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Technical experiment report

Overfeeding Experiments on a Laboratory Wastewater Treatment Plant in particular Consideration of Nitrogen and Phosphorus Reduction

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by

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Contents

List of abbreviations

BOD	biological oxygen demand	
C_B	titrant consumption of blank	[ml]
c_{eq}	equivalent concentration, normality	[mol/l]
C_S	titrant consumption of sample	[ml]
c_S	sludge concentration	[g/l]
COD	chemical oxygen demand	[mg/l]
DO	dissolved oxygen	[mg/l]
m_F	mass of filter	[g]
m_{F+S}	mass of filter and sample	[g]
MLE	modified Ludzak-Ettinger (process)	
P&I	pipe and instrumentation	
R&D	Research and Development	
UAS	University of Applied Sciences	
V_S	volume sample	[ml]
τ	retention time	[h]

Summary

This technical report is about one experimental part in the cross-border project Mare Purum between Sweden and Finland. The project is dealing with chemical, biological, and spectroscopic possibilities in wastewater treatment. In Vaasa the Novia- and the Vaasa Universities of Applied Sciences built a laboratory scaled plant to work on these issues. The plant is designed according to the Modified Ludzak-Ettinger process with slight changes based on laboratory possibilities and process controls. The main functionality is still corresponding to municipal treatment plants by using conventional methods like nitrification, denitrification and phosphorus precipitation.

The focus of the project is a modified biological treatment for a nitrogen reduction and studies of bacteria reaction on overfeeding attempts under changeable conditions. During this experiment three parameters in a specific range are changed. These are the sludge concentration, the dissolved oxygen and the retention time. The overfeeding, named a spike is based on an addition of high concentrated wastewater directly to the aeration basin of the plant which simulates an overload what can happen also to municipal wastewater treatment plants. The result of this is a disturbance to the normal activity of the bacteria doing nitrification with the effect that they are not fast enough to reduce the whole substrate and a peak can be measured in the effluent. The amount of the peak and the time it needs to get back to the normal level enable making statements of bacteria reaction to the spike. This reaction with focus of the chosen range of the parameters takes place in a positive way. Because of the different parameters used during a spike it is possible to find out which one or which interactions between these are significant or not.

Daily measurements of sludge concentration and Chemical oxygen demand (COD) gives assurance that the plant is running stable and they ensure results for the reduction of substrate by the plant. In constant conditions a reduction of 95% COD is possible. During a spike measurements of COD and ammonium at hourly intervals are giving the peaks for results about the significance of the parameters. Another result is that a determination of the pH development has shown that nitrification is effectively inhibited while doing a spike.

1 Novia and the Project Mare Purum

Novia is a Swedish-speaking University of Applied Sciences (UAS) in Finland. It has over 4000 students and a staff of 380 in 4 different Campuses along the Finnish coast line. Next to Turku, Jakibstad and Raseborg Novia acts also in Vaasa. Together with the University of Vaasa and the Vaasa UAS, Novia maintain a Research and Development (R&D) laboratory in Vaasa. [1]

One main R&D project Novia is involved is Mare Purum. The focus of Mare Purum is about biological wastewater facilities in the Botnia-Atlantica region. Therefore cross-border cooperation between Finland and Sweden makes sense. The participated universities are Vaasa UAS, Umeå University, Novia UAS, Swedish University of Agriculture Sciences and the Technology Centre Ketek LTD. The project is financed by the Botnia-Atlantica programme, Region Västerbotton and the Regional Council of Ostrobothnia. [2]

The project has started in March 2012 and will continue to June 2014. It is about the study of biological, chemical wastewater treatment facilities in focus of vibrational spectroscopic possibilities of flows. The principal topic of Mare Purum is clearly summarized in the headline: “Chemical, biological, and spectroscopic studies of flows in biologic wastewater treatment, Mare Purum”. [2]

The biological treatment of wastewater is a well-known and established technology and it is used in a lot of municipal wastewater treatment plants and in addition in the pulp and paper industry of this region. That's why there is a great interest to improve the knowledge of better treatment to hold the biological system of the Botnia-Atlantica region as the main concern. [2]

