KALMAR ECO-TECH'03
Bioremediation and Leachate Treatment
KALMAR, SWEDEN, November 25-27, 2003

PHYSICAL AND CHEMICAL TREATMENT OF LANDFILL LEACHATE - RECYCLING OF NITROGEN

Leif W Linde
Eskilstuna Energi & Miljö AB, Sweden

ABSTRACT

This paper presents a new type of plant to treat leachate from a municipal landfill. The plant is situated in Eskilstuna (pop. 90 000) a town-situated approx. 110 km west of Stockholm.
The main purpose of the plant is to reduce nitrogen, phosphorus, COD and heavy metals in the leachate from the Lilla Nyby landfill in Eskilstuna. Lilla Nyby landfill is a municipal landfill, which has been used for nearly 50 years to deposit industrial and municipal waste from the Eskilstuna community.
A drainage system in the landfill collects the leachate which is stored/equalized in a basin with a maximum volume of 40 000 m^3. The yearly amount of leachate is about 120-160 000 m^3. The leachate is pumped to the treatment plant.

The demands of the authority to meet are as follows:
NH3 (ammonium nitrogen) < 25 mg/l
COD < 200 mg/l
Total phosphorus (tot-P)< 0,3 mg/l
The normal composition of the untreated leachate is
NH3 (ammonium nitrogen)e~ 250 mg/l
COD ~ 400 mg/l
Total phosphorus (tot-P)~ 1,0 mg/l

Thus it is necessary to reduce the ammonium nitrogen with ~90% and COD with ~50%.

A request of a total tender with function warranty was made 2001.
6 contractors offer tender, 3 tenders are judged to be interesting, Pronea, Läckeby and Stork Engineering. Pronea offers chemical precipitation+ammonia-stripping/ absorption+activated coal-filtration, Läckeby offers SBR-treatment alt. NF+ ammonia-stripping/ absorption and Stork offers evaporation or reversed osmosis RO).

After a technical/economical evaluation the Pronea offer was considered to be the most interesting and was purchased. The process produces a useful chemical, ammonium sulphate, which can be used as an additive to the bio fuelled (wood chips) boiler in Eskilstuna. Two useful results will be reached: 1) The corrosion in the furnace caused by alkali metals will be reduced and 2) the ammonia additive to reduce NOX in the flue

https://doi.org/10.15626/Eco-Tech.2003.023

gases can be reduced.

The plant works as follows:

- Leachate is pumped to the plant (dim. capacity 20 m^3/h)
- Reduction of pH to 3 with sulphur acid and CO_2-stripping (reduce the buffer capacity)
- Rise of pH to 11,0 with sodium hydroxide and precipitation with ferric chloride ($FeCl_3$). Dosage of polymers to enhance the build up of flocks.
- Flock separation in lamella separator
- Further flock separation in continuous sand filter
- Rise of temp. to 50-60 0C through heat exchange
- Ammonia-stripping + ammonia-absorption
- Filtration in activate coal filter + pH-adjustment

Nitrogen in the leachate (ammonium nitrogen) together with sulphuric acid forms ammonium sulphate, at a concentration of 40%
The plant is not yet approved and taken over by the purchaser. Much work has been needed to trim the process in the plant.
A lot of problems have appeared and been solved. Some examples of the most essential items:

- Foam forming after the CO_2-stripper
- Transport of water drops from the ammonia-stripper to the ammonia-absorber
- Break down of process pumps for leachate (carbonate deposits), dosage pumps and valves
- Leakage of sulphuric acid and sodium hydroxide
- Sludge escape from the lamella separator (bad separation)
- Clogging in heat exchangers and stripper tower(carbonate deposits)
- Wrong placed flow meters

Preliminary results are:

- At least 90% ammonia reduction is possible
- Good phosphorus- and metal reduction
- If approved COD-reduction can be reached is still to be proved
- Good quality of produced ammonium sulphate
- The need of chemicals and energy yet to be evaluated

KEYWORDS

Leachate treatment; Landfill; Municipal waste; Nitrogen removal; Sweden.

