

Waste Water Treatment In Sweden



Himmerfjärden Wastewater Treatment Plant

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Abstract

The aim with this report is to describe wastewater treatment in Sweden in general and also specific the techniques used at Himmerfjärden wastewater treatment plant.

In the beginning wastewater treatment was a question about health in the towns but from around 1950-1960 the environmental problem started to be visible. Today mechanical treatment as well as treatment of biological oxygen demand (BOD) phosphorus and nitrogen is used.

Most Swedes are connected to a public wastewater treatment plant and of these 36% have the highest level of treatment, nitrogen treatment. About 1 million people have private treatment.

To let out wastewater is defined as ecological harmful activity and the laws defined in the environmental code have to be followed. There are also EU-regulations that are the same for the whole EU. Today regulations for how to handle the sludge are needed.

Himmerfjärden wastewater treatment plant is modern plant with full treatment. It serves about 250 000 persons in Stockholm's suburbs. Phosphorus is treated chemical, BOD and nitrogen biological.

Keywords: wastewater treatment plant, Sweden, himmerfjärdsverket, regulation, environment, BOD, phosphorus, nitrogen

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1 Introduction

Wastewater has been a problem since people moved to cities. In that time it was a question about health. The wastewater piping that was built only leads the water from the town to the closest watercourse. Later problems in the watercourse occurred. The fish died and the lakes became overgrowth. It was necessary to treat the water before letting it out.

Today the rights of letting out wastewater are regulated. Sweden has been and still is successful in wastewater treatment and the rules are the hardest in the world. But that does not mean that the problems are solved. Still more research is needed to figure out what kind of treatment the environment demands.

The aim with this study is to describe wastewater treatment in Sweden. What the regulations look like and how the treatment is made today. Problems and some possibilities are discussed, and a study of an existing wastewater treatment plant, Himmerfjärdsverket, close to Stockholm is made.

2 History of waste water treatment in Sweden

The problem with wastewater in Sweden started, like in all other countries, in the towns in the 18th century. To start with the problem was to dispose the waste to avoid sanitary problems.¹ During second half of 19th century building of the water supply system started. With the increasing use of water the need of sewage piping also increased but the development was slow. It was not before some towns got problems with cholera from drinking water building of sewage really increased.²

Most of the sewage piping ended in the harbour or in the channels within the city and this caused sanitary problem as well. In the year 1920 all Swedish towns had sewage piping,

¹ Augustinsson H 2003

² Svenskt vatten 2005

but only one had wastewater treatment plant that removed big particles in the sewage.³ In 1950:s biological treatment started to reduce bad smell. In the year 1955 only every fourth town in Sweden had some kind of wastewater treatment plant. The same year a law came that said that all municipalities has to take care of their sewage in waste water treatment plants, but it took a long time to make it reality.⁴