2 Basics

With a view to the municipal plants the treatment of wastewater concentrates on reducing biodegradable substances. By human sources, like urea and cleaning materials etc., the main substances which shall be reduced are nitrogen and phosphorus. In a high concentration in nature these substances can increase the growth of plants and algae dramatically. This process is called eutrophication. In order to do something against this it is necessary to treat the human wastewater. [3]

2.1 Nitrogen reduction

Nowadays the common plants are working with a biologically reduction of nitrogen. The first step is the hydrolytic decomposition of urea to ammonia.

$$(NH_2)_2CO + H_2O \rightarrow 2NH_3 + CO_2$$

In wastewater this reaction takes place in the sewage systems and it is nearly completed before the water arrive the treatment plant. A natural relationship between ammonia and ammonium in water ensure for ammonium which prevails. [4]

For a degradation of ammonium a biological reaction called nitrification takes place. This is a natural microbiological process which occurs anywhere the nitrifying bacteria meets the requirements. Next to some other groups of bacteria like Nitrospira, Nitrococcus and Nitrosocystis the most important ones are Nitrosomonas and Nitrobacter. Nitrification is a two step reaction whereby ammonium is firstly reduced to nitrite and then nitrite to nitrate. [4,5]

$$NH_4^+ + \frac{3}{2}O_2 \rightarrow NO_2^- + H_2O + 2H^+$$

$$NO_2^- + \frac{1}{2}O_2 \rightarrow NO_3^-$$

Because of needed oxygen, which has to be dissolved in the solution, the whole process of nitrification is aerobic. Therefore a continuous aeration is required. Another important matter is the development of hydrogen ions. This reduces the alkalinity in water and the pH can be so low that nitrification is limited or totally stopped. Other inhibiting thinks are the temperature and toxic substances like metals or metal ions. One main problem is the relatively low growth rate of the nitrifying organism, because the reaction produces a low energy yield. Therefore

an increasing of biomass in treatment plants can be very difficult and takes place very slow. [3,7]

The last step for a nitrogen reduction in wastewater is the denitrification. Heterotrophic bacteria are able to change nitrate to atmospheric nitrogen.

$$\frac{5}{4}C + NO_3^- + H^+ \rightarrow \frac{5}{4}CO_2 + \frac{1}{2}N_2 + \frac{1}{2}H_2O$$

In this reaction nitrate is the oxidizing agent. The denitrification is a strict anaerobic process otherwise the bacteria will prefer to use dissolved oxygen. [4,5]

The process of nitrogen removal in sum causes a pH reduction and for that reason it is important to take care of a constant pH level. By less organic matter, less nutrients or strong dynamic influences the whole process of nitrification and denitrificationcan can be stressed and it comes to a production of inhibiting intermediate products. These toxic or undesirable substances are nitrite, nitrite oxide and dinitrogen oxide which are poison and greenhouse gases. [5]

2.2 Phosphorus reduction

A natural phosphorus reduction takes place in a lot of biological processes. Bacteria needs phosphorus for building biomass, but nevertheless the consumption is very low. It is not possible to reduce the phosphorus concentration of wastewater to the needed level. The common solution is a physical and chemical process. Thereby phosphorus is fixed by precipitation with iron- or aluminium salts and the flocks formed removed by sedimentation. [6]

$$PO_4^{3-} + Fe^3 \rightarrow FePO_4 \downarrow$$

$$PO_4^{3-} + Al^{3+} \rightarrow AlPO_4 \downarrow$$

In municipal wastewater phosphorus is present in the form of phosphate. Together with iron- or aluminium ions it creates a hardly soluble substance which precipitates.

The high costs of the chemicals and the higher salt concentration in the water are considered as negative. Also the sludge production increases. [8]

3 Wastewater treatment plant, Putsari

In cooperation the Novia UAS and the Vaasa UAS have built a wastewater treatment plant named Putsari for research work in the Vaasa Energy Institute. This laboratory scaled plant is made for studies about the biological treatment of wastewater and spectroscopic measurements as a part of the Mare Purum project. The following section of this report will give all important information about the plant and the different substances used to keep the plant running.

