Novia University of Applied Sciences

Vaasa, 10 November 2012

Project Report: Anaerobic Treatment of Sludge from Municipal Wastewater Plant Pått in Stormossen

By Ngoc Dinh, Prabina Deshar and Heidi Holm

Table of Contents

1. Introduction

The main purpose of this project is to study operating and control systems for treating municipal wastewater sludge in a typical treatment plant. Our subject of research is the sludge treatment plant of Stormossen. The sludge that is treated at Stormossen originates from wastewater treatment process in Pått - a wastewater treatment plant located in Vaasa (the relationship of end products between Stormossen and Pått is illustrated in the attachment).

Sludge is the solid constituents of sewage that precipitate during treatment and are removed for subsequent purification. The composition of sludge after being treated at a municipal wastewater plant is water, organic and inorganic substances and pathogenic organisms. For the aim of following EU environmental Regulations and Directives; protecting human health and retaining normal and sustainable development for ecology, sludge is prohibited to be let out into nature untreated but must be processed responsibly. For instance, the high content of phosphorous and nitrogen would cause eutrophication and reproduction problems among fishes if it would constantly be poured out into the sea. However, since the treated sludge (humus) is so rich in nutrients such as nitrogen, phosphorous and other valuable organic matters, it can well be used as fertilizer in farming. Sludge treatment also reduces the volume of sludge, limits spreading of contaminants to nature and reduces the smell problem.

2. Project Results

2.1. Unit Processes in Sludge Treatment

The sludge is treated at Stormossen in three unit processes: mixing with water (homogenization), anaerobic digestion and dewatering. Before the sludge is brought to Stormossen it is dewatered in a centrifuge at Pått (reducing water in the sludge makes the transportation easier). The achieved dry substance content is 12-14%. Transportation of sludge from Pått to Stormossen takes place about 6 times per day, and each transport contains about 10 to 12 tons of sludge. The average total amount of sludge coming to Stormossen is about 17,000 tons annually. After the sludge arrives at Stormossen, it is stored in two storage tanks, LS1 and LS2, which can hold about 100 m^3 each. Here follows a description of the three unit processes of the sludge treatment in Stormossen. The full process can be viewed in attachment - a process layout.

Unit process 1: Mixing with water - Homogenization

From the storage tank the sludge is pumped to a mixing unit where it is mixed with warm water from water tanks VS1 and VS3. This part of the process is called homogenization. The aim of this unit process is to warm the sludge to the right temperature, to get a suitable amount of dry substance, and to make the sludge a homogenous liquid. The last feature is accomplished by a set of rotating knives that disperse solid content in the sludge while it is being blended with water.

After the homogenization the dry substance content in the mixture should be 6-7%, so that it can be properly blended during the digestion process. This percentage is reached by mixing equal parts (weight) sludge and water.

Before the mixture is pumped to the digestion tank it is, if needed, pumped through a heat exchanger where the temperature is raised to the required 55 degrees Celcius.

Figure 1: Water tank

Unit process 2: Anaerobic digestion

Anaerobic digestion produces two main products: Digestate and biogas. In Stormossen plant, there are two digestion bioreactors, BR1 for sludge from wastewater treatment and BR2 for bio waste treatment. In this small project, we just conduct research on bioreactor 1 as it is the reactor for treating wastewater sludge from Pått.

Bioreactor 1 was constructed by blasting the rock and its walls consist of a tunnel in the rock that is slammed with concrete. The upper end of the tunnel is fixed with a cover which allows the anaerobic environment. Both the lid and the bottom are made of steel. The volume of the reactor is 1500 m^3.

The mixture is pumped into the reactor through an inlet which is positioned approximately in the middle of the reactor height. Digestate is removed from the reactor by means of an open pipe in the upper part of the reactor while ensuring that the level in the reactor is kept constant.

Figure 2: Top of the reactor

The entry of sludge is either from LS1 or LS2. The feeding is never in parallel but always one at a time. During the day, however, usually waste is used from both containers. The amount of mixture fed to BR1 is about 65-75% by LS1. The sludge remains in the reactor for 12-14 days, if it stays for a shorter time the bacteria are washed out faster than they can reproduce. There are three types of bacteria used in the reactor. First one is bacteria that hydrolyze, second one is bacteria producing acetic acids and the third is bacteria producing biogas (methane). Even if no substrate is added the bacteria are still alive, and keep working.