Tätorternas avloppsrening 1940–2000

Municipal wastewater treatment in Sweden, per cent of the urban population

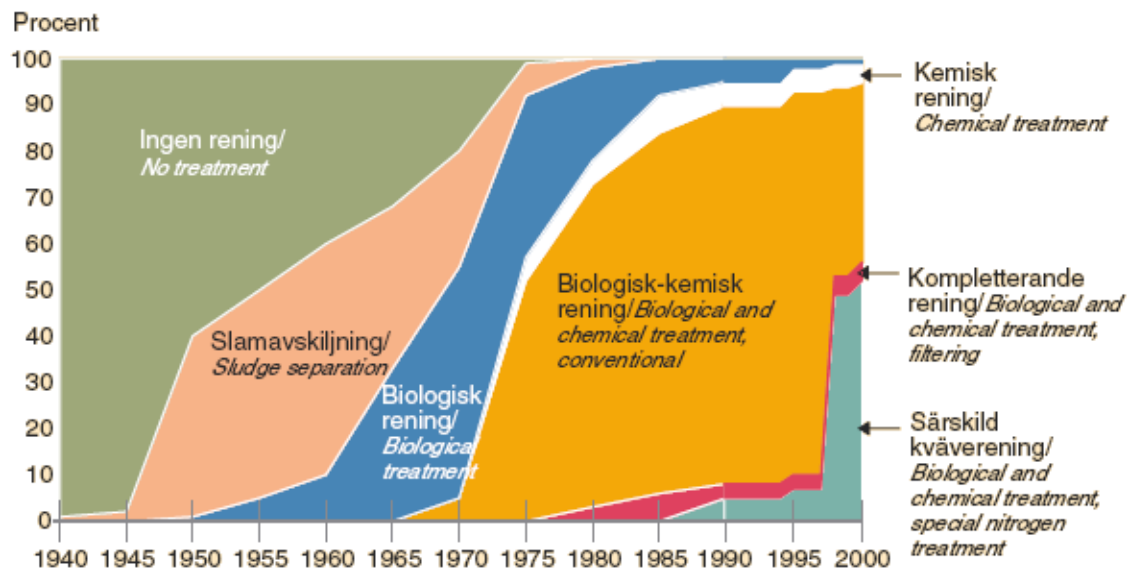


Figure 1: Municipal waste water treatment in Sweden 1940-2000, percent of urban population (source: Swedish Environmental Protection Agency)

Until the 1960s wastewater treatment was only a question about health and sanitary for human beings, but in the sixties the environmental problem started to be visible.⁵ The increased amount of nutrients in the seas made them overgrowth and the fish died. The problem was the big amount of phosphorus in the water. In the 1970s the government gave financial aid to the municipalities for building better waste water treatment plants that also included chemical treatment for phosphorus. In just a few years the water quality in the recipients got much better.

³ Augustinsson H 2003

⁴ Augustinsson H 2003

⁵ Widell, A 2003

In the middle of 1980 a new problem with over fertilization occurred.⁶ This time the problem was in the Baltic Sea and not in the small lakes. The problem was nitrogen that caused for example algal bloom. The building of nitrogen treatment started and today all big wastewater treatment plants close to the coast has nitrogen treatment. In figure 1 you can see the historical development of wastewater treatment in Sweden from 1940 to 2000.

3 Modern waste water treatment

Sweden has about 2000 public, often municipal, wastewater treatment plants.⁷ Totally they treat 1.5 km³ water every year. That is about twice as much as the drinking water reaching the consumers. The rest of the water is from drainage, surface water, and leakage. All Swedish citizens living in an urban area, which is about 7.7 million people, is connected to one of these wastewater treatment plant. The rest of the population, 1.3 million, has private treatment.

36 % of the population, with public treatment, has the highest level with biological, chemical, and nitrogen treatment. The majority, 58 % has chemical and biological treatment and the remaining 6 % has biological or chemical treatment.⁸ Today the pollution of Swedish water areas from wastewater is on the same level as 100 years ago, and the rules for discharge of wastewater is the hardest in the world.

The biggest problem in Sweden is private wastewater treatment and treatment in small plants for less than 2000 persons.⁹ Many of these plants have insufficient treatment and some old buildings in the countryside have no treatment at all. New built houses need permission for the wastewater treatment, but the rules for this treatment are not final yet. The biggest problem with private treatment is phosphorus. Most of the phosphorus from

⁶ Svenskt vatten 2005

⁷ Svenskt Vatten (general)

⁸ Svenskt Vatten (general)

⁹ Swedish environmental protection agency 1

wastewater comes from private treatment, even if it is just a small part of the total water. A big source for phosphorus is detergent, and one solution can be to forbid detergent containing phosphorus in these houses.

3.1 General laws

To let out waste water is in Swedish law defined as ecologically harmful activity, and therefore has to follow the laws defined in *the environmental code (miljöbalken)* which contains all laws related to the environment. Connected to the environmental code are statutes and regulations. There is also a law called “*VA-lagen*” (water and sewage law) saying that all municipalities have to take care of water supply and waste water treatment for the urban areas.