3.1 Plant overview

Putsari is built according to the Modified Ludzak-Ettinger (MLE) process. The following figure 1 represents a simplified scheme of the plant with an anoxic selector. [9]

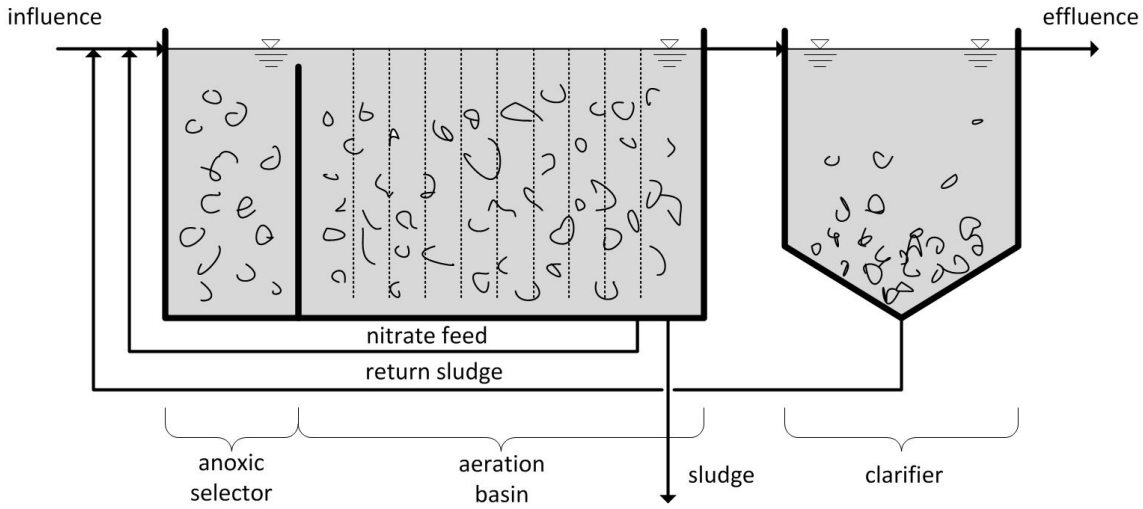

Figure 1: MLE process, Putsari

The influent or the wastewater is send directly to the permanently mixed and with bacteria filled anoxic selector. The used wastewater is generated synthetically for receiving the same conditions over the whole experiment period. A flocculant (PIX) is also added for a phosphorus precipitation and later on for a removal. By overflow the water reach the aeration basin. This basin is aerated by air and also mixed over the whole time and the bacteria here start with nitrification for the nitrogen removal. The main part of the suspension in the aeration basin is pumped back to the anoxic selector. The anaerobic conditions arrange a denitrification and the nitrogen are reduced in total. Because of the decreasing of the pH there is also lime milk added to the selector. The aerobic and the anaerobic basins together are forming an activated sludge system. Again by overflow the cleared water reaches the clarifier. The bacteria and the flocks sink to the bottom and they are returned to the anoxic selector as well. The cleared water leaves the clarifier on the top by another overflow. The difference to a

normal MLE process is that the sludge is not removed from the bottom of the clarifier but from the aeration basin. [9,10]

The figure 2 shows an original photography of the plant Putsari used in the Mare Purum project. The filling volume of the plant is 10l.

Figure 2: Putsari

3.2 Process control

For a continuously operation with the treatment plant Putsari it is necessary to have a controlled process running autonomous as possible. As a summary of all process controls and how they interact is a pipe and instrumentation scheme (P&I scheme) in figure 3 represented. The scheme is drawn the other way around (the flow from right to left) with the reason that the original plant Putsari is designed in the same way by standing in front of it. Pictures of some parts of the plant are listed in the Annex on pages 26 and 27.