1 INTRODUCTION

Eskilstuna is the chief town in Eskilstuna Municipality (90.000 inhabitants) and is situated about 110 km west of Stockholm. The biggest landfill for municipal waste is situated 6 km east of downtown Eskilstuna and named Lilla Nyby. The landfill has been used since 1956 and municipal waste from households and industries has been disposed. Because of existing industries in Eskilstuna working with metals (galvanic technical industries) sludge with heavy metals and other waste from these industries have been disposed causing content of heavy metals in the leachate.
Organic matters in the landfill (mainly from household waste) are digested and among other things form methane, CH_4, and carbon dioxide CO_2. The landfill gas has been collected with a system of vertical gas wells and used as a fuel for a gas engine producing electricity to the grid and heat to the district heating system since 1994.
The total area of the landfill is about 34 hectares and about 4-5 million tons of waste has been disposed since 1956. A drainage system in the landfill collects the leachate which is stored/equalized in a basin with a maximum volume of 40 000 m3. The basic design of the landfill Lilla Nyby is shown below (fig.1):

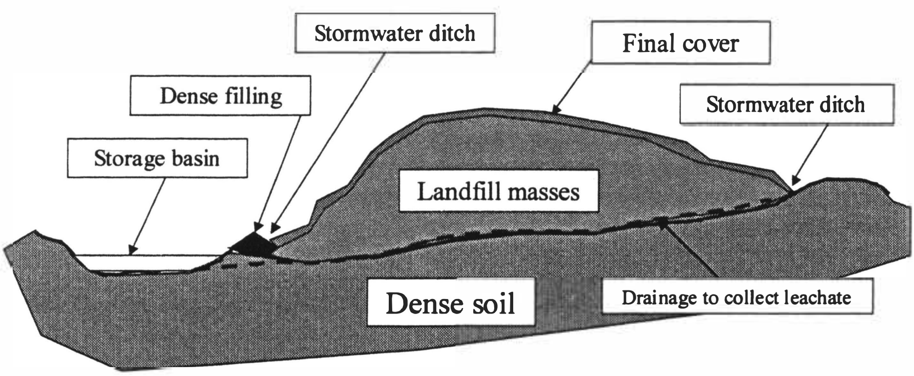


Figure 1 Basic design of Lilla Nyby landfill

The yearly amount of leachate is about 120-160 000 m3. The leachate is pumped to the treatment plant.

A normal composition (average values) of the leachate is shown down (input):

Parameter	Unit	Dim input	Demand output
Conductivity	ms/m	500	-
PH		7,1	?
COD	mg/l	400	200
BOD_7	mg/l	30	10
Total nitrogen	mg/l	250	75
Ammonium nitrogen	mg/l	250	25
Total phosforus	mg/l	1,0	0,3
Cloride	mg/l	500	-
Alkalinity HCO_3	mg/l	2000	?
Iron	mg/l	50	5
Manganese	mg/l	2,0	-
Copper	µg/l	75	5
Zink	µg/l	400	75
Crom	µg/l	15	20
Nickel	µg/l	50	50
Lead	µg/l	20	5
Cadmium	µg/l	1,0	0,3
Mercury	µg/l	0,1	-
Phenol	mg/l	0,1	-
Coliform bact.	antal	-	<10 000 pcs/100 ml
E-coli	antal	-	<1000 pcs/100 ml
Fecal strept.	Antal	-	<300 pcs/100 ml

Eskilstuna Energi & Miljö AB, a company 100% owned by the Eskilstuna community is responsible for operating the Lilla Nyby landfill. Since the collecting system of leachate was built (more than 30 years ago) the leachate has been pumped the sewage treatment plant (STP) Ekeby in Eskilstuna without causing any special operating problems to the STP. However the local environment authority and the country board decided 1999 that a local treatment plant for the leachate should be built at the landfill. The company appealed this decision, first at the Environment Court (Miljödomstolen) and later at the Higher Environment Court (Miljööver-domstolen). The company's opinion was that the best (and cheapest) solution was to treat the leachate at Ekeby STP. The courts decision was that a local treatment plant for leachate should be built at Lilla Nyby landfill. The output demand of different parameters is shown above.

Thus the company examined different treatment processes, which could meet the output demand of various parameter values. Among examined processes where

- Aeration and treatment in a constructed wetland
- Biological treatment e.g. SBR (Sequential Batch Reactor)
- Evaporation
- Reversed osmosis (RO)
- Chemical precipitation, ammonia-stripping/absorption, activated coal

Local treatment in a constructed wetland was no option because of lack of available space in connection to the landfill.

Biological treatment could be possible but problems could appear because of the low content of BOD in the leachate. There could be problems to reduce the COD enough. Another thing that could cause problems was the low temperature of leachate in the winter. In e.g. a SBR process it is not easy to heat exchange.

Evaporation could be possible – one Swedish plant is in operation at a landfill near Skara – but was expected to be expensive. Another problem could be the recirculation of concentrate from the evaporation back to the landfill.

Reversed osmosis is used to treat leachate at some landfills in Europe but there is no experience in Sweden. Probably such a plant would be expensive and the operation costs are high, especially the change of membranes.

At last a process of chemical precipitation, ammonia-stripping/absorption and activated coal filtration was unknown and there was no experience at such a plant anywhere. This latter process was suggested by prof. Mats Westermark, KTH, Stockholm. A process like this had been used to treat condensate from the flue gas treatment of a bio-fuelled boiler.