The environmental code is a collection of laws related to the environment. The main purpose is to promote sustainable development so upcoming generations get a healthy and good environment.¹⁰ Sweden also has defined 16 global environmental goals for protection of the environment. Examples of these goals related to water are: no over fertilization, non-poisonous environment, ground water of good quality and living seas and watercourses.¹¹ The environmental code and the environmental goals together rule the environmental issues.

The environmental code has a part called *general consideration rules*. The person responsible for an activity, for example a wastewater treatment plant, has to take these rules into account.¹² The rules say briefly that you should be informed about what harm your activity can cause, both to human beings and to the environment. You should use the technology that is best for the environment. You should husband raw materials and energy, reuse and recycle as far as possible and use renewable energy sources. You should also locate your activity to the best area to do not harm humans or nature.¹³

¹⁰ The environmental code 1 chap 1 §

¹¹ Swedish environmental protection agency 1

¹² The environmental code 2 chap

¹³ The environmental code 2 chap

To run a wastewater plant that is bigger than 2000 personal equivalents you need permission. In the permission is stated how much water the plant is allowed to take care of and how much they can let out of phosphorus, biochemical oxygen demand and nitrogen. These values are set individual depending on the quality of the recipient and they are mostly only recommended values. Average values in Sweden are 0.5 mg/L phosphorus and 15 mg/L BOD. For Nitrogen the level is 15 mg/L for treatment plants close to the coast that serves 10 000 to 100 000 persons. For bigger plant the value is 10 mg/L.¹⁴ Swedish waste water treatment plants has no problems with the limits for phosphorus or BOD but the nitrogen level is harder to reach, because of more sensible treatment. In table 1 is total amount of phosphorus, nitrogen and BOD, both in and out and percentage of purification listed. The numbers are valid for year 2002 (within brackets year 2000) and includes all wastewater treatment plants in Sweden bigger than 2000 personal equivalents.

Table 1: total in and outlet of nutrients to swedish waste water treatment plants bigger than 2000 pe. Year 2002 (2000).¹⁵

	Phosphorus	Nitrogen	BOD
Tons in	7 090 (7 743)	40 999 (41 296)	208 201 (213 923)
Tons out	351 (424)	18 036 (18 977)	8 158 (9 784)
% purification	95 (95)	56 (54)	96 (95)

Since 1994, when Sweden signed the EES agreement, EU laws have to be followed. According to EU-directive, all wastewater from urban areas has to be treated at least secondary, i.e. biological treatment. You also have some quality demands for the water.¹⁶

Sweden has hard laws for wastewater treatment, so the EU-directive should not be hard to follow, but there is some disagreement in the interpretation of the rules. A part of the problem is that Sweden and EU has different ways to work with these questions. In Sweden the most important is not to reach a limit value for the treated water, but to see

¹⁴ Öberg, S 2004

¹⁵ Öberg, S 2004

¹⁶ Swedish environmental protection agency 3

what damage on the environment the water might cause. On a EU level the numbers are more important and it is also easier to administrate. There is also a question about definitions where Sweden and EU do not agree.¹⁷

4 How to treat wastewater

In general wastewater is treated in three ways: Mechanical, biological and chemical. The mechanical step removes big particles like condoms, sanitary napkins, cloth and other thing that do not belong in the sewage and have to be removed to not destroy the technical equipment. Also smaller particles like sand that easy can be sedimented are removed mechanically. Biological treatment reduces biological oxygen demand (BOD) and nitrogen, things that are solved in the water. Chemical treatment is used mainly to reduce phosphorus. Some of the poisonous matters and heavy metals are separated with the sludge.

4.1 Biological treatment of BOD

Biological oxygen demand, BOD is usually organic substances that is solved in the water and therefore not possible to reduce by sedimentation. It is important to reduce BOD because if not, the decomposition of this matters use all oxygen in the recipient and the growth of other organisms are limited. In the Baltic Sea this problem has been so serious in some places that the seabed is dead because of no oxygen.