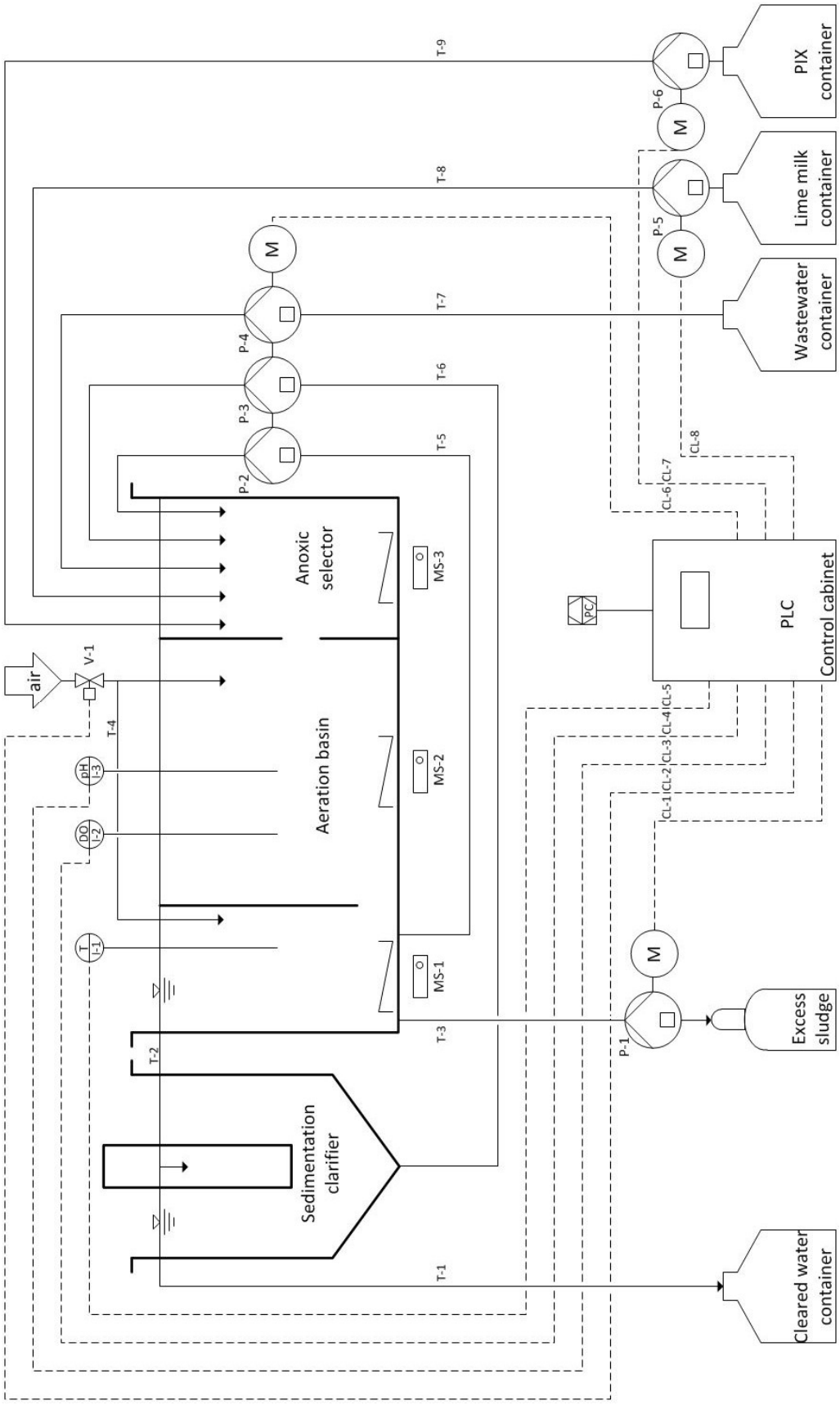

Figure 3: P&I-scheme Putsari

Table 1: Putsari installations in P&I

pumps + electric motor	
P-1	excess sludge
P-2	nitrate feed
P-3	return sludge
P-4	influent/ wastewater
P-5	Lime
P-6	PIX
tubes and pipelines	
T-1	effluent/ clarified water
T-2	aeration basin to clarifier
T-3	excess sludge
T-4	air for aeration basin
T-5	nitrate feed
T-6	return sludge
T-7	influent/ wastewater
T-8	Lime
T-9	PIX

control lines	
CL-1	P-1 (excess sludge) control
CL-2	V-1 (air flow) control
CL-3	pH - measuring
CL-4	dissolved oxygen - measuring
CL-5	temperature
CL-6	P-2, P-3, P-4 (flow) control
CL-7	P-6 (Pix flow) control
CL-8	P-5 (Lime flow) control
other	
I-1	measuring unit for temperature
I-2	measuring unit for dissolved oxygen
I-3	measuring unit for pH
V-1	ventile for air flow regulation
MS-1	magnetic stirrer aeration basin 1
MS-2	magnetic stirrer aeration basin 2
MS-3	magnetic stirrer anoxic selector

