decreased in the islands with the highest fixed prices - but a more thorough analysis is needed to determine if this is a fact.

### *Suggestions*

We recommend that the fixed price for households does not exceed approximately 1/3 of the total price, in average.

Different models can be used to calculate the fixed price, for example the sum can be equal to the expenses for construction and renovating the pipe system, which is “fixed” expenses not proportional to water consumption.

Figure 1. Household water consumption (m<sup>3</sup>/inhabitant) compared to fixed annual price (euro) per household in the island capitals.

### **Industry**

Big water consumers as fish industry usually pay a low fixed price, if any, compared with households. In some of the islands the big consumers pay a reduced price pr m<sup>3</sup> water - this may be justified from an economical point of view, but not from a sustainable point of view.

### *Suggestions*

Price reductions for big consumers is not recommended, on the contrary, a progressive price for big consumers could be considered, especially if the water resources is limited.

### **Other price systems**

Today it is possible to install electronic water meters, and calculate water consumption in different intervals of the day or seasons. This makes it possible to set different prices during the day or season, for example setting the prices higher during peak consumption periods or seasons where groundwater level is decreasing (summer). Such “time-variable” prices could be an instrument in sustainable price policy.

### **Taxes**

Taxes are a part of the water price in all the B7-islands. But from the consumers point of view, it is the total price (variable + fixed) which is interesting, not how big a share of the price is taxes.

A special tax, relevant in relation to sustainability, was introduced in Denmark in 1994: The state taxed the loss of water from the waterworks pipe systems, when the loss exceeded 10% of the water production.

This tax, which is very high, has effectively forced the waterworks to increase the effort to reduce water loss from pipe systems. The waterworks was of course not happy with the increased taxing, and argued that the state should use the profit from the tax in groundwater protection - with no success.

Figure 2: Groundwater production and loss from a waterworks on Bornholm. A systematic detection and mending of leaks in the pipe system was made during 1989. Water meters was installed from 1990-1994. State tax on water loss was introduced in 1994.

## References

(1) Status Report 1998, June 1999: B7 SUSWAT - Sustainable Water Supply in the Baltic Sea Islands.

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## 6.3 MODELS FOR ORGANIZING SUSTAINABLE WATER SUPPLY

### PREFACE

It is very difficult to define exactly the term “sustainable water supply” because first of all we have to answer the question what “sustainable” is in respect to. Is it meant economically, sustainable in the term of water resources or just ecologically? It would be the best if the definition of this term “sustainable water supply” includes all these aspects. But unfortunately I have to agree with the definition everybody uses nowadays and which - except with a few lacks - corresponds mostly to all life sphere aspects.

Therefore, this term should mean a certain water supply system where high quality modern equipment, effective and environment-friendly technologies is used; professional services and management from the waterworks and where the water use is most economical.

### 1. Background

Typically, the municipalities of all B7 islands are responsible for organization of water supply in their administrative territory. Water supply is normally organised as public or private. Most of municipalities operate the public waterworks. They keep professional employees or use private companies for operating waterworks. The pump houses installation of pipelines etc. all belongs to the municipalities.

Each private waterworks is managed by itself in the B7 islands. Only few of the private waterworks have an employee managing the daily routines. Normally they are operated as leisure-time activities.

The described situation in the field of water supply in the B7 islands can't all over be considered as sustainable. Although the present situation in the islands of EU the situation is certainly better than in islands of Estonia, a real need for sustainable water supply is still required in all islands.

## 2. THE BEST SOLUTIONS

In the villages and areas where the number of water consumers and the density of population are high, the **public water supply** will be the best solution. Also in the areas where naturally good quality water resource is insufficient or the quality of raw water is an unsatisfactory the best solution is would be the public water supply.

In the rural areas where the shortage of raw water is not acute and where the water consumers are located sparsely, and establishing of common water supply would use large amount of water pipes, it is much more economical to organise the local **private water supply**. These waterworks are situated isolated without connection to other waterworks.

In some remote areas and in the smaller islands it is the most suitable and cheapest way to use the small water supply and the simple single well water supply.

## 3. SUSTAINABLE WATER SUPPLY

In my opinion the managing of the sustainable water supply can be organized as:

- Municipal owned enterprise;
- Private non-profit water company;
- Mixed owned non-profit enterprise (in the form of a joint stock company).

The municipal owned water enterprise is managed by the municipality of it own. Such organising of the waterworks management is sustainable if:

- There is no need for solving difficult technical problems of water supply system;
- There are experienced water specialists in the staff of the municipality.

The private non-profit water company is another arrangement of the management model. Such private company has a special contract of renting with the local municipality. The lease of the municipality and the private water company regulate detailed the relations between them. This lease includes all requirements for the right operation of the water company. By this lease, the municipality has ownership of the building of the waterworks, also the right of any kind of control activities and the right of corroboration water tariffs and taxes. The municipality has an obligation for finding out the new investments and finances to establish the new needful waterworks buildings. This kind type of the organising-is sustainable if:

- There are many difficult technical problems that should appear
- There are no specialists of waterworks in the staff of the municipality.

The mixed ownership water company would also be a possible model for organising sustainable water supply. It is a very important aspect that most of (more than 50%) stocks should be owned by the municipality.

## 4. Conclusion

As conclusion it could be said that it is not a rule that the private sector is good and the public sector is bad. It very is important to connect the best features of both sectors considering the factual situation and concrete needs of each individual state and the islands.

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## **6.4 COPPER PIPES CAUSING BAD QUALITY OF WASTEWATER SLUDGE**

### **PREFACE**

In Gotland, investigations have shown that the copper content in wastewater sludge is high. Concentrations as high as 1100 mg copper/kg DS (dry substance) is not unusual.