During normal operation the mixture is pumped into the reactor every half an hour Monday to Friday, 6:00 a.m. to 16:00. If required the system can pump more sludge into the reactor at any time of the day (24 h) (see more about which amount to be pump into the reactor in the control system part below).

The temperature in the reactor has to be at least 55 degrees Celsius and the bacterial strain that is there belongs therefore to the thermophilic range. Thermal energy is supplied by external heating of the material pumped into the reactor. Heating is provided in part by warm water mixed with waste and partly by passing through a heat exchanger before entering the reactor. Because the reactor was blasted out of the mountain there is a lot of energy stored in its walls. This means that the temperature is kept constant in the reactor even though there is no input during evenings, nights and weekends.

Stirring in the reactor takes place by injection of gas and function to the biogas is led from the top of the reactor through a compressor, which forces the gas into the bottom of the reactor. Agitation in progress for 30 minutes stirring and then 30 minutes break. The semi-continuous supply of mixing process brings the variation in the production of the biogas. On Monday morning when no substrate has been input to the bacteria throughout the weekend, the gas production is near a stationary state, and it is relatively constant over time. When the input starts then the response of the gas is immediately seen. Since the gas is gone out this process, the dry substance content in digestate is lower than in the incoming sludge.

Unit process 3: Dewatering

After leaving the bioreactor, the digestate has a dry substance content of 5% and is therefore is pumped into a centrifuge for dewatering. Before coming to the centrifuge, polymers are added to the digestate in P1SA and P1SB so that particles can flock to become bigger ones in centrifuge, the rotating bowl forces water apart from the digestate which later has a dry substance content approximately as high as 30%. After being dewatered, the digestate becomes a drier substance called humus. To prevent foam and bubble formation while the digestate is spinning around in the centrifuge, a foam control agent called Ashland 5350 is also added before dewatering.

As the centrifuge's capacity is not sufficient for taking care of all digested sludge that coming out from the bioreactor during the day, two balancing vessels are used to store the

exceeding part. Only when the input has ceased (often in the afternoon) does the centrifuge continues to dewater the stored sludge.

Figure 3: The centrifuge used for dewatering the digestate

Figure 4: End digestate

2.2. Control System

The process works more or less like an industrial process, and is to a high degree automated. The process is controlled from a logistic central. Even though the sludge treatment plant is highly automated, it still needs to be supervised by staff.

All the unit processes can be viewed through a computer software that gives details about every unit e.g. temperature, pressure and volume. These data are measured by devices such as built-in thermometers and are then shown on the computer screen. Most of the automatic functions work either by commands such as to start pumping when content is at a certain level, and fill a tank to 95%, or to start pumping every 50 minutes and pump for 10 minutes. The last one can also be combined with a command like to stop pumping when the content reaches the maximum amount, e.g. 100 m3, per day. In other words, the automaton might be configured in different ways depending which pump or basin it is controlling.

The system also monitors the process, and alarms if something is wrong. For instance the temperature in the bioreactor has to be between 54 and 56°C, outside that range the bacteria will start producing less gas and different kind of disturbances might appear. If the temperature is not right an alarm alerts the supervisor that the temperature is too low/high, and more warm/cold water can be added to get the right temperature.

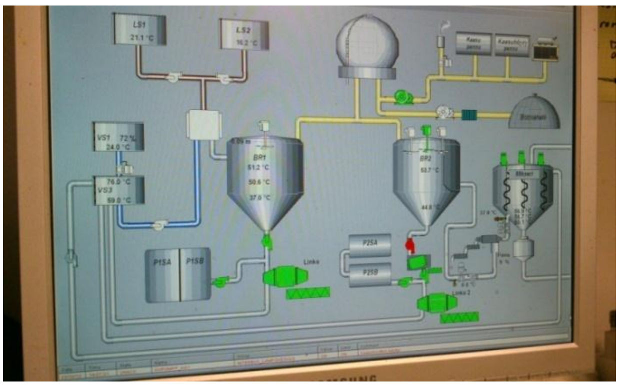


Figure 5: A view over the whole process from computer

The process works smoothly digesting sludge, whose consistent and amount is more or less the same every day, week and year. The control of the process is adjusted to this and works smoothly, and it is easy to adjust to the few changes that might appear.

It is also important to monitor the quality of the end products. Tests are taken from the humus (dewatered digestate) on a monthly basis. Among other things the levels of Nitrogen, Phosphorous, Potassium, heavy metals and bacteria are checked. The quality of the gas is measured on an irregular basis. The amount of biogas produced is one indicator of how well the process is working. The more gas that is produced, the better the process is working.