The influent, the nitrate feed and the return sludge flows are regulated by the Programmable Logic Controller (PLC). The three peristaltic pumps (P-2, P-3, P-4) have all the same rotation speed, because they are installed on one electric motor. A difference between these three flows is achieved by various diameters of the tubes T-5, T-6 and T-7. The settings for the PLC are made manually, what is important to set a specific retention time through the plant by giving a variable influent flow.

By removing excess sludge it is possible to regulate the biomass growth and thus the sludge concentration. This has also to be set manually to the PLC which controls the pump P-1.

The aeration basin has three measurement sensors (I-1, I-2, I-3) installed. These are available for detecting temperature, dissolved oxygen and pH. For getting a constant level of dissolved oxygen the PLC is used to control the air valve V-1 and thereby the air supply to the aeration basin. The same happens to the pH. Here the PLC regulates the pump P-6 for the lime supply. The setpoint for the pH during the experiments is attuned to 7,5. It is recommendable to check the sensors at least once a week.

The PIX flow to the anoxic selector for the phosphate precipitation is constant around 50 ml/h the whole time.

The PLC is combined with a computer which saves all relevant data. This is necessary to show changes in specific values after doing an experiment.

3.3 Wastewater preparation

As already said is the used influent a synthetic prepared wastewater. This used to have nearly the same conditions like normal wastewater. The reason for this is that it is easier to provide a solution with constant concentrations with a synthetically one. Another advantage is that there is no need for a primary clarifier because of the absence of solids which has to be removed otherwise.

Table 2: substances for 5l synthetic wastewater solution

substances		mass [g]
organic		
peptone		80,0
meat extract		55,0
urea	CH_4N_2O	15,0
anorganic		
sodium chloride	NaCl	3,5
calcium chloride	$CaCl \times 2H_2O$	2,0
magnesium sulfate	$MgSO_4 \times 7H_2O$	1,0
dipotassium hydrogen phosphate	$K_2HPO_4 \times 3H_2O$	14,0

By preparing the synthetic influent it is advantageous to have a high concentrate which will be diluted afterwards. This concentrate consists of different organic and inorganic substances which are solved in distilled and deionised water. In table 2 these substances and the quantities for a 5l solution are listed.

First it is necessary to fill a 5l Erlenmeyer flask with around 2l of distilled and deionised water. The substances will be weighed on an analytical balance with the assistance of spoons and plastic shells and then given to the flask. It is helpful to shake the flask after every addition. Afterward the Erlenmeyer flask has to be filled up to the mark and placed on a magnetic stirrer for mixing until there are no solids in it anymore. After one or two hours the concentrated solution is ready. For storage it has to be filled in plastic bottles and put in a freezer.

Before using the synthetic wastewater for the plant the concentrate has to be diluted. It is the objective to have always the same substrate input to the plant also by various influent flow. Therefore the correct dilution has to be calculated before. For example by a retention time of 10h and a plant volume of 10l the influent flow has to be 1l/h. The substrate load is measured in Chemical oxygen demand (COD) and the concentrated synthetic wastewater has around 30.000mg/l COD. The load of COD for the influent has to be around 430mg/h. Therefore the

dilution factor of the concentrate has to be 1:70 (concentrate to influent). With a various influent flow and constant load to the plant this factor has to be changed.

3.4 Lime milk preparation

The regulation of the pH requires an addition of lime milk. The preparation of lime milk needs calcium hydroxide which will be solved in water. The objective is to have a calcium hydroxide saturated solution.