Research at the Vattenfall laboratories in Älvkarleby has shown that an additive of ammonia sulphate to the furnace of a biofueled boiler could reduce the corrosion in the furnace (at the steam pipes) and also reduces the need of ammonia dosage to reduce NOX in the flue gases from the boiler. In a process with ammonia-stripping/absorption ammonia sulphate will be produced as a by-product in the treatment process. This could be an interesting treatment option because Eskilstuna Energi & Miljö AB has a large bio fuelled boiler to produce electricity (37 MW) and heat (65 MW).

A request of a total tender with function warranty was addressed to 12 contractors. The contractors could propose any solution they wanted to meet the demands of treatment.

6 contractors offered tenders. After examination and evaluation 3 tenders were judged to be interesting, the tenders from the companies Pronea, Läckeby and Stork Engineering.

Pronea offered chemical precipitation + ammonia-stripping/absorption + activated coal-filtration.

Läckeby offered SBR-treatment alt. NF (nano filtration) + ammonia-stripping/absorption and Stork offers evaporation or reversed osmosis (RO).

After further evaluation and calculations the Pronea offer was selected. A comparison between the different offers showed that Pronea had the most favourable offer (se below):

Process	Investment Mkr *)	Annual cost kkr	Cost/m^3 kr
Läckeby, NF+NH_4	7,80	3089	25,74
Stork, RO	7,50	3935	32,79
Stork, evaporation	13,90	4023	3353
Pronea, see above	6,27	2346	19,55

*) Excl. building

Other reasons to chose the Pronea solution was

- The lowest investment cost
- The lowest operation cost (lowest cost per treated m^3)
- Recycled ammonium from leachate which together with the sulphate in the sulphur acid create a useful chemical which has a market value
- Offered capacity in the basic offer is 160 000 m^3/year compared with the other offers 120 000 m^3 /year
- Lower energy consumption
- Higher security of operation with physical/chemical process than with biological
- Compact plant placed in existing building
- Short delivery time
- No operation experiment is necessary to comply the guarantee

2 METHODS

Description of the leachate treatment plant

Leachate from the landfill is collected from a drainage system and is led or pumped to a storage basin (fig.2) with a total volume of 40 000 m^3.
From the storage basin the leachate is pumped with a speed regulated suction pump (fig.3) to the treatment plant.
The pump can be regulated between 5-30 m^3/h and is operated from treatment plant via a radio modem. Signals from the pump speed and the level in the storage basin are transmitted from the pump station to the treatment plant.

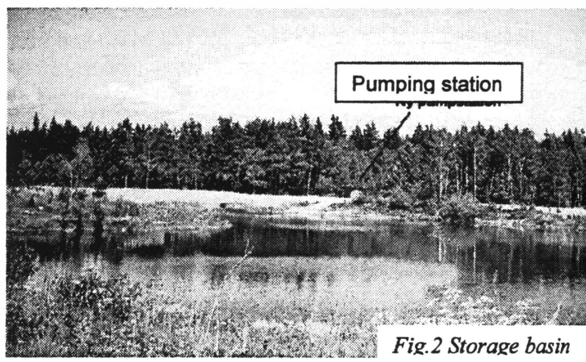


Fig.2 Storage basin

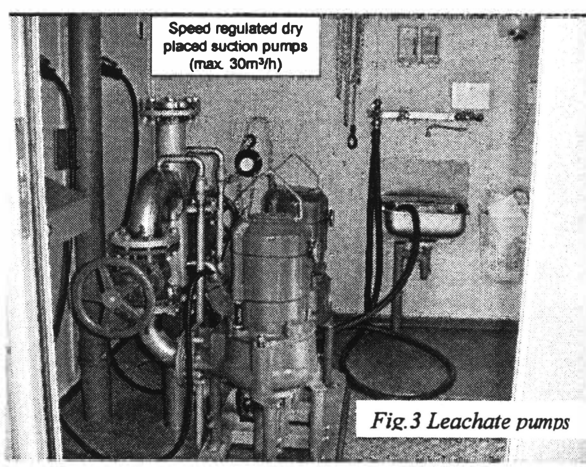


Fig.3 Leachate pumps

The treatment of the leachate can briefly be described as follows:

- Leachate is pumped to the plant (dim. capacity 20 m^3/h)
- Reduction of pH to 3 with sulphur acid and CO_2-stripping (reduce the buffer capacity)
- Rise of pH to 11,5 with sodium hydroxide and precipitation with ferric chloride ($FeCl_3$). Dosage of polymers to enhance the build up of flocks.
- Flock separation in lamella separator
- Further flock separation in continuous sand filter
- Rise of temp. to 50-60 0C through heat exchange
- Ammonia-stripping + ammonia-absorption
- Filtration in activate coal filter + pH-adjustment