In the wastewater treatment plant BOD is decomposed by bacteria to carbon dioxide and water. To make this efficient the water is mixed with air, containing oxygen. The bacterium works best in temperate water, so the treatment works best in the summer and in the south part of Sweden. In north part biological treatment is not used, because it is hard to make it working and its not really needed because of small population and big, turbulent water flows. To install biological treatment in this part would cost very much money and probably not do any improvement on the environment¹⁸

¹⁷ Bjurhall, R 2004

¹⁸ Bjurhall, R 2004

The EU regulations for biological treatment says that all waste water treatment plants located lower than 1500 meters above sea level should have biological treatment. Above 1500 m it is colder and hard to use biological treatment and therefore the exception. This definition is not so good because it is the temperature and not the height that determine if biological treatment is possible or not. In north part of Sweden it is much colder than in for example the Alps, but it is not so high above the sea level. Sweden interpret this rule as “above 1500 meters or comparable” and means that biological treatment is not needed in this area.¹⁹

4.2 Phosphorus treatment

Phosphorus treatment started in the 70s because of the overgrowth in lakes. Phosphorus is an important fertilizer for all plants, and in lakes and other fresh water phosphorus is limited for the growth. If more phosphorus is added, more growth will occur. This is the reason why phosphorus treatment is so important. Today all water in Sweden is defined as sensitive for phosphorus and the regulation is hard. The limit in treated water is 0,3 – 0,5 mg/L, compared with the EU regulation saying 1-2 mg/L.²⁰ The average outlet in Sweden is 0.3 mg/L.²¹

The treatment is usually chemical. You add a metal salt for example aluminium- or iron salt. These salts bind the phosphor and can be separated by sedimentation. A new way to treat phosphorus biological is used in some cases, but it is still hard to control. The idea is to alternate aerobic and anaerobic environment for the bacterium that will take up phosphorus. The bacterium with the phosphor is separated with sedimentation. The advantages with this treatment are that less chemicals is used and less sludge is produced. The problem is that it is still hard to regulate.²²

¹⁹ Bjurhall, R 2004

²⁰ Bjurhall, R 2004

²¹ Öberg, S 2004

²² Krizanac E, 2005

4.3 Nitrogen treatment

For about 20 years ago, the problems with overgrowth caused by nitrogen become visible. In salt water nitrogen and not phosphorus is the limiting nutrient. Sweden has nitrogen treatment at all big waste water treatment plants close to the coast from the border to Norway to Dalaälven, about half of Sweden's coast in Baltic sea. Further north in the Baltic Sea there is no use of nitrogen treatment because only phosphorus is limiting the growth. The same in Sweden's inland.²³

Nitrogen treatment is usually biological. The bacterium decomposes ammonium to nitrate and then to nitrogen gas that is emitted to the air. The first part, nitrification is aerobic and takes usually place in the tank where COD is treated. The second part, denitrification, is anaerobic and takes place in the next tank.²⁴

When it comes to nitrogen treatment Sweden and EU have different points of view. First of all EU do not distinguish phosphorus and nitrogen when it comes to sensitivity for over fertilization, and according to this all watercourses in Sweden are sensible for nitrogen because they are defined as sensible to phosphorus. EU also thinks that nitrogen treatment is needed in the whole Baltic Sea and not only in the south parts. Sweden also means that treatment in the inland is not needed because the level of nitrogen will decrease on the way to the Baltic Sea because of sedimentation and biological activity. EU doesn't like this idea either because it is hard to prove that the level is decreased.²⁵

4.4 Which treatment is more important, nitrogen or phosphorus?

Since the problem with nitrogen became visible, Sweden has spent a lot of money on nitrogen treatment. The phosphorus treatment was already very good so the nitrogen treatment was considered the biggest problem. Lately a big discussion if it is right or not has started. Some scientist mean that the whole Baltic Sea should be considered as fresh water and therefore more sensitive to phosphorus and much of the money spend on

²³ Bjurhall, R 2004

²⁴ SYVAB 2

²⁵ Bjurhall, R 2004

nitrogen treatment is wasted. On the west coast where the water is saltier there is no doubt that nitrogen treatment is effective.²⁶