Around 20g of calcium hydroxide has to be given in a 5l canister and then it has to be filled with distilled and deionised water. Because calcium hydroxide is not easily dissoluble in water it first build a suspension which has to be shaken one day. After that the surplus calcium hydroxide has to be removed and therefore it has to stay at least two days in a bucket to be sedimented. The clear fluid has to be taken off and can be used as the required lime milk. The result comes near to the maximum saturation of calcium hydroxide in water (20°C) of 1,7g/l. [11]

3.5 PIX preparation

A chemical called PIX-105 or Fennofloc F 105 is used for the phosphate removal in this experiment. This prefabricated mixture of substances is based on ferrous sulphate. For preparation it has only to be diluted for using it in the right concentration. 240g of this chemical will be weighed on a balance and filled in a 10l canister. The canister is to fill up to the mark and after a short shake the diluted flocculant is ready. [12]

Pictures of the synthetic wastewater, the effluent or cleared water, the lime milk and the PIX-solution are listed in the Annex on pages 27 and 28.

4 Experiment

After giving all important information about the plant the following section will report all necessary things doing the experiments with it. The first step is to keep the plant running constantly. Problems with the right sludge concentration and for this purpose with the correct excess sludge flow rate has to be clarified. After that point begins the main task for this part of the project. In this section the important things will be told about the experiment and about the measurement methods.

4.1 Spike

The experiment is called a spike. That means as a summary a simulation in which the wastewater treatment plant Putsari will be overfeeded. The objective is a review of the bacteria reaction in the case that there is a lot of more substrate present then they are used to.

4.1.1 Parameters

Before doing a spike some parameters there has to be defined. These are the sludge concentration (c_S), the dissolved oxygen (DO) and the retention time (τ). From spike to spike these parameters will be changed in a certain range which is shown in the following table 3.

Table 3: range of parameters

parameter		low	high	unit
disolved oxygen	DO	1,5	3,5	mg/l
sludge concentration	c_S	3	6	g/l
retention time	τ	8	12	h

With three different and changeable parameters it is possible to try eight spikes. For getting an overview and to know the best order of the spikes a parameter cube is created which is shown in the next figure.

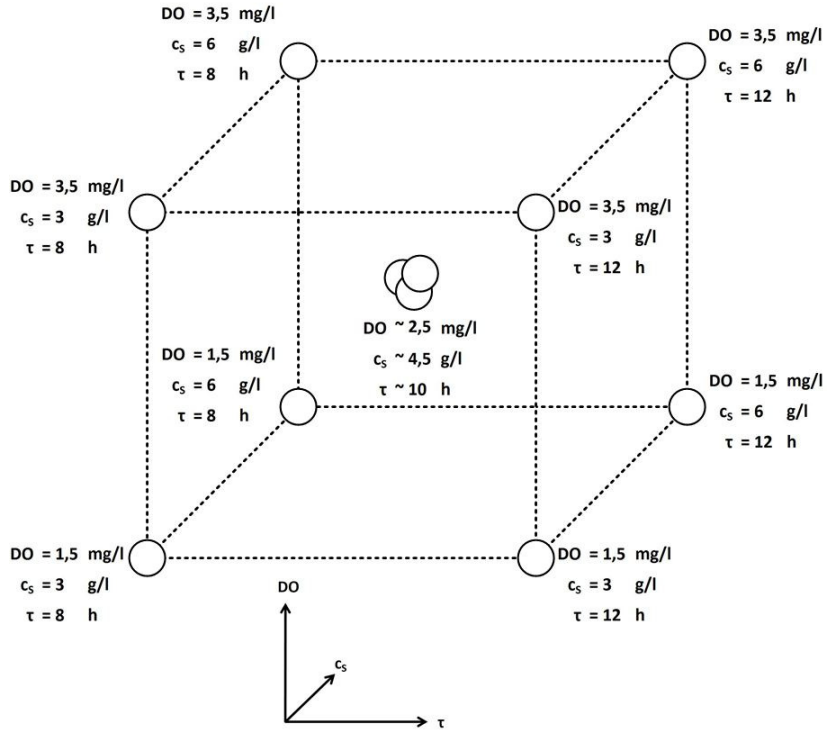

Figure 4: parameter cube

Next to the spikes in the corners of the cube it is possible to do some spikes with parameter values in the middle of each range. These are called central points.

