

# STOCKHOLM WATER SUPPLY AND SEWERAGE

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Stockholm is the capital of Sweden. The heart of the city is built on 13 small islands at the junction where Lake Mälaren runs into the Baltic Sea. The Greater Stockholm area has approximately 1.4 million inhabitants. Approximately 650,000 people live in the city.

The Stockholm Water Company (Stockholm Vatten AB) produces and supplies drinking water to over one million people in Stockholm, Huddinge and the neighbouring municipalities (Ekerö, Haninge, Nacka, Tyresö, Lidingö, Botkyrka, Salem, Solna and Värmdö). The company also treats the wastewater of Stockholm, Huddinge and six neighbouring municipalities (Ekerö, Haninge, Nacka, Tyresö, Sundbyberg and Järfälla).

The majority of the Stockholm Water Company is owned by Stockholms Stadshus AB (91%); 7% is owned by the city of Stockholm directly and the remaining 2% by the municipality of Huddinge. The number of employees in the whole company is currently 645. The operations of the company are financed by drinking water and wastewater charges, and it has cooperative agreements with the waterworks of Riga, Kaunas and St. Petersburg. One of Stockholm Water's long-term aims is to receive ISO 14000 certification for the entire system by the year 2002.

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## I Water supply system

### System characteristics in 1998

People connected to network	1,079,500	
Water tariff	4.45	SEK/m <sup>3</sup>
Total volume of water charged	106.2	Mm <sup>3</sup>
Stockholm	79	Mm <sup>3</sup>
Huddinge	7	Mm <sup>3</sup>
Neighbouring municipalities	23.2	Mm <sup>3</sup>

Water production	121.8	Mm <sup>3</sup>
Norsborg	75.0	Mm <sup>3</sup>
Lovö	46.8	Mm <sup>3</sup>
Chemicals consumption		
Aluminium sulphate	3917	t/a
Lime	1365	t/a
Water glass	91	t/a
Ammonium sulphate	41	t/a
Chlorine gas	32	t/a
Sodium chloride	73	t/a

### **Water sources**

Lake Mälaren is the source of raw water. The water is purified at the Norsborg and Lovö waterworks. Lake Bornsjön is a reserve water supply of the Norsborg plant. Norsborg waterworks produces 60% of drinking water. It was built in 1903, at which that time it pumped water from Lake Bornsjön. In 1923 Lake Mälaren became the main water supply. 40% of Stockholm's water is produced at the Lovö waterworks, which was built in 1933 in the Drottningholm area.

### **Water consumption**

Water consumption has decreased constantly 2% per year in accordance with the general trend of energy and water conserving attitudes and equipment. At the same time, the population is growing 1% per year in the same area.

### **Water supply network**

The public water pipe network in Stockholm and Huddinge is 2200 kilometres long. The average time spent by the water in the network is theoretically 20 hours.

There were 364 leaks in water network in 1998, total amount was 10 Mm<sup>3</sup>. It is estimated that almost 1/3 of the leaks into sewage pipes involve drinking water.

The most common sewer pipe material is steel (88 %). Nodular iron (6 %), grey iron (5 %) and others (1 %) are not often used.

### **Water treatment**

The water purification process includes screening, chemical precipitation using aluminium sulphate, flocculation, sedimentation, rapid filtration and slow filtration. Lime, chlorine and ammonium sulphate are added to maintain good quality in the network.

1. Pumping station  
- takes the water from Lake Mälaren

## 2. Screening

- removes coarse objects, fish and aquatic plants
- after screening, aluminum sulphate is added to induce chemical precipitation at the next stage

## 3. Flocculation basin

- $\text{Al}_2(\text{SO}_4)_3$  is mixed into the water

## 4. Sedimentation basin

- precipitant is added
- the impurities form flocks and sink to the bottom

## 5. Rapid sand filter

- water goes through the rapid filter in about five minutes
- the filter consists of a 1-meter-thick sand layer
- removes even the smallest remaining flocks
- filters are equipped with modern control systems

## 6. Slow filter

- filtering in slow filter take two to three hours
- the slow filter purifies water biologically from micro-organisms, which could cause bad taste or odour

## 7. Clean water tank

- before water enters the tank chlorine is added to prevent bacteria from growing in the pipe network
- before water enters the tank lime is added to prevent corrosion and the precipitation of metals in pipes

## 8. Water reservoir

- pure water is pumped into water towers to maintain constant pressure

Sludge consists of approx. 50% aluminium hydroxide and 50% organic matter, with a small amount of lime sludge. Waste sludge is used as a soil improvement agent or in soil production (picture “ Use of sludge as soil improvement and in soil production in Stockholm”). Furthermore, about 1670 tons of sludge (dry matter) is pumped into Lake Mälaren per year.