One of the problems with overgrowth in the Baltic Sea is algae bloom in the summer. These organisms have an advantage that they can use nitrogen in the air, so some scientists means that the level of nitrogen in water is not so important, but only the phosphorus. Some experiments with nitrogen treatment have been done in Himmerfjärden wastewater treatment plant (the one studied later on). These experiments show that nitrogen treatment has been effective and the quality of the water in the recipient has increased. Critics say that these experiments are not a good example, because there has never been a big problem with over fertilization in the part of Baltic Sea where the plant is located. Other experiments has been done on other places, also with good result, but here critics says that the level of phosphorus has been lower too so they mean that the nitrogen treatment gave no effect. The discussion will go on, and we have to wait for the conclusions.²⁷

4.5 Sludge problem

One problem with wastewater treatment is to make the water as clean as possible. The next problem, that can be just as hard as the cleaning, is to take care of the sludge produced. Every year about 1 000 000 ton sludge is produced in public waste water treatment plants in Sweden. This sludge contains a lot of nutrients, for example 2.8% phosphorus and 3.8% nitrogen, and this sludge is a good fertilizer on fields. This is the best use for the sludge from an ecological and recycling point of view but the problem is that the sludge contains other substances, like chemicals and heavy metals, which can be harmful in big amounts.²⁸

Swedish environmental protection agency has defined limits for different substances in the sludge for spreading on fields for food production. Today at least 55% of the sludge from public wastewater treatment plants is below these limits, but the use is still

²⁶ Nilsson, A 2005

²⁷ Nilsson, A 2005

²⁸ Swedish Environmental Protection Agency (2)

controversial in many cases.²⁹ Today we use so many chemicals and we don't know what harm they might cause in a longer time, or in which amounts they are not harmful. In 1999 there was a discussion about flame retardant containing bromine and for a while sludge was not used on the fields. In the future more discussions like this can be actual.³⁰ Before the discussion about flame retardant started as much as 20 % of the sludge was used on the fields, but today it is about 10%. The rest is treated and used in other ways, because since 2005 it is illegal to deposit organic matter so all Swedish wastewater treatment plants have to make something with their sludge.

Before the sludge can be used for anything, it has to be stabilized. The numbers of microorganisms are reduced and also the amount of easily decomposed organic matter. This can be made in bioreactors that produce biogas. The sludge contains a lot of water, so it needs to be dried somehow. Depending on what you should use the sludge for, you need to dewater it more or less.

It is hard to find out how the sludge is used because it is changing often and there is a lack of data about use and quality. Most of the sludge is used to make soil for golf courses, planting, etc. This soil is not used for producing food so its use is not controversial. Another use is to fertilize energy forest. Some of the plants can actually clean the soil from heavy metals and other harmful substances, which make it possible to use the land for food production later. It is also possible to fertilize "real" forest but it is not widely used yet. In some places burning of the sludge is used for distance heating and it is also possible to use the ash as fertilizer. Many public wastewater treatment plants need to find a long lasting solution for the sludge but they don't want to spend so much money yet because the regulations and recommendations from authorities are not final.

²⁹ Öberg, S 2004

³⁰ Augustinsson, H 2003

5 Himmerfjärden Waste Water Treatment Plant

To describe more in detail how wastewater is treated in Sweden today a wastewater treatment plant is studied. The name is *himmerfjärdsverket* (Himmerfjärdens waste water treatment plant) and is located close to Stockholm. The plant treat water from some of Stockholm's west suburbs and about 250 000 persons and 35 000 pe from industry is connected. A company, SYVAB that is owned by the six municipalities that is connected, runs the plant. The plant started its activities in 1974 and today it is a top modern complete wastewater treatment plant with an average flow of 110 000 m³/d.³¹