The plant is designed to operate automatically and is regulated by an ABB controller system and supervised by a modern iFIX-system with a pointing screen. The system is connected to the company's intranet. The water process is shown in the following process scheme (fig. 4)

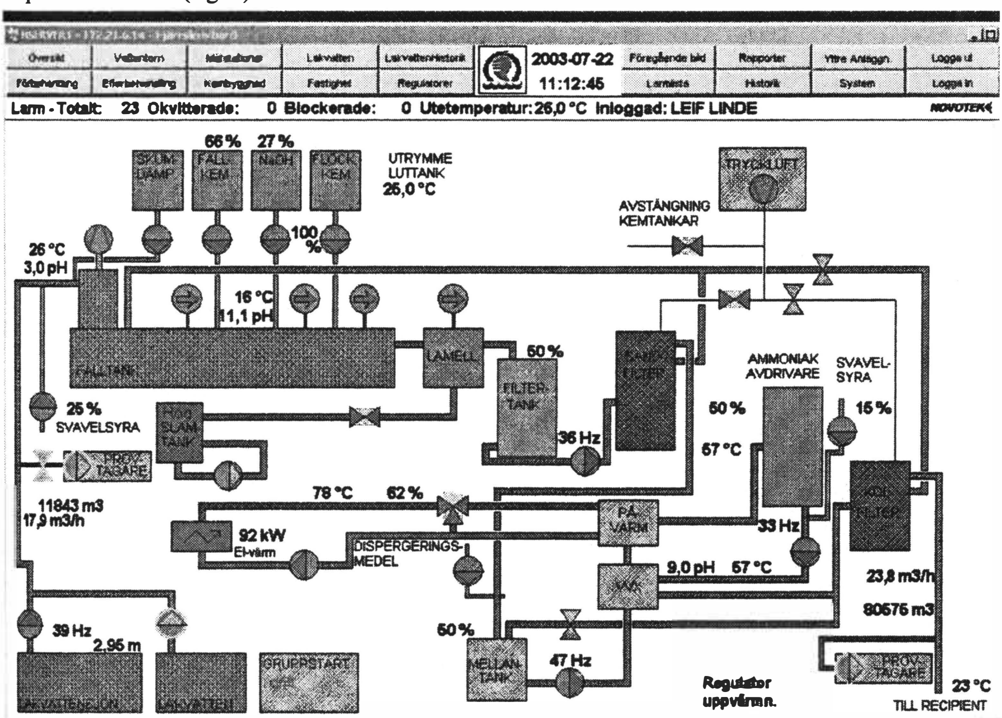


Figure 4 Water process scheme

Small word list: Lakvattensjön - storage basin for leachate; lakvatten- leachate
skumdämp- chemical for foam reduction; vvx- heatœxchanger;
fälltank -precipitation tank; påvärm - heat exchanger for additional heat

Svavelsyra -sulphur acid; provtagare - sample point
The stripping and absorption process is shown in fig. 5