## Water quality

Stockholm’s water is soft/medium-hard (5-6° dH). The quality of water is being monitored constantly.

	Raw water		Treated water	
	Norsborg	Lovö	Norsborg	Lovö
Colour index, Pt mg/l	18	19	<5	<5
Turbidity, FNU	1.8	1.4	0.04	0.05
pH	7.7	7.8	8.5	8.5
Conductivity, mS/cm	18.2	26	24.4	30.2
Alkalinity, $\text{HCO}_3$ , mg/l	45	71	49	74
Total hardness, mval/l	3.4	5.1	4.2	6.1
Aluminium, mg/l	0.05	0.081	0.02	0.023
Calcium, mg/l	17	26	23	34
Ammonium, mg/l	0.017	<0.01	0.04	0.05
Nitrate, mg/l	0.18	0.26	0.24	0.34
Nitrite, mg/l	0.003	<0.002	0.002	<0.002
Fluoride, mg/l	0.31	0.33	0.23	0.23
Chemical $\text{O}_2$ consumption, $\text{mgO}_2$ /l	5.4	5.9	2.4	2.9
Total organic carbon, mgC/l	6.3	7	3.7	4.1

Iron, Fe, mg/l	0.06	0.06	<0.03	<0.03
Coliform bacteria no/100 ml	20	15	<0.1	<0.1
Escherichia coli no/100 ml	5	4	<0.1	<0.1

## II Sewerage System

Stockholm's first wastewater treatment plant was taken into operation in 1934. Three plants, Henriksdal, Bromma and Loudden, are operating Nowadays in Stockholm today. The treatment is carried out in four stages: screening, chemical precipitation of phosphorus (with ferrous sulphate), biological treatment involving the removal of nitrogen and finally filtration. Treated wastewater is discharged into Lake Saltsjön, which is part of the archipelago and the Baltic Sea. In 1998 the amount of discharged wastewater was 151.6 Mm<sup>3</sup>.

The fourth treatment plant was built in Huddinge in 1998 to handle storm waters from the Huddinge road. It consists of a slow-flowing, meandering river (the Fullerstaån), a sedimentation reservoir to clean the storm water from the Huddinge road and the Kyrkdammen dam, which also serves as a rainwater storage facility.

### System characteristics

Sewerage system properties of Stockholm					
Discharged wastewater in 1998					
Stockholm				150.7	Mm <sup>3</sup>
SYVAB				137.8	Mm <sup>3</sup>
				12.9	Mm <sup>3</sup>
Total people connected to sewerage				1,016,802	p
Wastewater tariff				8	SEK/m <sup>3</sup>
	Unit	Hendriksdal	Bromma	Loudden	Total
People connected to network	%	67	30	3	n. 900,000
Wastewater flow	m <sup>3</sup> /d	242,000	117,000	12,700	371,700
Discharged wastewater in 1998	Mm <sup>3</sup>	89.8	43.5	4.7	138
	%	65	32	3	100
Overflow after screening	m <sup>3</sup>	12,000			
Quantity of dry matter	T	12,800	5600	900	19,300
Used chemicals:					
Ferrous sulphate	T	7100	2840	250	10,190
Polyaluminium chloride	T			127	127
Polymer	T	71.4	43	5.3	119.7
Sand and cleanings	T	2600	850	140	3590

### Wastewater network

Wastewater is led away largely with the help of gravity via the sewers to the treatment plants. A large number of pumping stations and storage facilities supplement the pipe system. The length of the sewerage, including storm water drains, is 3035 km. One third comprises wastewater pipes, one third storm water pipes and one third combined tunnels.

It is estimated that almost 1/3 of leaks into sewage pipes involve drinking water. Leaks in 1998 were about 35 l/min/km.

In 1998 there were 241 blockages in sewers and 283 blockages in sewer service pipes. The most common sewage pipe material is concrete (78%), followed by PVC (20%). The remaining 2% is not specified.

### Wastewater loading

<b>Wastewater loading in Stockholm, mean values 1998</b>			
<b>Hendriksdal</b>	<b>Influent</b>	<b>Effluent</b>	<b>Reduction, %</b>
Suspended solids, mg/l	240	2	99
BOD <sub>7</sub>	180	2	99
Total nitrogen, mgN/l	34	7	80
Total phosphorus, mgP/l	5.9	0.1	98
NH <sub>4</sub> , mgN/l	23	1	97
Nitrate, mgN/l		5.3	
COD <sub>Cr</sub> , mgO <sub>2</sub> /l	370	27	93
<b>Bromma</b>	<b>Influent</b>	<b>Effluent</b>	<b>Reduction, %</b>
Suspended solids, mg/l	190	2	99
BOD <sub>7</sub>	140	3	98
Total nitrogen, mgN/l	26	14	44
Total phosphorus, mgP/l	3.7	0.1	97
NH <sub>4</sub> , mgN/l	18	2	87
Nitrates, mgN/l		11.1	
COD <sub>Cr</sub> , mgO <sub>2</sub> /l		29	
<b>Loudden</b>	<b>Influent</b>	<b>Effluent</b>	<b>Reduction, %</b>
Suspended solids, mg/l	200	7	96
BOD <sub>7</sub>	180	6	97
Total nitrogen, mgN/l	35	40	43
Total phosphorous, mgP/l		0.02	
NH <sub>4</sub> , mgN/l	25	6	76
Nitrates, mgN/l		13	
COD <sub>Cr</sub> , mgO <sub>2</sub> /l		40	

