Water management and technology in Swedish municipalities.  
Assessment of possibilities of exchange and transfer of experiences

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Abstracts

The water and wastewater infrastructure began to be developed in Sweden more than one hundred years ago. Much attention was given, in the beginning, to fire prevention and hygienic problems with water borne diseases. Somewhat later storm sewers (combined system) were constructed to remove storm water and wastewater and then successively more efficient wastewater treatment plants were developed. Today water and wastewater handling is seen as a multidisciplinary subject where also attention is given to possible effects of climate changes and possibilities for resources recovery.

Implementation of advanced water and wastewater systems involves not only different technologies but also effective administration and legislation. The implementation may be on national (also involving EU directives), regional and local scale. As a case study, the local implementation will be illustrated for the municipality Växjö in South Sweden with about 80,000 inhabitants.

Key words: historical development, management, policies, Sweden, Växjö, water, wastewater

History developments

Sweden has today about 9 million inhabitants and is, on average, rich in water. Water is abundant in the Northern part but in a few parts in especially in South Sweden and the archipelago water scarcity has been observed. The many in-land lakes are often sensitive to pollutants and the Baltic Sea has severe problems with pollution and eutrophication.

Developments of water and wastewater systems began with fire prevention in cities more than a century ago. The reason was the many wooden houses and many fires caused destruction of large parts of the cities. Design of water mains had to consider that enough water could be supplied. At about the same time it was gradually understood by medical expertise that different outbreaks of epidemics were caused by water borne pathogens.
The solution to this problem was to transport water with a high water quality and led to a gradual increase of water infrastructure with water mains and pipes.

Storm water and sewage were led out in open ditches or channels. They were gradually substituted with mains for discharge of storm water and wastewater. Environmental concern led to building of wastewater treatment plants with start of extensive building of plants to remove visible pollutants by mechanical treatment around 1930, to remove organic materials by biological treatment around 1950, to remove phosphorus by chemical precipitation around 1970 and modification of the biological treatment to also include nitrogen removal around 1990. The possible need to remove pharmaceuticals and antibiotic microorganisms is much debated at present.

**Administration and legislation**

The responsibility for water supply and drinking water in Sweden lies on the Ministry of Health and Social Affairs and for environmental protection on the Ministry of the Environment. The ministries have as central supervisory agencies the National Food Administration and Swedish Environmental Protection Agency (SEPA), respectively. Decisions at a regional level are made by County Administrative Boards and most permits for wastewater treatments plants are issued by these boards or alternatively by environmental administration in municipalities. Only for large and complex activities permits are issued by regional Environmental Courts.

Water and wastewater services are normally provided by local authorities or municipally owned companies, which own and operate all facilities. Privatization has taken place only to a small extent to for instance operate the systems for a certain period or getting both ownership and responsibility for operation of the systems. Municipalities can determine fees for water and wastewater services to cover own investments and capital and running costs. According to Swedish legislation no profits are allowed. Water and wastewater handling is today much influenced by EU directives such as the EU Water Framework (Hannerz, 2008).

**Source control and sorting of streams**

Large industries in Sweden such as pulp and paper and mining industries have separate water supply and wastewater treatment. Most of the other industries have their water supply from municipalities and they also discharge their wastewater into the sewer net. Earlier these discharges were the main problem for the sewer net and treatment plant. Stringent rules were, however, gradually developed and in principle only industrial discharges are allowed with similar properties as municipal wastewater. Other pollution sources have increased in importance and different actions to improve source control include:

- Changes of building materials inside buildings as use of plastic material instead of copper in water pipes
• Use of water saving equipment as low-flushing toilets, high-efficient washing and
dishing machines, etc
• Changes in external building materials to decrease the amount of corrosion
products in storm water
• More stringent rules on air pollution (cars, no lead in gasoline, energy production)
to decrease pollutant supply to storm water
• Forbid or restricted use of certain chemicals
• Taxes on certain products as on energy
• Information campaigns to use environmentally friendly products, avoidance of
using toilets for toxic discharges etc

Sorting of different streams is common practice in industries (process waters, cooling
water, storm water, wastes from kitchens and toilets etc) and sorting is motivated by
improved possibilities for product recovery and to facilitate treatment. Sorting has also
been discussed for households of different streams but has not come into practice in
urban areas. Examples are urine sorting toilets, sorting of black water and grey water for
separate treatment. Main emphasis has, however, been laid on separation of storm water
from wastewater.

About 85% of the Swedish population is connected to the municipal water net and to
sewer and storm water systems. Wastewater and storm water can be transported by
combined or duplicate systems. The combined system is characterized by transport of
wastewater storm water and drainage water in one common pipe. To reduce overflow
combined systems are sometimes equipped with detention basins. Combined systems are
used in city parts built before about 1955.