2.3. End Products

The anaerobic treatment of sludge at Stormossen results in four products: gas, humus, water and excess sludge. Part of the water used in the process is recycled in the process. The rest of the water coming out from the process is first roughly treated in the Stormossen water cleaning plant, and is then sent back to Pått for further treatment. Excess sludge that comes out from the process is sent back into the process. The two end products of the process are gas and humus. The gas is used for heating and energy purposes and the humus is used as compost. Here follows a closer view of the utilization of gas and humus produced in the process.

Gas

The amount of gas produced annually in reactor 1 is about 1.5 million m^3 in which the methane content is 64%. The energy content of clean methane gas is 9.944 kWh/Nm3. This means that the amount of energy that can be produced per year is:

$$1.5 \times 10^6 \text{ Nm}^3 \times 64\% \times 9.944 \text{ kWh/Nm}^3 = \quad 9546240 \text{ kWh}$$

The gas is dried through cooling, and then sent to the gas storage.

Figure 6: The gas storage

The primary use for the gas is heating. Stormossen uses the gas for its own heating needs. For instance the water used in the sludge treatment is heated by burning the gas resulting from the process. Gas is also sold. For instance, the sports arena Botnia Hall and the football field neighboring it are heated by gas from Stormossen. Some nearby companies also buy gas for heating. The gas is sent to the customers through a direct pipe line connection.

It is also possible to use the gas for producing electricity. A gas engine and a generator convert the methane gas into electricity. The power of the gas engine is 720 kW electricity plus about 700 kW heat. The electricity is primarily used at Stormossen, and it covers 60-70% of their energy need. Excess electricity is sold and fed into the electricity grid. This is the case especially during night.

Humus

More than 5000 tons of humus with a dry substance content of 30 % is produced per year, and after further treatment it can be used for planting purposes. The humus has been proven to be clean enough to be used as fertilizer and compost. The raw humus is mixed with wood chips, and placed in long strings on the compost field. It stays there for 3-6 months and is blended on a regular basis with a special machine, which moves over the string and mixes it. After that the string is mixed with soil and stored in another place for 2 years before it is sold.

Figure 7: Compost field

2.4. Challenges and Problems

Compared to bio waste sludge, sludge from wastewater treatment is easier to treat. Sludge is so homogenous so it hardly clogs the pipes. The main challenge in the daily operation of the facilities is the amount of sludge coming in. The dimensioning of the operation units is on the edge of being too small due to an increase in the population and their usage of resources. The bottleneck is the first unit process, mixing with water.

There are no personnel at Stormossen during evenings and weekends, but sludge can still be received in the storage tanks. Problems arise if too much sludge is coming in during a too

short time period. The amount of sludge that has to be left untreated is about 2000 tons per year.

The big amount of sludge coming in does not allow any breaks, and therefore it is difficult to do service on the facilities. Moreover, if bioreactor is overloaded harshly then the biological content can be killed, which would destroy the process. Overloading can be like pumping in 500 m^3 per day during a longer period of time. Fortunately, until now the micro-organisms have not been killed in reactor 1. Once it nearly happened in reactor 2, which treats bio waste. The reason was the reuse of process water.

Too high concentrations of heavy metals could also kill the biological content, but so far this has not happened. Once a high concentration of mercury was measured, but it is not sure that the mercury came from the sludge originating from Pått. Too high levels of ammonium can also make the digestion process work poorly.