4.1.2 Preparation and process

The most important thing before starting a spike is that the three parameters have constant values which mean that the plant is running stable. A spike is an overfeeding try and it is necessary to add substrate in a high concentration. In this experiment 300ml of the synthetic wastewater concentrate have to be added to the aeration basin to simulate this overfeeding. This corresponds to 9g of COD. The duration for one spike is around 12h and in the time the sampling and thereupon the measurements taking place. For correct measurements, attention should be paid to the sampling. During the first 6 hours every half hour and after that every hour a sample is removed from the effluence and filled in small labelled plastic bottles. Directly after every sampling the bottles are stored in the fridge for stabilisation.

4.2 Measurements

In this project some measurements should be done every day to control the running plant. This is important to know what happens to the plant, to know in which quality the wastewater is treated and to react immediately to any possible disturbances.

4.2.1 Sludge concentration

The sludge concentration in the basins of the plant has to be checked twice a day. This concentration is the most difficult thing to handle for example by changing from one spike to another. For reducing or increasing the sludge concentration it is possible the change the excess sludge flow.

The sample for the sludge concentration has to be taken with a small plastic cub directly from the aeration basin. The rest of the analysis is based on filtration with glass microfiber filters (Whatman size: GF/A). For best results the filters should be washed with approx. 100ml distilled water and be placed for 1 hour in a drying kiln. The dry filter has to be weighed on an analytical balance and the value has to be noted as m_F. The next step is to determine the volume of the homogenized sample with a measuring glass and the sample volume V_S has to be noted. After that the filtration can be started. A vacuum in the special Erlenmeyer flask is received by a water jet. The following figure 5 shows the used apparatus.

Figure 5: filtration apparatus

The filter with the cake on the top has to be removed and placed in the drying kiln for 1 hour. If there is a high sludge concentration expected it is recommendable to dry the filter for 2 hours. The filter with the dried cake has to be weighed again (m_{F+S}). The concentration of the sludge c_S in g/l can be calculated with the following formula 7.

$$c_S = \frac{(m_{F+S} - m_F) * 1000}{V_S}$$

4.2.2 Chemical oxygen demand (COD)

The COD of the influence and the effluence should be determined once every day. Because of this it is possible to receive the reduction from wastewater to cleared water caused by the plant. During a spike the COD is crucial for the analysis results and gives the most important information for this project.

A COD Cell test is used for this measurement. Test kits from the Merck KGaA contain the needed reagents. The first step is to clean the samples by centrifugation, because solids can disturb the result. The reaction cells (reaction cells Merck KGaA) have to be filled with 2ml

sample and one cell as a blank with distilled and deionised water. After shaking every cell they have to be placed in a thermoreactor (Hach COD reactor) and heated there for 120min at 148°C. Then the cells have to be shaken again and cooled down to room temperature (≈20°C). The first measurement takes place in the photometer (Hach DR/2000 direct reading Spectrophotometer) at 320nm. Therefore a present program for the COD measurement has to be entered. The blank resets the program and the following tubes with the samples can be measured directly after this. [13]

The COD value can be read from the display. The range of this test is from 0 to 150mg/l COD and if a value exceed the sample has to be diluted and the test repeated again. The figure 8 represents pictures from the thermoreactor and the used photometer. [13]

Figure 6: thermoreactor (left) and photometer (right) for COD test

Instead of using photometry it is also possible to use titration for getting COD results. The reaction solution has to be filled from the cells into beakers and two drops of ferroin-indicator has to be added. The titration is made with a 0,05M ammonium iron(II) sulfate and the consumption has to be noted. The used titrator (Metrohm 876 Dosimat plus) is shown in figure 8.

Figure 7: titrator for COD test

Attention must be paid to make sure that there are no gas bubbles in the tubes. This can be received by using an installed program which flushes the tubes twice.

The COD in mg/l can be received from the following formula 8. The c_{eq} is the normality or equivalent concentration of the ammonium iron(II) sulfate solution. C_B and C_S are the measured consumption of titration fluid and V_S is the sample volume. [7]

$$COD = \frac{8000 \cdot c_{eq} \cdot (C_B - C_S)}{V_S}$$

4.2.3 Ammonium concentration

The ammonium measurements are made during a spike from the same samples as used for the COD test. Next to the COD, ammonium gives information about how the bacteria react on the overfeeding try.

