NEW DIRECTIONS IN SWEDISH RESEARCH ON WATER AND WASTEWATER HANDLING

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ABSTRACT

Research activities in Sweden related to water and wastewater handling have in general been focused on solving the different problems due to the contamination of groundwater, lakes and the marine environment. Technical research has been focused on optimising the built systems and the development of new methods. At present there is a shift in research priorities. This shift is due to problems to meet requirements of sustainable development and has therefore a multi-disciplinary approach. The background of the new direction for research is given and examples of important research activities are introduced.

KEY WORDS

research, stormwater, sustainability, Sweden, water, wastewater

INTRODUCTION

In the early part of this century, 70 % of the Swedish population lived in rural areas. Today the corresponding figure has diminished to less than 20 % (Table 1). Sweden has at present a population of 8.8 million with most people living in the southern half of the country.

Table 1. The distribution of the Swedish population in 1990 (Rolén, 1996)

Category	Size (persons)	Number	Population (persons)
Urban localities	200-	1843	7,162,615 (83 %)
Rural agglomerations	50-199	2362	252,000 (3 %)
Sparsely populated areas			1,180,000 (14 %)

More than 1/3 of the urban dwellers live in the three main metropolitan areas of Stockholm, Gothenburg and Malmö. The number of summer houses in Sweden has more than doubled since 1960, and there are now approximately 650,000, many of which are located along mountain range, the coast and lake-sides (Boverket, 1996).

Sweden is in a favourable position with regard to average fresh water availability with a per capita internal renewable water resources of 21,110 m^3 per year in 1990. Some regions in Sweden may, however, have water scarcity as parts of the coastal zone and south Sweden. Around 90 % of the population, as well as schools, hospitals, small industries etc, are connected to central water and wastewater handling systems. The water supplied by these systems amounts to about 130 m^3 per capita and year, which is less than 1 % of the total renewable water resources in Sweden. Out of the yearly drinking water production 51 % is withdrawn from surface water sources, 24 % from groundwater and the remaining 25 % is surface water treated by artificial infiltration (Ødegaard et al., 1996). Nearly 800,000 wells are privately owned (Boverket, 1991).

Sweden has more than 2,100 publicly owned water works of which the large majority is municipality owned. The larger industries as the pulp and paper and mining industries have their own water sources. The withdrawal of freshwater is about 340 m^3 per capita and year and the industry is the largest user (Table 2). The average per capita household consumption of water is in Sweden about 195 l/d.

Table 2. Withdrawal of freshwater by sector in Sweden (Ministry of Foreign Affairs and SEPA, 1998).

Sector	Withdrawal, %
Industry	70
Households	16
Agriculture	5
Miscellaneous	9

There are now approximately 2,000 municipal wastewater treatment plants and 95 % of the population in towns and agglomerations with more than 200 inhabitants are served by plants with tertiary treatment, i.e. biological and/or chemical treatment, or more (Figure 1). As a result of improved municipal wastewater treatment, pollution discharges have been reduced substantially (Figure 2).