According to new EU-regulations implemented in Swedish regulations, the copper content is not allowed to exceed 600 mg/kg DS, if the sludge is going to be used to fertilize agriculture land. It is of great importance to reduce the copper content in the Gotland sludge so that the nutrients can be recycled. If the sludge can't fulfil the quality requirements it will be replaced with artificial fertilizers that contains cadmium. Environmentally, cadmium today is a greater problem than copper.

To deposit the sludge in landfills with or without previous combustion is not a sustainable solution.

### **1. Cause of copper corrosion**

The high copper content in the wastewater depends on the high hardness of the Gotland groundwater, i.e. high calcium and magnesium content.

The water corrodes the copper pipes in the buildings and the released copper is transported by the wastewater to private settling tanks or municipality-own sewage plants. In the sewage plants, the coppercontent in the sludge is enriched by settling.

For the problems to arise, two requirements must be fulfilled:

- The piping must be made of copper.
- The water must have a high hardness.

### **2. Preventative measures**

Those geographical areas that have water with high hardness and still haven't installed copper pipes in a larger extent, ought to investigate if their water is aggressive or not.

If the water occurs to be aggressive, the selection of pipematerial should be directed to other alternative materials.

In Gotland copper pipes have been used by tradition during a long period of time, and to change the pipes would be a very expensive alternative.

The municipality of Gotland is today investigating the possibilities to soften the water so that the aggressivity is reduced and thereby fulfilling the EU-regulation concerning sludge.

### 3. Simple investigation

An initial study could consist of measuring the copper content in the drinking water in a building with installed copper pipes. The result could then be used to decide whether it is worthwhile to do a more detailed investigation.

The municipality of Gotland has made that type of investigation to define and correlate the copper problem.

Copper is an essential metal, i.e. the human body needs a certain amount of the metal to function. Also plants need copper to grow.

However, in too large doses copper is poisonous for both animals and plants. Concentrations greater than 0,2 mg/l could stain sanitary goods and hair (during hair washing). In concentrations larger than 1,0 mg/l, the taste of the water could be affected. If the concentration exceeds 2,0 mg/l, there is a risk for diarrhoea and nausea, especially among children.

Certain combinations of water and copper quality could give rise to concentrations over 5 mg/l, if the water has been standing in the pipes over night.

### 4. Conclusion

When changing and renovating water systems alternative materials should be used. No copper pipes should be used when constructing new buildings.

### 5. How to substitute copper?

Copper is today the most dominating pipematerial in residential buildings in Sweden.

Pipes and joints are used in all parts of the tap water system. Copper is a flexible, temperature resistant, light resistant and durable material.

In principle copper can be replaced by other materials, for example:

- PVC-pipes (polyvinylchloride)
- PP-composite-pipes (polypropylene)
- Stainless steel-pipes
- PEX pipes (cross linked polyethylene)

The three first alternatives are disqualified because PVC-pipes contain chlorine that has negative environmental effect, PP-pipes have a complicated joining method and the stainless steel pipes are very expensive.

### 6. Pex

The most suitable alternative today seems to be the PEX-pipe. The advantages with this pipematerial are: Low weight, low friction, no welding, simple tools, good pressure shock absorber, environmental friendly material and low price.

The disadvantages with this material are: A cheap durable joining method as good as soldering is missing, it is difficult to mount the pipes visible and free ( the stiffness is not sufficient ) and can only withstand temperatures up to 95 Celsius degree.

When constructing new buildings, there are no practical problems to change to PEX pipes. The building walls can be adjusted to the use of PEX, e.g. thicker walls in bathrooms to facilitate hidden mounting of the PEX pipes. The outer pipes can be mounted before casting the concrete.

When repairing and rebuilding it is a bit more complicated to change to PEX due to difficulties to mount the PEX pipes visible and free. The limiting factor is how much of the building one is able to demolish to be able to mount the pipes in a hidden manner.

Electrical heaters and heat exchangers are available in stainless steel and in enamel. The enamel type has the disadvantage that it needs renewal of the protecting anodes in regular time intervals.

## **7. Examples**

Some Gotland examples to mention are:

### ***Day nursery “Forellen” in Visby***

The rebuilding and additional building (805 m<sup>2</sup>) of the nursery was projected as an ordinary installation with copper pipes. The entrepreneur replaced on his own suggestion the copper pipes with PEX pipes. Free mounted pipes were mounted in stiff electrical (EP) pipes. However the heat exchanger and inlet tubes to the washbasins was made of copper. The cost of this alternative was not different from the cost of a copper installation.

### ***Old people’s home “Åvallegården” in Klinte***

The new construction of an old people’s home (2400 m<sup>2</sup>) was also projected as an ordinary installation with copper pipes. But PEX pipes was installed instead of copper pipes. The outerpipes was mounted before casting the concrete construction. Some copper pipes remain in the distribution central, heaters and inlet tubes to the washbasins. Also this case showed no increased costs by selecting PEX instead of copper.

### ***New constructions***

Theoretical comparison of new construction of a private one family house (125 m<sup>2</sup>): Two alternatives were compared, copper pipes and PEX pipes. Tekniska förvaltningen’s planning department made calculations and found that there was no significant difference in costs between the two alternatives.

### ***Comprehensive rules***

Tekniska förvaltningen has implemented the rule that always avoids the use of copper pipes in their own constructions.

The technical municipal committee has stated that sound environmental choices should be made when constructing new buildings. For that reason, no copper should be used within the committees area of responsibility. In addition, copper should be avoided as far as possible at reparations and rebuilding.

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