Duplicate systems with separate transport of wastewater one pipe and storm water in
another pipe have mainly been built for new building areas as many suburbs after 1955.
Storm water in dense populated areas may be treated locally by use of infiltration or
constructed wetlands. In rural and sparsely populated areas storm water may be
transported in open ditches and directly discharged into the recipient.

**Process technology development**

Wastewater treatment plants were often gradually built during in a long period with for
instance a mechanical step in 1930, followed by a biological step in 1950 and then a
chemical precipitation step in 1970. Biological treatment (most often with the activated
sludge process) and post-precipitation became the dominating process scheme. When
requirements came on nitrogen removal the most common way was to increase the
volume of the aeration basin of the activated sludge process and use of pre-
denitrification, i.e. use of an oxygen free zone for denitrification and an aerated zone for
nitrification. A lot of modifications exist and much work has been laid on lowering the
operational costs for the built plants by finding ways to decrease the need for chemicals
and energy for instance by use of process modifications, better equipment and efficient methods for monitoring and process control (Lundin, 2007).

In the future it may be necessary to reach more stringent effluent requirements for instance replacing existing process parts with new technology or supplementary treatment. Some of the process technologies that are studied include:

- Use of biological phosphorus removal and often with low dosages of chemical coagulants to a final step
- Use of the anammox process for removal of nitrogen in supernatants from digesters
- Use of oxidation technology (as addition of ozone) or adsorption by activated sludge to remove organic micro-pollutants and antibiotic resistant pathogens
- Use of membrane technologies

**Resources recovery**

Much attention is today given in Sweden on possibilities to recover different resources in influent wastewater. Energy recovery has been given a high priority and heating pumps are used at many plants to recover the heat in wastewater and use it for central heating systems. The produced biogas in digesters is today considered as suitable for use as fuel for instance for busses.

In many countries the water content in wastewater is the most valuable resource to recover. However, this use is not considered in Sweden except for a few cases for irrigation. The other components in wastewater that are evaluated for recovery are (Hultman et al., 2007):

- Inorganic materials as sand for recovery by washing sand removed in grit chambers. This technology has increased during the last years
- Organic materials not only for biogas production but also during incineration of for instance rags and paper removed in pre-treatment steps
- Phosphorus recovery has been considered both by leaching of ashes from incineration of sludge, treatment of dewatered digested sludge and as recovery of magnesium ammonium phosphate. No full-scale plant exists at present in Sweden with phosphorus recovery

**Implementation of water management and technologies in Växjö municipality**

*National and local aspects*

The Swedish government has set up 16 environment goals which national administrative organizations like the Swedish Environment Protection Agency tries to find practical strategies to implement. The implementation should also be in agreement with for
instance EU directives and international commitments. The different environmental goals are normally formulated as a partial way to obtain sustainable development and are valid on different aspects on all environmental aspects. As an example one goal is requirements that at least 60% of the used phosphorus should be recovered in order to avoid depletion of natural resources as for instance apatite.

At a local level many municipal have developed own environmental plans to consider both the national strategies and the local conditions (Hannerz, 2008). An important aspect of local implementation is Agenda 21 which describes the need and benefits to give the inhabitants possibilities to influence the planned strategies and their local consequences. Växjö municipality will be used as an illustration of local implementation. The municipality is situated in the middle of south Sweden and has today a population close to 80,000 inhabitants and with a varied trade and industrial activities and a growing university.

General local implementation in Växjö municipality

In May 2006 the politicians adopted the new steering document: Environmental Programme for the City of Växjö. EcoBUDGET is an environmental management system developed for steering and following-up the goals in the environmental programme. Three profile areas were developed: Living Life, Our Nature and Fossil Fuel Free Växjö (Växjö municipality, 2006)

The profile area “Fossil Fuel Free Växjö” got much recognition as two international rewards in 2007 for the ambitious programme with goals and results and was also recognized by for instance BBC London. The emission of carbon dioxide from Växjö was estimated to have decreased by 30% per capita between 1993 and 2006. As Växjö municipality by ICLEI-Local Governments for Sustainable has suggested Växjö to be the greenest city in Europe many strategies and implementation methods may be used as good illustration examples (Växjö municipality, 2008)

Concerning aspects to comply with for instance the EU Water Framework Directive much attention was given to lake restoration, storm water handling, future water supply and wastewater treatment and these aspects will be described in the following.