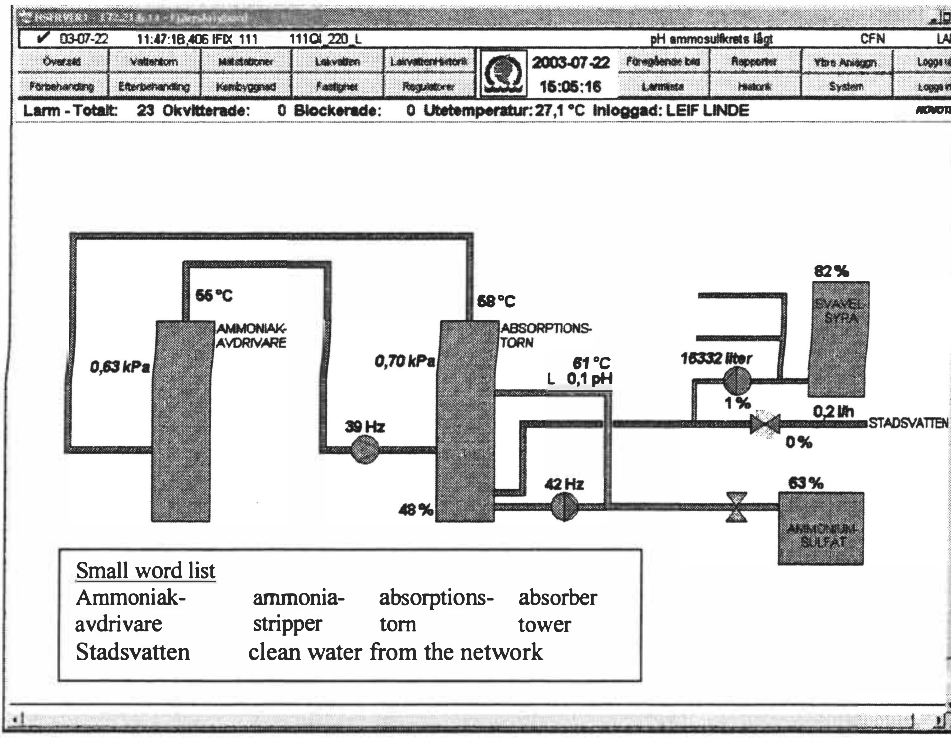


Figure 5 Scheme of stripper/absorber

In the plant there are several pH-meters to measure the pH-value and regulate the dosage of sulphur acid and sodium hydroxide. Dosage of ferric chloride and polymer is flow regulated. It is possible to recirculate sludge from the lamella separator back to the flocculation tank to enhance the build up of the flocks. In the plant water is pumped with speed regulated electrical motors. Outgoing water from the ammonia stripper tower is heat exchanged with the incoming water to the stripper. To raise the water temperature to the desired level – normally between 50-60 °C - it is necessary to add heat via a small heat exchanger from an electrical heater. The water is distributed evenly over the filling in the ammonia stripper tower. A speed regulated fan blows air in counter stream to the water in the stripper tower. Ammonia leaves the water as a gas and is transported to the absorber tower. The gaseous ammonia comes into the filled absorption tower from the bottom and meets a solution of water and ammonium sulphate with at pH-value of about 3,0. When more gaseous ammonia is dissolved, the pH-value will rise and this is compensated by adding more sulphur acid. When the level of ammonium sulphate at the bottom of the absorber tank reaches a certain level, the liquor is pumped to a storage tank.

Sludge is intermittently taken out from the lamella separator and is stored in a sludge tank. Sludge from the back washing of the continuous sand filter and the continuous active coal filter is led back to the flocculation tank. The theoretical background of the various processes in the plant is not presented in this paper. For further information about these look in ref. (1) and (2) Pictures of various parts of the treatment process are shown in figures 6 - 9.