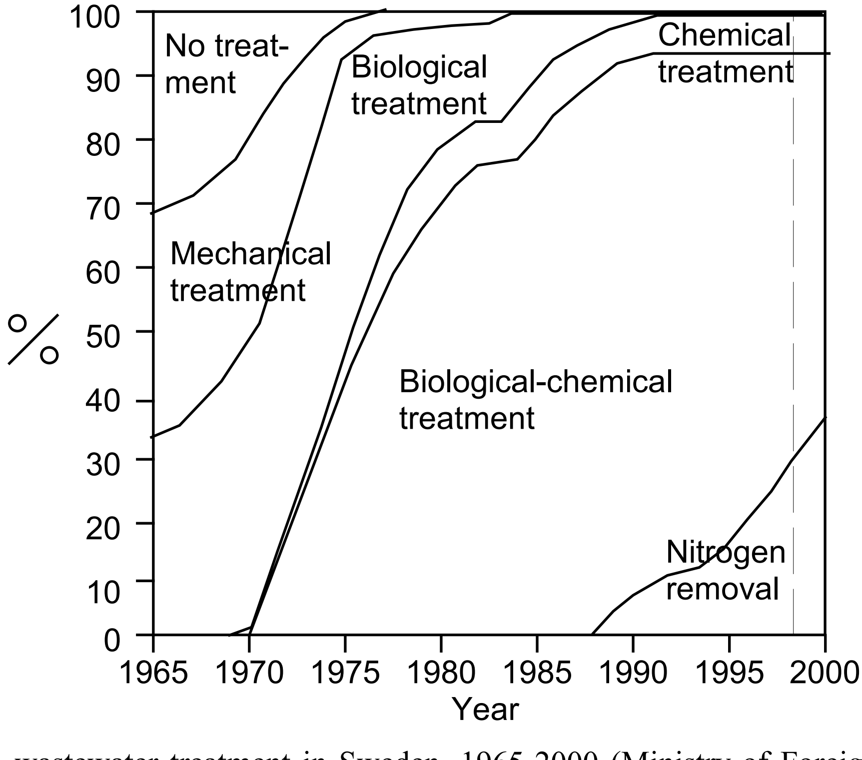

Figure 1. Municipal wastewater treatment in Sweden, 1965-2000 (Ministry of Foreign Affairs and SEPA, 1998).

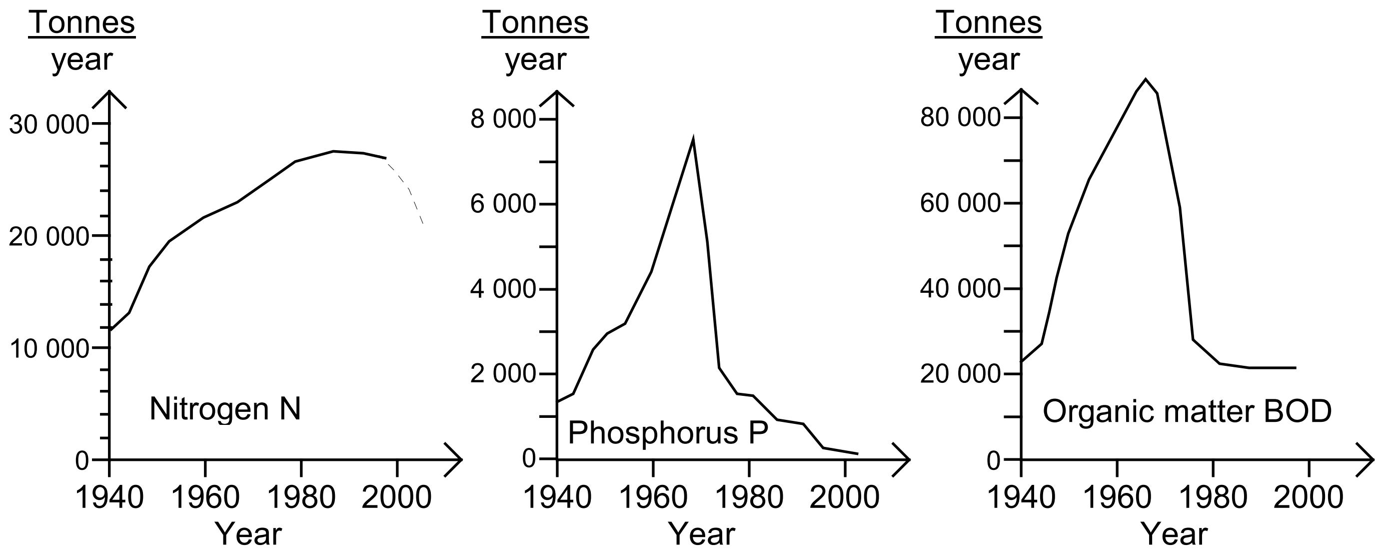

Figure 2. Discharges of nitrogen, phosphorus and organic matter from municipal wastewater treatment plants. The increases are attribute to an increase in connection of households and small industries to the plants. The reductions are attributable to improved treatment (Ministry of Foreign Affairs and SEPA, 1998).