Lake restoration

In the municipal district of Växjö there are more than 200 lakes covering 13% of its area. Lake Helgajön north of Växjö has been used as drinking water resource since 1887 but is much influenced by different discharges. The four largest lakes (Lake Trummen, Lake Växjösjön, Lake Norra and Södra Bergundasjön) are interconnected and had large problems with eutrophication due to sewage discharges and low water renewal. Projects were therefore started to restore the lake quality and feasibility of different restoration methods were evaluated. The chosen method was suction dredging of bottom sediments and treatment of the removed sediments. The system is illustrated in Figure 1. Treated
clarified water was returned to the lake and removed sediments were used as fertilizer for parks.

![Diagram of the restoration technique.](image)

**Figure 1. Diagram of the restoration technique.**

(1) Suction dredger designed to operate with minimal turbidity and mixing, (2) sedimentation basin, (3) runoff water, (4) precipitation of phosphorus and suspended matter with aluminium sulphate, (4a) automatic dosage, (4b) aeration, (4c) sedimentation, (4d) sludge pond, and (5) clarified runoff water, (6) The dried sediment is used as fertilizer for parks. *Source: internal material from Växjö Municipality.*

Data for three restored lakes are shown in Table 1. *Source: internal material from Växjö Municipality.*

<table>
<thead>
<tr>
<th>Facts</th>
<th>Trumen</th>
<th>Växjösjön</th>
<th>Södra Bergundasjön</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total area</td>
<td>0.99 km$^2$</td>
<td>0.87 km$^2$</td>
<td>4.3 km$^2$</td>
</tr>
<tr>
<td>Depth before resto.</td>
<td>2.1 m</td>
<td>6.0 m</td>
<td>6.0 m</td>
</tr>
<tr>
<td>Depth after resto.</td>
<td>2.5 m</td>
<td>8.0 m</td>
<td>10.0 m</td>
</tr>
<tr>
<td>Costs</td>
<td>$400 thousand USD</td>
<td>$4.2 million USD</td>
<td>$5.3 million USD</td>
</tr>
</tbody>
</table>

*Storm water transport and treatment*

The central part of Växjö municipality cannot remove storm water in a safe way in certain parts of the central parts. The solution chosen was to construct a 230 m long channel (called Linne channel). The channel width varies between 9-12 m and the detained volume of the channel is 3000 m$^3$. Two culverts are connected with a diameter of 1.2 m to the channel supplying storm water from other areas. The channel is shown in

![Linne channel at different water levels.](image)

**Figure 2. Source: internal material from Växjö Municipality.**

**Figure 2. Linne channel at different water levels (left) high level, (right) low level**
The storm water is treated before discharge into the restored lakes (Lake Trummen, Lake Växjösjön and Lake Södra Bergundasjön). This is done by use of water ponds for flow equalization and sedimentation of suspended solids followed by constructed wetlands. This is shown for Bäckaslöv treatment system with one storm water pond and a downstream constructed wetland before discharge into Lake Bergundasjön (Figure 3).

Figure 3. Bäckaslöv treatment system for storm water.
*Source: internal material from Växjö Municipality.*

Effects of treatment of storm water by use of ponds for Lake Växjö for the concentration of phosphorus in the outlet are shown in Figure 4. A steadily decrease has been obtained since year 1985.

Figure 4. Concentration of phosphorus in the outlet from Lake Växjö.
*Source: internal material from Växjö Municipality.*

*Future water supply and treatment*

About 85% of the population in Växjö is connected to municipal water and wastewater systems (as in average in Sweden). The other part of the population has private alternative systems as wells for water supply, handling of toilet wastes in septic tanks or composting toilets and treatment of grey water by infiltration. The water source for supply of water to central parts of Växjö comes, since more than a century ago, from Lake Helgasjön. As its water quality has gradually declined due to
increased urbanization and industrial activities different methods have been evaluated to secure water supply with a high quality for the future. Based on seven different alternatives the chosen alternative was to use ground water from an esker and with the use of re-infiltration of ground water. This system will be implemented during the end of 2008 and it is estimated that the chosen system can supply water with a good quality to about 70,000 persons (Al-Najjar, 2007).

Wastewater treatment

A new wastewater treatment plant has been built to secure water quality in Lake Norra Bergundasjön and the river from the outlet (Mörrumsån). Effluent requirements as yearly average values were less than 0.2 mg P/l and 10 mg BOD₇/l and at least 50% nitrification. From a technical point, the phosphorus requirement is the most difficult to obtain and continuously operated sand filters (DynaSand) were installed as the last step and showed an efficient removal efficiency. Obtained degree of nitrification and nitrogen removal was 72% and 69%, respectively, during 2007. Higher efficiency on nitrogen removal may be needed in the future due to EU regulations.

References


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