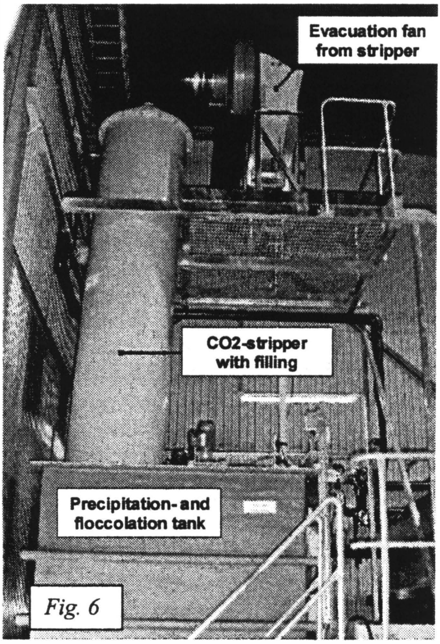


Fig. 6

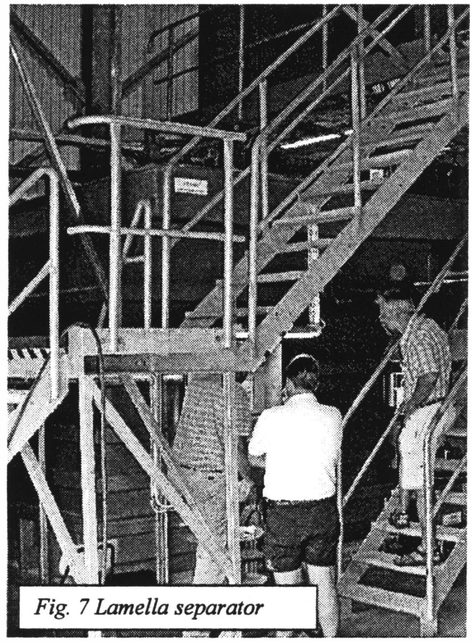


Fig. 7 Lamella separator

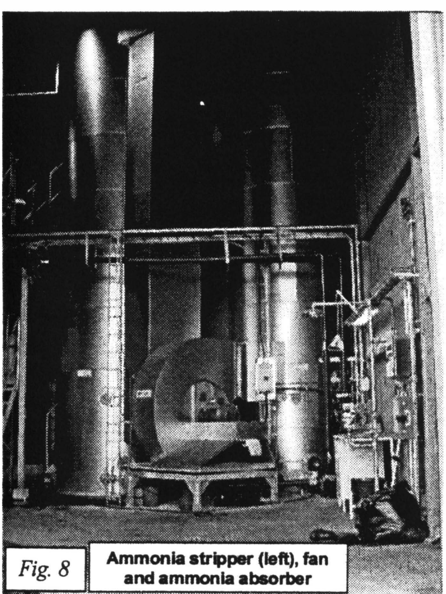


Fig. 8 Ammonia stripper (left), fan and ammonia absorber

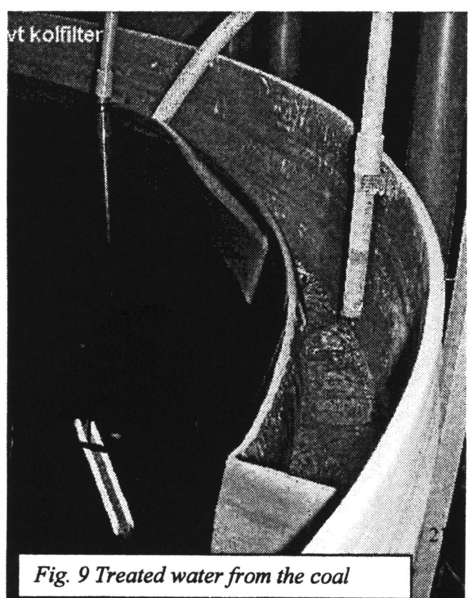
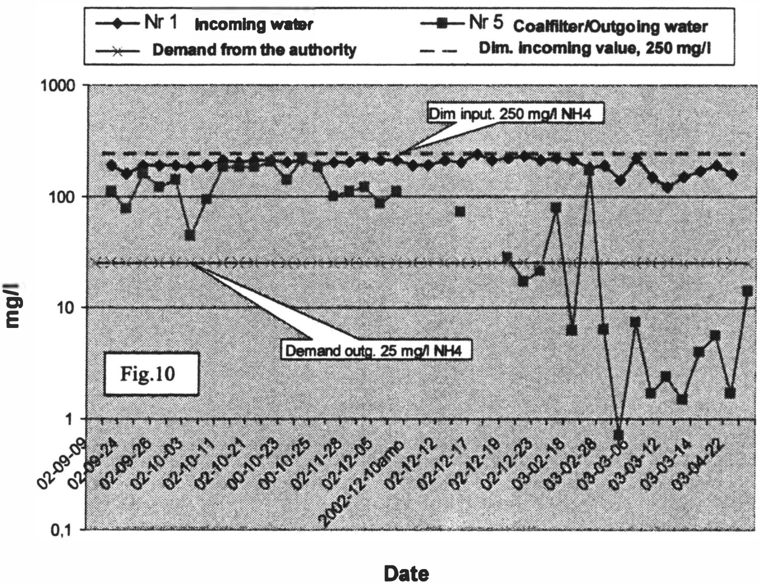


Fig. 9 Treated water from the coal

3 RESULTS

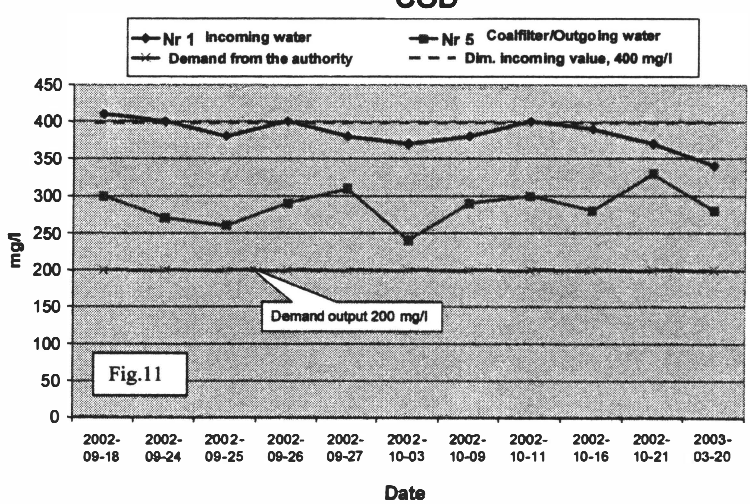
Most of the results are preliminary because of problems in the operation of the plant.