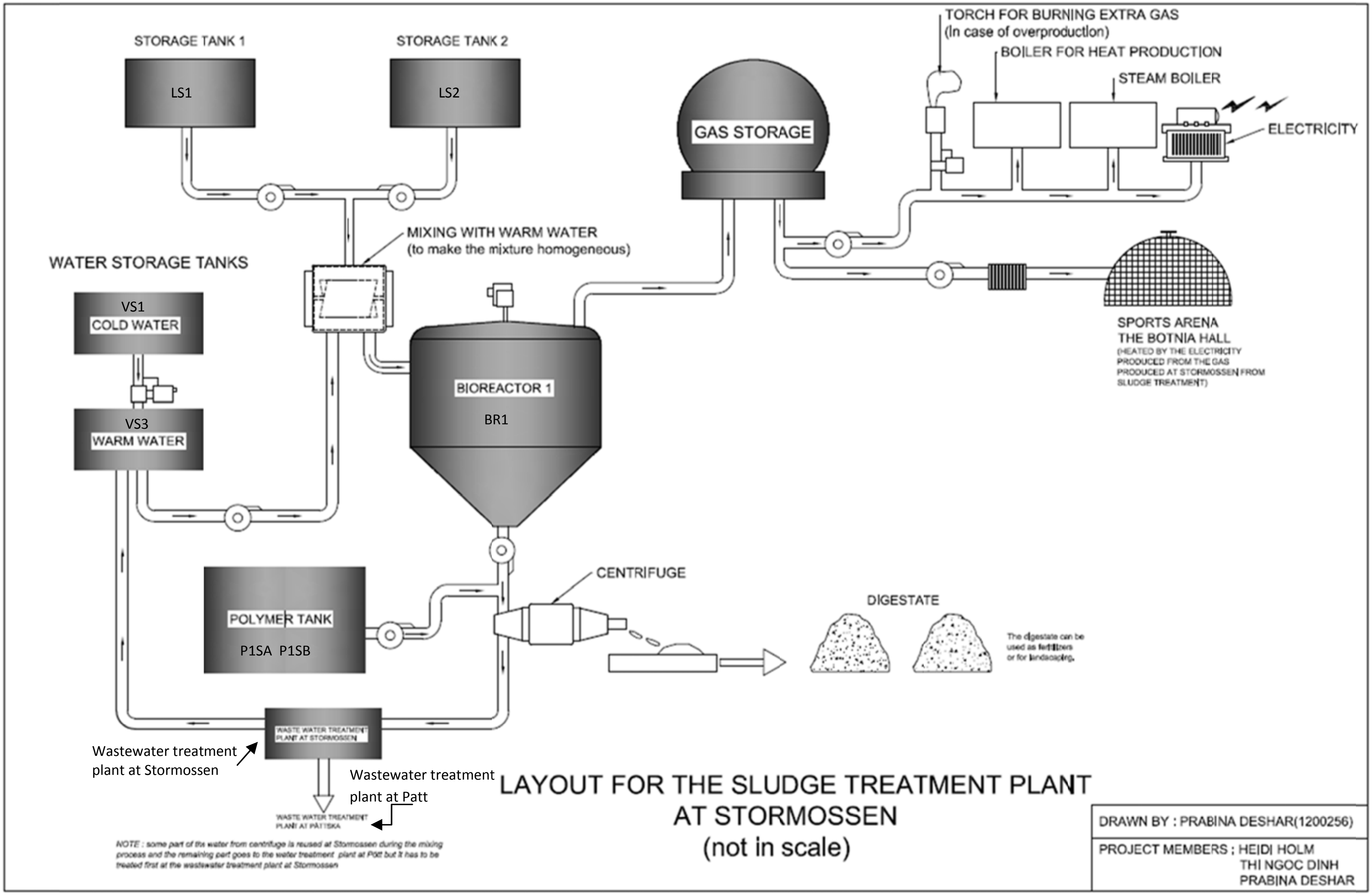
One other challenge is to be able to separate enough sludge, in other words at some point you need to get the sludge out of the process. In the water coming out from the process there is still a small amount of sludge. Part of the sludge is separated in Stormossen's own waste water treatment plant, and goes directly back into the process. Part of the sludge remains in the water and it reaches Pått in the water which is sent there. Eventually it comes to Stormossen.