Considerable attention has been paid to the wastewater transport systems, in order to improve the control of both the quantity and quality of the incoming wastewater, and to reduce the pollution via overflows in the sewers and through storm water drains from paved areas. Among the measures being taken are the separation of surface water from wastewater, through the substitution of old combined sewers for duplicate system, flow equalisation installations in existing combined sewers, plus leakage control. Measures applied in Sweden to specifically control stormwater are for instance local infiltration at source or special treatment facilities, such as artificial wetlands, before the discharging the stormwater into the nearest water body (Ministry of Foreign Affairs and SEPA, 1998).

HISTORICAL BACKGROUND OF SWEDISH DEVELOPMENT OF WATER AND WASTEWATER HANDLING SYSTEMS

An approach to universal formulation of integrated environmental management is the so-called DPSIR-approach, accounting for the Driving forces in society, the Pressures on the environment caused by these driving forces, the State of the environment as a consequence of these pressures and the Impacts imposed by that state and finally the Responses of society with respect to measures with which to remedy the situation (Harremoës, 1998). Developments of wastewater treatment systems have been much influenced by developments in society. Different driving forces have changed priorities from focus on hygienic aspects as starting point via gradual improvements of treatment methods to a focus more related to - in addition to earlier requirements - recycling of resources, energy savings and recovery, public participation and interactions with other sectors in society. Develepments of water and wastewater handling systems are illustrated in Table 3.

Table 3. Developments in Swedish water and wastewater handling systems.

Time period	Driving forces in society (examples)	Effects on environment	Remedies
Before 1930	Population growth; urbanisation	Contamination of local water sources; spread of waterborne diseases	Supply of water from an uncontaminated water source
1930 - 1990	Increasing standards in houses (WC, bath etc); increased use of different products; rapid growth of economy	Impairment of the environment due to discharges of different substances, although compensated by different remedies	Gradual building of water and wastewater handling infrastructure incl. different treatment steps (cf. Figure 1); efficient control of industrial discharges
1990 -	Increased awareness of environmental issues and its relation to life style	Improved environmental quality especially on a local scale due to decreases of discharges	Development of Agenda 21; multi-disciplinary approaches to problem solutions; use of international environmental standards as EMAS and ISO14000

Regarding wastewater treatment focus has been given on a specific problem and with a change every 20 year (Table 4; cf. Figure 1).

Table 4. Changes in priorities of wastewater treatment in Sweden

Time	Main problem	Remedies
From 1930	Visible pollutants	Mechanical treatment
From 1950	Low oxygen contents in recipient (odour, killing of fish etc)	Secondary/biological treatment
From 1970	Eutrophication of lakes	Tertiary/chemical treatment
From 1990	Marine eutrophication improved removal	Removal of nitrogen/ phosphorus
From 2010 (predicted)	Efficient recovery of resources (as phosphorus and energy); minimisation of deposition of sludges	Eco-cycling, implementation of Agenda 21, modified sludge handling, increased public participation/responsibility

APPLICATION OF SUSTAINABILITY AND AGENDA 21 IN SWEDEN

When the Brundtland Commission's "Our Common Future" was published in 1987, the concept of sustainability rapidly became accepted internationally and in Sweden. The definition of sustainability in the Brundtland report is: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". The sustainability concept also involves social and political aspects. Greater equality means basic changes of patterns of consumption, the allocation of resources and, consequently, life-styles. A sustainable environment cannot be achieved without the political commitment to make necessary changes. The concept of sustainable development may be regarded as a key to understanding the relationships between environment and development. It calls for a sense of responsibility with respect to our actions that extends to every part of the world, and to future generations (Clarke, 1994; Hultman and Levlin, 1998).