Ammonium nitrogen

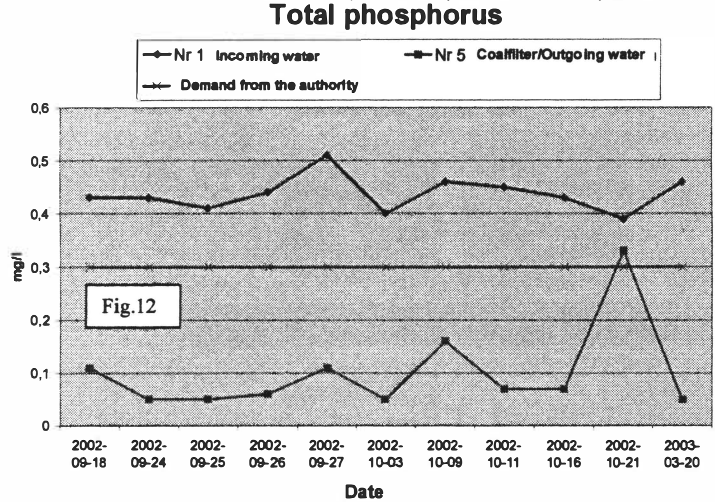


Because of a lot of operation problems (se below in discussion) there has not been any continuous operation for a longer time. When the plant has been working well it has shown good reduction of ammonia nitrogen. It is possible to meet the desired demand NH_4<25 mg/l (*fig.10*)

COD



About 30% of the COD content is removed in the chemical precipitation. How much of the COD which can be removed in the active coal filter has not yet been determined. Perhaps it could be difficult to meet the desired demand of max. 200 mg/l in the output (*fig. 11*).



The reduction of phosphorus takes place in the chemical precipitation. Normally there should be no problem to get values below the permitted limit 0,3 mg/l *(fig. 12).*

Result of reduction of other parameters:

- The reduction of alkalinity HCO_3 is almost 100% in the CO_2-stripper
- The reduction of heavy metals results in output values below the desired demands (except copper whose value rises probably after the heat exchangers)

Preliminary consumption of chemicals is (per treated m3 leachate):

- Sodium hydroxide 1,8 l/m^3 (50% concentration)
- Sulphur acid 1,3 l/m^3 (96% concentration)
- Ferric Chloride 0,06 l/m^3
- Polymer 3 g/m^3 (Inchem Diat 49, 50% active polymer)
- Anti-foam chem. 6 g/m^3

Energy consumption has not yet been evaluated. The electrical heater has a maximum effect of 92 kW but the energy consumption is depending on the leachate temperature and the efficiency of the recovery heat exchanger. The heat exchanger is dimensioned for a heat recovery of 90% but the efficiency depends on how clean the heat exchanger is.

The ammonium sulphate solution produced is very clean and has a concentration of 40%.

The sludge production of the plant has not yet been evaluated. Sludge is intermittently removed from the lamella separator and is stored in a tank. Today the sludge is transported back to the landfill but in future perhaps the sludge will be dewatered before deposit. The sludge is easy to concentrate. Experiments will show if it is easy to dewater.

Experiments with the use of ammonium sulphate as an additive to a boiler furnace has shown that two positive results can be reached:

- The corrosion in the furnace caused by alkali metals will be reduced
- The ammonia additive to reduce NOX in the flue gases can be reduced

Experiments have been carried out at different heat production plants using bio fuels e.g. wood chips, in Eskilstuna and other places. The ammonium sulphate solution is sprayed into furnace (fig. 13).

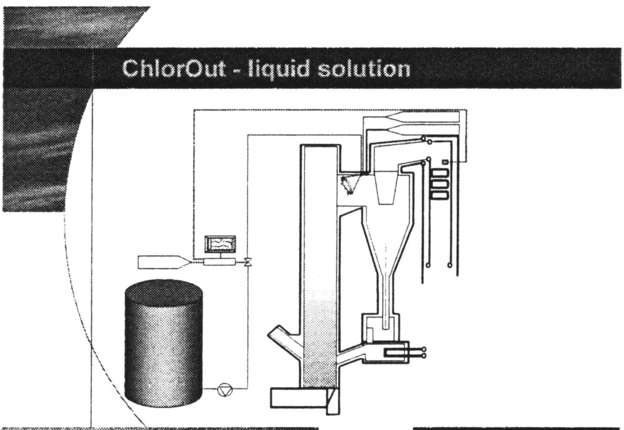


Fig.13

As could been seen in fig.14 the reduction of KCl (potassium chloride) has increased when ammonium sulphate is added. This will cause less corrosion in the furnace (fig. 15).