Figure 2: Area of uptake and transportation tunnels to the wastewater treatment

Source: Himmerfjärdsverketplant

Because let out wastewater is an ecologically harmful activity, the company needs permission according to the environmental code. Himmerfjärdsverket has permission to let out treated wastewater from the communities, not more than 130 000 m³ per day (average). The treated water must not contain more than (annually mean values) 15 mg/l BOD, 0.5 g/l phosphorus and 15 mg/l nitrogen. For year 2003, 101 000m³ per day was treated. The incoming water contained 167.5 mg/l BOD, 6.2 mg/l Phosphorus and 35 mg/l Nitrogen. The treated water contained 6.7 mg/l, 0.31 mg/l respectively 4.1 mg/l.³²

³¹ SYVAB 1

³² SYVAB 2004

5.1 Description of the water treatment ³³

In figure 3 you can see a schematic picture of the wastewater treatment plant. The water runs through tunnels to the plant. In figure 2 you can see this tunnel system. The tunnels end up in a rock shelter 50 m under ground. Here all particles bigger than 20 mm are separated with bar screens and are deposited. Ironsulfide is added to the water to coagulate phosphorus. Then the water is pumped up to the surface. At the surface the sand trap is located. It separates sand and other heavy materials. The sand is washed to separate organic matter, and then it is deposited. After the sand trap is the fine bar screens that separate particles bigger than 2 mm. These are also deposited. Totally 677 ton is deposited every year. Of this 22 ton is sand. The rest is anything from sanitary napkins and condoms to cloth and toys. The treatment this far is mainly to protect the technical equipment. The sand and the particles from the bar screens are not biological and can therefore be deposited.

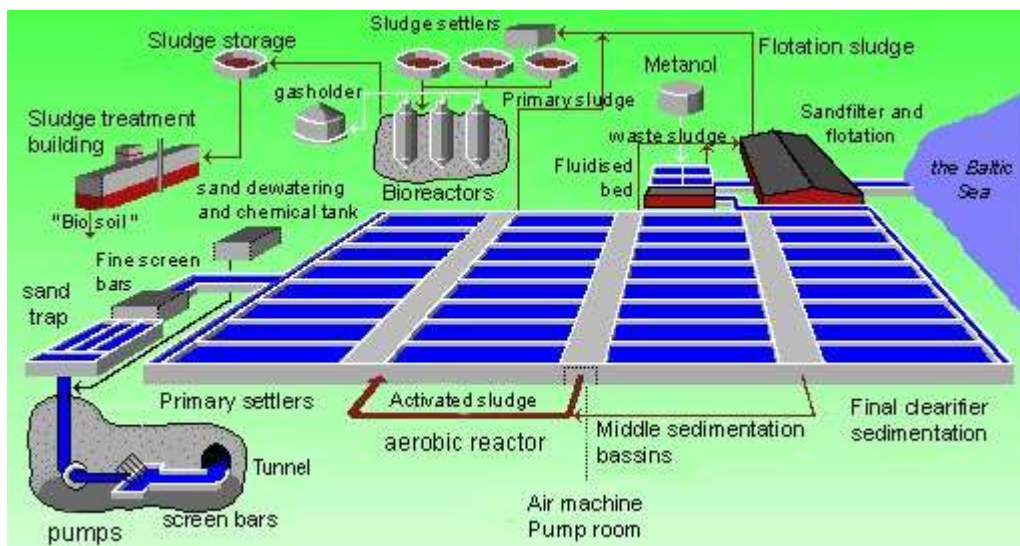


Figure 3: Schematic picture of Himmerfjärdsverket (source: himmerfjärdsverket)

Next step in the treatment is sedimentation. In the eight primary settler basins about half of the non-dissolved organic matters and half of the phosphorus are separated. Rakes on the bottom remove the primary sludge and it is pumped to the sludge settlers. After the sedimentation there is time for biological treatment. In the tanks sludge with bacterium eat the biological matters that is solved in the water. The process is aerobic and therefore

³³ SYVAB 2

a pump blows in fine air bubbles at the bottom of the tank. The air is regulated so it will always be enough oxygen to treat the water. The microorganisms produce carbon dioxide and water and they also make the first step in the nitrogen treatment by changing ammonia to nitrate.