Agenda 21 is an action plan for the 1990's and the 21st century, elaborating strategies and integrated programme measures to halt and reverse the effects of the environmental degradation and to promote environmentally sound and sustainable development in all countries. The Agenda comprises some 40 chapters and totals over 800 pages. One chapter in Agenda 21 has the title "Local Authorities Initiatives in Support of Agenda 21" and recognises that local authorities have a crucial role in implementation of ideas in Agenda 21. The work has become an important issue in Sweden and today all of the Swedish municipalities have started to work on processing and producing their own local Agenda 21 (Andersson et al., 1997).

Sweden's ultimate vision in environmental work is the establishment of an ecologically sustainable society. The purpose of the environmental policy is to protect human health, preserve biological diversity, manage natural resources, and protect natural and cultural landscapes (Ministry of Foreign Affairs and SEPA, 1998). Main environmental objectives and strategies are shown in Table 5.

Table 5. Main environmental objectives and strategies in Sweden (Ministry of Foreign Affairs and SEPA, 1998)

ENVIRONMENTAL OBJECTIVES		
Resource management	Land and water use	Pollutants
• Phosphorus in natural cycle • Valuable natural gravel • Metals in the natural cycle	• Green forests • A rich cultivated landscape • Majestic alpine environment • Seas in balance • Living lakes and water courses • Good groundwater • Flourishing wetlands • A well built-up environment	• Limited climatic impact • Protective ozone layer • Only natural acidification • Clean air • No eutrophication • No persistent organic pollutants • Safe radiation environment
STRATEGIES		
• Energy efficiency improvements • Reduced use of materials • Closed-loop eco-cycles • Waste management	• Knowledge • Consumer awareness • "Principles", e.g precautionary principle	• Environmental management systems • Physical planning • International work

URBAN WATER AND WASTEWATER HANDLING IN RELATION TO SUSTAINABILITY PRINCIPLES AND AGENDA 21

Urban water and wastewater systems should fulfil the following functions:

- Provide water for a variety of uses (in households, factories, offices, schools etc.)
- Remove wastewater from users in order to prevent unhygienic and other unfavourable circumstances
- Remove stormwater from streets, roofs and other surfaces in order to avoid damages from flooding

These functions could be regarded as the basic ones and have been the basis for urban water systems design. Sustainability principles and Agenda 21, however, imposes requirements of how these functions should be fulfilled. The requirements may be related to:

- Resources needed for fulfilment of the functions i.e. primary (as nutrients, water, etc), secondary (as nutrients, space, energy, etc), natural (as natural waters, atmosphere, soil, etc), and antrophogenic (knowledge, creativity, money, etc) (Larsen and Gujer, 1997).
- Recycling and use of resources from wastewater and sludge handling (water, energy, nutrients etc)
- Beneficial use of water for pleasure and recreational aspects of urban culture (Larsen and Gujer, 1997)
- Integration of urban water management with other sectors in society (agriculture, waste handling, city development, building industry etc)
- Possibilities for participation of public, interest organisations etc

These additional requirements have given rise to additional research needs. Much work has been done to describe these needs and formulate research programs. The work has mainly been done by informal research groups, that have submitted their ideas to MISTRA (The Foundation for Strategic Environmental Research). A planning support has recently been given from MISTRA to work out a research program based on ideas described in "Sustainable Urban Water Systems" submitted in 1997. The modified program will be submitted to an international evaluation committee in the end of October 1998 and a decision from MISTRA is expected in the middle of December 1998.

The content of this program represents many of the main ideas for the need of research to meet future requirements for urban water handling. The following description of new directions for research on water and wastewater handling has partly its roots from this program, although other ideas are also presented. A platform aiming at identifying guiding principles and goals for sustainable urban water systems and indicating priorities for research in the area was developed by Ødegaard et al. (1996).