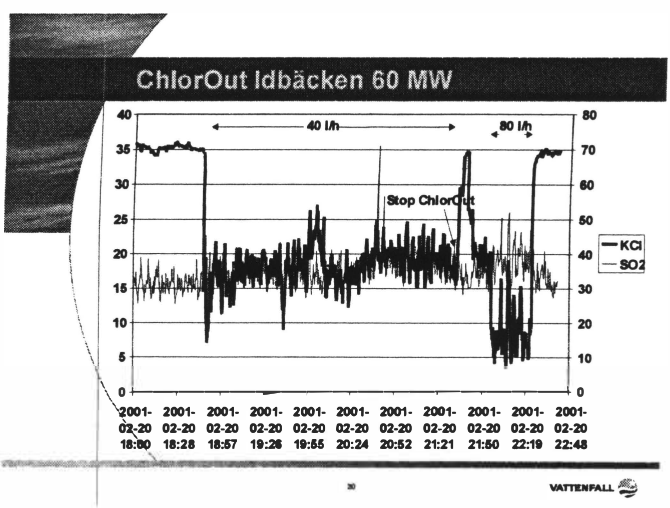


Figure 14

Figure 15

4 DISCUSSION

4.1. Operation

The plant is not yet approved and taken over by the purchaser. Much work has been needed to trim the process in the plant. A lot of problems have appeared and been solved:

Some examples of the most essential items:

1. Foam forming after the CO2-stripper
2. Transport of water drops from the ammonia-stripper to the ammonia-absorber
3. Break down of process pumps for leachate (carbonate deposits), dosage pumps and valves
4. Leakage of sulphuric acid and sodium hydroxide
5. Sludge escape from the lamella separator (bad separation)
6. Clogging in heat exchangers and ammonia stripper tower (carbonate deposits)
7. Misplaced flow meters

Severe foaming occurred in the flocculation tank when the leachate fell through the CO_2-stripper. The only solution to avoid foaming was to add an anti foaming chemical.

Difficulties were observed to get a clean solution of ammonium sulphate and a concentration of 40%. The reduction of ammonia nitrogen in the treated water from the coal filter was also noticed to be bad. Water drops transported from the ammonia-stripper to the ammonia-absorber and drops of ammonium sulphate back to stripper caused this problem. The solution of this problem was to install drop catchers in the ammonia-stripper and the ammonia-absorber and to make some modification in the design.

Deposits of calcium carbonate have caused the break down of pumps and valves. The solution of these problems has been to change pumps and valves and use different design. E.g. 3-way valves have been changed to hose valves.

Leakage of sulphur acid and sodium hydroxide has occurred (luckily not at the same time) because of the choice of faulty materials in fittings. There has been one serious leakage of sulphur acid when about 200 l destroyed the electrical heater.

Sludge escape has been observed from the lamella separator. Change of polymer and dosage and recirculation of sludge from the separator back to the flocculation tank has solved this problem.

The main problem has been the clogging of heat exchangers. After 1-2 day the resistance to the pumps has been too big and plant has stopped. In the beginning there was only one heat exchanger line. It was necessary to build a second parallel line with automatic change of lines when necessary. A clogged line can be automatically washed when the other line is in operation.
Different wash chemicals have been used, citric acid or sulphur acid. It has not yet been decided which chemical will be the best to use. A dispersion chemical will be tried to avoid calcium carbonate deposits in the heat exchangers.

There have also been problems with deposits of calcium carbonate in the ammonia stripper tower. After some weeks the distributor of leachate over the filling clogs and deposits have grown on the filler material. The solution of this problem is not yet solved.

In the beginning the flow meter of leachate was placed at the outlet of the carbon filter. This was not working well because of air bubbles following the water and causing great variations in the measured flow. This was not good for the regulation of the process. A new flow meter was installed in the inflow pipe to the plant and the problem was solved.

4.2. Results

The experience up to this time is that all parameters can meet the demand values except COD.
Because of the above different problems it has not been possible to run the plant for a longer time. Perhaps it will be necessary to change the activated coal in the filter and after that measure the possible COD-reduction.
Because of different operating conditions during the trimming of the plant it is has not yet been possible to evaluate the chemical and energy consumption for certain.

4.3. Economy

The economy is yet to be evaluated.

5 CONCLUSIONS

A new design of leachate treatment plant has been built in Eskilstuna, Sweden. The plant shall meet serious demands stated by the authority. Up to now it has shown that most of the demands can be reached. The plant produces a useful chemical, ammonium sulphate, which can be used as an additive to a bio fuelled boiler at Eskilstuna district heating system. The removed nitrogen from the leachate is recycled.

6 REFERENCES

[1] Daniel Ponce de Leon Perez, 2002, Performance of an Ammonia Stripper for wastewater Treatment (Ammonosulf Method), Master Thesis Work in chemical Engineering, Kungliga Tekniska Högskolan.

[2] Daniel Ponce de Leon Perez, Prof. Mats Westermark, 2002, Ammonia Stripping Process Design Tool, Excel-calculation. Kungliga Tekniska Högskolan.

The above references can be found at http://www.vattenavlopp.info/leachate