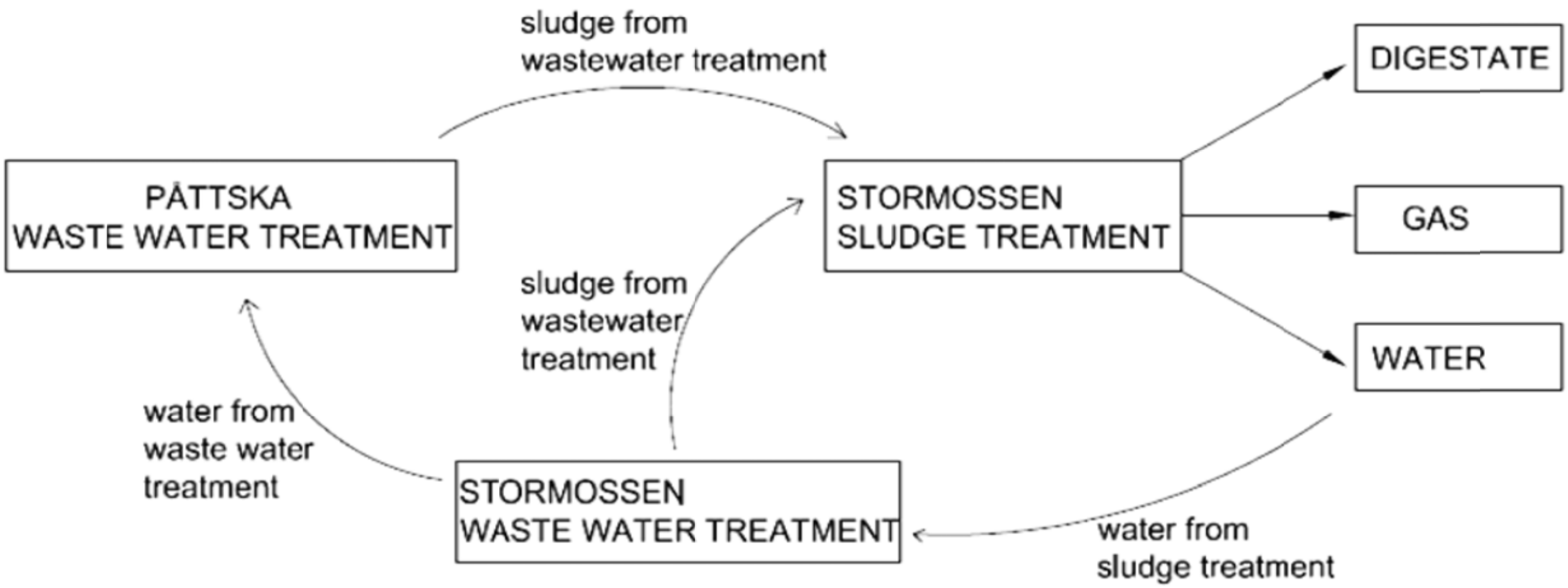
3. Conclusion

Conducting this project opens opportunities for the group's members to understand more about the relationship between theoretical knowledge from textbooks and the practical applying of models and technologies in treating wastewater sludge. We learn that besides treating sludge for humane purpose by removing poisonous matters, this process can be utilized to improve soil and make a small earning by selling electricity.

References

- Discussion on 23rd October 2012 with Stormossen workers Johan Saarela (planning engineer) and Johanna Penttinen-Källroos (environmental manager of R&D department)
- E-mail conversation: Nisse Lithén (plant manager) on 7th November 2012
- Kartläggning av bioreaktor 1 vid stormossen, final thesis by Janne Öhman, Åbo Akademi
- Water Technology – An Introduction for Environmental Scientists and Engineers. Third edition, 2010.N.F.Gray
- http://ec.europa.eu/environment/waste/sludge/index.htm
- http://sv.wikipedia.org/wiki/Reningsverk
- http://www.naturvardsverket.se/Start/Verksamheter-medmiljopaverkan/Avlopp/Avloppsvattnets-miljopaverkan/


STORAGE TANK 1
LS1
STORAGE TANK 2
LS2
GAS STORAGE
TORCH FOR BURNING EXTRA GAS
(In case of overproduction)
BOILER FOR HEAT PRODUCTION
STEAM BOILER
ELECTRICITY
MIXING WITH WARM WATER
(to make the mixture homogeneous)
WATER STORAGE TANKS
VS1
COLD WATER
VS3
WARM WATER
BIOREACTOR 1
BR1
SPORTS ARENA
THE BOTNIA HALL
(HEATED BY THE ELECTRICITY
PRODUCED FROM THE GAS
PRODUCED AT STORMOSSEN FROM
SLUDGE TREATMENT)
CENTRIFUGE
DIGESTATE
The digestate can be
used as fertilizers
or for landscaping.
POLYMER TANK
P1SA P1SB
WASTE WATER TREATMENT
PLANT AT STORMOSSEN
Wastewater treatment
plant at Stormossen
Wastewater treatment
plant at Patt
WASTE WATER TREATMENT
PLANT AT PÄTTISKA
NOTE : some part of the water from centrifuge is reused at Stormossen during the mixing process and the remaining part goes to the water treatment plant at Pätt but it has to be treated first at the wastewater treatment plant at Stormossen
LAYOUT FOR THE SLUDGE TREATMENT PLANT
AT STORMOSSEN
(not in scale)
DRAWN BY : PRABINA DESHAR(1200256)
PROJECT MEMBERS ; HEIDI HOLM
THI NGOC DINH
PRABINA DESHAR



SLUDGE CYCLE FROM
PÅTTSKA TO STORMOSSEN