The annual overflow (wastewater flow without treatment) was under 0.25 % of the total amount of wastewater (150 Mm<sup>3</sup> in 1998).

Stockholm Water produces and consumes energy. Its total energy turnover amounts to 2100 GWh. Most of this is represented by the energy content of the wastewater (heat and organic material). Actual energy consumption is slightly more than 200 GWh/year, of which 95 GWh is bought, the rest is produced internally. 12 % of the electrical energy consumed is produced at the Henriksdal combined power and heating plant. Its electricity generators are powered with biogas. 60% of heating requirements at the sewage plants are met by biogas. The rest is met by utilising waste heat from blowers and combined power and heating plants, as well as by the heat recovered from the heat exchangers.

The flow chart of each wastewater treatment plant is as follows:

#### 1. Screening

- separates solid material up to even small waste particles

#### 2. Grit removal

- sorts out smaller but relatively heavy particles like sand and coffee grounds
- the amount of matter from screening and grit removal was 3360 tons in 1998
- after treatment,  $\text{Fe}_2(\text{SO}_4)_3$  is added to induce precipitation of phosphorus 11-20 gFe/m<sup>3</sup>.

#### 3. Pre-Aeration

- water is aerated to mix the ferrous sulphate well

#### 4. Primary sedimentation

- most of the phosphorus is removed: ferrous sulphate causes the phosphorus to precipitate as solid particles and sediment on the bottom
- sludge is taken to sludge treatment

#### 5. Bioreactor phase – Anaerobic tank

- the nitrate-rich wastewater is mixed with active sludge, which contains micro-organisms
- micro-organisms convert the nitrate nitrogen into nitrogen gas, which is ventilated out

#### 6. Bioreactor phase – Aerobic tank

- air is added in the aerobic tanks
- micro-organisms are nourished by the residual organic matter in the wastewater
- the nitrogen is also converted from ammonium nitrogen to nitrate nitrogen

- the nitrate-rich water is pumped over to the anaerobic tanks

#### 7. Secondary sedimentation

- in secondary sedimentation the sludge containing micro-organisms and phosphorus drops to the bottom because the flow is so slow
- the water becomes almost completely free from solid pollutants
- part of the sludge is returned to the anaerobic tank to maintain the suitable micro-organism culture
- excess sludge is led to the mud-thickening phase

#### 8. Deep-bed sand filter

- the wastewater passes a filter that consists of expanded clay and sand
- the flow rate is under 10 m/h
- the biological process continues in the filter, and a small amount of ferrous sulfate is also added to filter and remove any remaining phosphorus

#### 9. Heat pump

- the heat stored in the treated water (+15 °C) is recovered by heat pumps of Stockholm Energy
- heat is used in the city's district-heating network

The discharge pipe is in Lake Saltsjö, which is a part of the Baltic Sea. The discharge depth is 30 metres. Wastewater rises up to level of 10-15 metres and then forms an outgoing current.

### **Sludge treatment**

#### 1. Mud thickening

- excess mud from the secondary sedimentation is fed to mud thickening (the rest goes to the centrifuge or back to aeration)

#### 2. Centrifuge

#### 3. Sludge tank

#### 4. Digestion

- part of the organic content of the sludge is degraded in the digester
- the digestion tanks contain propeller agitators to boost the reaction
- forming biogas (methane) is collected into gasholders
- methane is used as fuel in the wastewater treatment plant's boilers: the treatment plant is almost self-sufficient in meeting its heating requirements
- gas can be also used to produce electricity and as fuel for cars (Bromma)

#### 5. Sludge storage

- digested sludge is stored

#### 6. Sludge dewatering

- in dewatering, the water content of the sludge is reduced again
- after dewatering, some polymer is added to the sludge

#### 7. Centrifuge

- reduces the volume of sludge and facilitates transportation
- centrifuging reduces the sludge to only 5 % of its original volume; the moisture content is the same as in moist soil.

#### 8. Sludge silos

- dry sludge is stored in sludge silos
- sludge is used to improve soil if its metal content doesn't exceed allowable limits