After the biological treatment, the active sludge needs to be separated and pumped back to the active tank. This is made in middle sedimentation basins and in final clarifier sedimentation. Because there is always growing more and more bacterium, some of the sludge is separated and pumped to the floatation building. The water continues to the fluidised beds where denitrification takes place. Bacterium takes care of this treatment as well, but it is an anaerobic process with no oxygen. The bacterium grows on small sand grains that are floating in four tanks. To make sure these don't fall down to the bottom, the water is added from the bottom and flows up with high speed. The bacterium needs food, but all organic matter is already decomposed and therefore methanol or ethanol is added. The produced nitrogen gas is released to the air.

The water reaches the last step in the treatment, the sand filter, where the last particles are separated. The filters are about 70 cm thick and contain three layers, rough, finer and, at the bottom, the finest. The 10 filters are back flushed regularly and the flush water is pumped to the floatation building. In the floatation building oxygen-saturated water is pumped into the dirty water. Small air bubbles are released and bring the pollutants to the surface, where they are separated and pumped to the sludge settlers. The remaining water is pumped back to a special part of the sand filter.

The purified water is released in the Baltic Sea at 25 meters depth. The whole treatment takes about 20 hours and separates 90% of nitrogen, 95% of phosphorus and 97 % of BOD. Totally 150 ton nitrogen, 11 ton phosphorus and 250 ton BOD is released every year to the recipient.

5.2 Sludge treatment³⁴

The first step in sludge treatment is the sludge settlers. The sludge is dewatered and the result is 96% water in the sludge. Then the sludge is stabilized in the bioreactors. The reaction is anaerobic and the bacterium produce biogas (carbon dioxide and methane). This gas is used for heating of the reactors and the buildings and also for drying of the sludge. The reaction takes place at 55 °C to get the sludge more hygienic. At that temperature harmful organisms are killed.

After the bioreactor, the sludge is stored before going to the sludge treatment building. Here the sludge is dewatered in sludge centrifuges and sludge driers. After the centrifuge the sludge contains 72-74 % water and after the driers only 10-20 %. The separated water is brought back to the sand trap and treated again. The remaining sludge is called *biosoil*. In year 2003 26 000 ton biosoil was produced (6100 ton dry substance) Most of the biosoil is used to cover land areas for parks, cover of deposits etc, but SYVAB is looking for alternatives. In 2003 80 % was used to cover land areas, 20 % was deposit, 1,5% was used for tests of fertilizing forest and 0,5 % was burned, also as a test. The sludge could not be used as fertilizer on fields because of too much Zinc.³⁵ This problem might be solved if the zinc source is found, and the water is treated at the source and not when it reaches the plant.

6 Conclusions

Wastewater treatment in Sweden is good, especially the public treatment. Private treatment is still a problem that needs to be solved. In Sweden the recipient decides the treatment needed. To improve the treatment more research about the effects in the recipient is needed, especially on medicine and other chemical substances we don't know so much about. The easiest way to solve the problem with chemicals is to never let out these substances in the sewage and here information to the public and to industries is important.

³⁴ SYVAB 2

³⁵ SYVAB 2004

The laws in Sweden regulates the outlet of waste water good, but it needs to be harder for private treatment, and it also needs to be fully implemented with the EU-rules. There is also a need for clear rules about how sludge should be treated. Here both rules and research is needed to find a long lasting solution. The best use is to fertilize fields with the sludge, but because the sludge contains some harmful substances it is not so common today. Most of the sludge is used as soil, but for golf courses and covering of old mines and other that is not used for food production.

Himmerfjärden wastewater treatment plant is a big, modern plant with mechanical treatment and treatment of BOD, phosphorus and nitrogen. The result of the treatment is good and more that 90 % of the substances are reduced. The sludge is a problem that needs a lasting solution. Today it is treated to get biogas for the plant and the rest is used mostly for soil production.

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