MAJOR DRIVING FORCES THAT MAY CHANGE URBAN WATER SYSTEMS AND MOTIVATE RESEARCH ACTIVITIES

Savings of chemicals and recycling of resources

In Sweden there is a general consensus to diminish the use of chemicals for different purposes. Industries have successfully used many methods to change the production technology to diminish the discharges of pollutants.

About 25 per cent of the water supply in Sweden is obtained by surface water treated by artificial infiltration. By this method the use of chemicals (precipitation coagulants and disinfectants as chlorine) can be diminished significantly, the problems of handling of sludges is also diminished and the temperature of the water may be rather constant during the year. In addition, the water produced is biologically stable and will therefore present less problems related to biofilms (for instance hygienic risks) and corrosion. The general trend in Sweden is to promote artificial infiltration and for instance Stockholm is at present evaluating the possibilities to use this method for the water supply in the city.

Research needs in this area is much based on better understanding of biofilm formation on surfaces during infiltration, mechanisms for producing a stable water and possibilities to use only a low disinfectant dosage without hygienic risks.

There has been a strong debate in Sweden if the central systems for wastewater handling can fulfil requirements for recycling of resources as nutrients. Main focus has in this case been laid on phosphorus, that may be a limiting substance in the future. The reason for this debate is the fact that resources (as nutrients) are mixed together with toxic substances (as heavy metals, specific organic pollutants and pathogens). A significant success has been obtained of source control of pollutants that can be measured as for instance the metal concentration in sludges. Some interest organisations and food industry have questioned the use of sludges for agriculture purposes. The Swedish policy in general is, however, that it is both beneficial and necessary to return nutrients and organic matter from urban sewerage sludge to agricultural land. Research needs have therefore been identified to modify present practice of wastewater handling:

- Detoxification of sludges or production of different products from sludges (cf Hultman and Levlin, 1997).
- Use of urine separating toilets and separate handling of the urine
- Evaluation of phosphorus uptake by plants of different mixtures of soils and wastewater products

Savings of water and energy and recovery of energy

Sweden is rich concerning average available water per capita in contrary to many other countries. The general need for solving water scarcity will probably lead to the development of water saving machines for dishing and washing, effective water fittings, low-flushing toilets, water meters etc. It is estimated that this development would make it possible to decrease the water consumption in Sweden from the present 195 l/p,d to about 100 l/p,d (approximately 50%) in modern buildings without negative consequences on hygiene, living standard etc. Although saving of water is not a primary goal, the water consumption is much related to the consumption of heated water. The general need for energy saving will therefore also include water saving methods. Some identified research needs are:

- Effects of water saving methods on existing water and wastewater systems (drinking water quality, transport of suspended solids in sewers, risks for freezing etc)
- Public acceptance of different water saving methods (including the use of water meters and low-flushing toilets)
- Energy recovery in treatment plants (including heat pumps and use of methane gas)
- Methods for extreme water saving technologies for certain applications (areas with severe water scarcity etc)

Local handling and beneficial use of storm water

Urban storm water is rain water and melt water that runs off streets, roofs and other surfaces in cities. The main purpose of storm water handling is to avoid flooding. Storm water was historically carried away by ditches and small creeks to the nearest stream. Later on storm water was fed into the sewer net (combined system) and later on in separate pipe nets (separate system). The main problem with the combined system is the overflows of polluted wastewater during storms. The separated system may lead to disturbances of the natural water cycle and discharges of pollutants. Research needs and actions to avoid present problems of storm water handling are:

- Source control of pollutants to storm water
- Increased local handling of storm water
- Changes in city planning to improve possibilities of a natural water cycle in urban areas
- Beneficial use of stormwater (irrigation, artificial lakes etc)

Water and wastewater handling in relation to other sectors

Water and wastewater handling is interlinked with many other sectors in society. Different examples are:

- Agricultural sector (irrigation, use of sludge etc)
- Solid wastes sector (use of disposers, joint treatment in composting and incineration etc)
- Energy sector (incineration of sludge, use of methane, heat pumps for central heating etc)
- Building sector (use of sludge in landscaping, as building material etc)
- Industrial sector (use of phosphate in sludge as a raw material for the phosphate industry etc)

The increasing complexity of society gives rise to several research needs of water and wastewater handling interlinked with other sectors as:

- Evaluation of technologies for improved combination of water and wastewater handling with other sectors
- Organisation forms to promote efficient combinations water and wastewater handling with other sectors

Role of city development on water and wastewater handling

The population in Sweden is distributed between 3 metropolitan areas (Stockholm, Gothenburg and Malmö), towns and cities between 2000 and 100000 and villages and rural areas. These areas will have different "optimal" solutions for water and wastewater handling. A sustainable structure of the society is resting on the opportunities for people finding solutions to problems in their everyday lives, and to find houses and buildings that correspond to their way of living.

Research efforts are needed to evaluate possible developments of cities and how these developments may influence solutions of sustainable systems for water and wastewater handling. Interactions must be considered of the city and surrounding areas to develop suitable eco-cycles.

Public participation in water and wastewater handling

The key actor in achieving sustainable development is the individual. Successful water management requires an active contribution from the consumers. By use of information campaigns the public may be encouraged to buy washing and cleaning products that are as environmentally safe as possible and to dispose hazardous waste at specifically arranged points instead of pouring them into the sewage system.

Research is needed to better evaluate the role of public participation to achieve sustainable solutions of water and wastewater handling. In these studies it is important to include the role of life-style (cf Forsberg, 1998).

Guiding principles and goals for sustainable handling of urban water and wastewater systems

Water and wastewater handling may be performed in many ways including local or central systems, separated or non-separated systems, nature based or technical methods for treatment etc. Independent of the choice of system these should comply with certain guiding principles and goals. These may be summarised as (Ødegaard et al., 1996):

- Water quality in surface and groundwaters should not decline over time and should meet long-term environmental goals.
- The urban water systems should also supply the population with healthy and good drinking water in the future.
- Water-borne diseases should be prevented.
- Water supply should be met out of effective runoff only without lowering the groundwater level.
- Urban water management should promote urban quality of life i.a. by the provision of attractive green areas and high quality water for recreation.
- Wastewater should be regarded as a multipurpose resource and methods should be developed for recovery and use of materials and energy.
- Methods should be considered to integrate wastewater and solid waste handling.
- Methods should be developed for efficient recovery and reuse of sludge and sludge products. Sludge and other residue products should not be accumulated on deposits.

- Efficient source control and detoxification should be used.
- Future water, wastewater and stormwater systems should provide services needed in a cost-effective way. Criteria and methods for evaluation of cost-effectiveness and sustainability should be developed.
- Public participation and awareness should be encouraged.
- Efficient collaboration should be developed between users, owners and other actors in urban water management.

Research needs of different of these guiding principles and goals have been discussed earlier. However, it is also necessary to perform studies on a system level. Important research needs include:

- Use of system analysis
- Use of technical and hygienic risk analysis
- Cost analysis

SUMMARY

Much research is needed to improve and optimise existing central and local water and wastewater handling systems and to develop new methods. This research is performed by grants from research organisations or by municipalities and companies. A change in research directions has gradually occurred in order to comply with sustainability principles and driving forces that may change urban water systems. Important new research activities in the future include:

- Savings of chemicals and recycling of resources
- Savings of water and energy and recovery of energy
- Local handling and beneficial use of stormwater
- Water and wastewater handling in relation to other sectors
- Role of city development on water and wastewater handling
- Public participation in water and wastewater handling

In addition to these problem oriented areas the system function should be evaluated by methods as system analysis, technical and hygienic risk analysis, and cost analysis.

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