The test is a photometric determination of ammonium via indophenol blue. The maximum value for ammonium with this method is 2mg/l. Therefore a strict plan for a correct dilution is required. The sample has to be filled in a 25 Erlenmeyer flask up to the mark. Now three

different chemicals and 1ml of each must be added. These chemicals are sodiumcitrate, phenolnitroprusside and alkaline sodiumhypochloride.

For preparing sodiumcitrate in the concentration of 1,2ml/l, 175g trisodiumcitradehyddrate ($NA_3O_7C_6H_5 \cdot 2H_2O$) has to be dissolved in around 600ml distilled water in a 1l Erlenmeyer flask. 15ml of 0,34mol/l NaOH has to be added and the solution has to be boiled until the volume is fewer than 500ml. After a fast cooling to room temperature the sodiumcitrate has to be diluted to 500ml again. For phenolnitroprusside 13,5g phenol (C_6H_5OH) and 0,15g sodium nitroprusside ($Na_2Fe(CN)_2NO \cdot 2H_2O$) have to be dissolved in 500ml of distilled water and the solution has to be stored in a brown bottle. The alkaline sodiumhypochloride is made by pipetting 20ml sodiumhypochloride (5,3mg/l active chlorine) to a 100ml volumetric flask. The flask has to be filled up to the mark with 0,34mol/l NaOH and stored afterwards in a brown bottle.

After the addition of the chemicals the samples have to be stored in the dark and after two hours the passing reaction is completed. The absorbance is measured by a photometer (Shimadzu UV-1650PC) at 655nm by using a blank with distilled water. A calibration by means of standard solutions is necessary. The next figure 8 displays the used photometer in combination with a computer. [7]

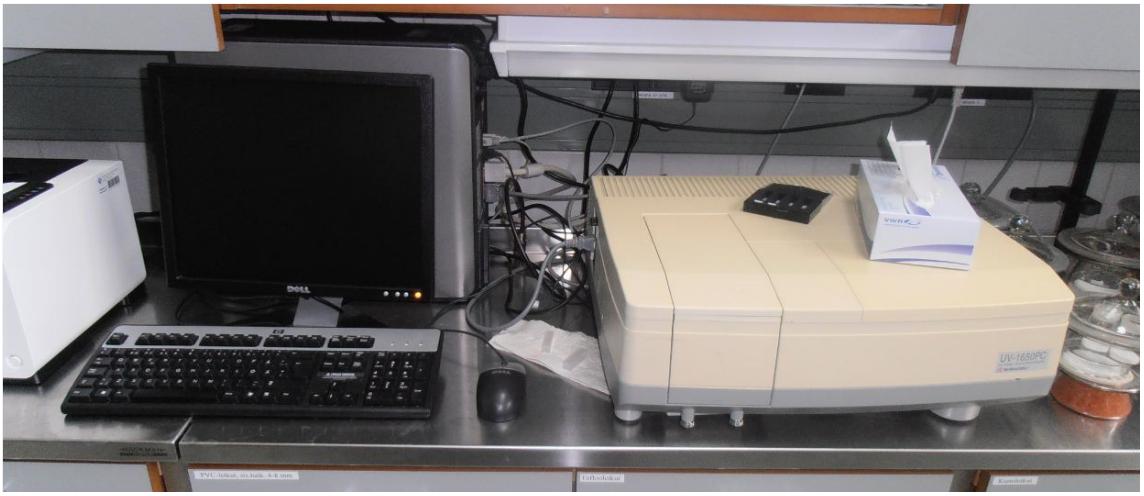

Figure 8: photometer and computer for ammonium test

4.2.4 Lime consumption and pH

Because of the PLC and the use of a computer as a server the lime consumption and the pH can be easily recorded. The main server is collecting the whole data of the plant going through the PLC and it is possible to copy the needed information from any time of the whole test duration.

5 Results and Objectives

The daily COD results of the plant Putsari have shown that in a stable process it is possible to reduce the COD from influence to effluence in average around 92% up to 95%. A one-hundred-percent rate of reduction could be impossible because the COD is measured in a biological reduction. That means the difference between COD and BOD can be reduced in a chemical way but not with this biological based plant. The reason for measuring COD instead of BOD is the occurrence of big problems and measurement deviations in the BOD tests that have been made.

The rest of this section represents results of one spike from the 17th June 2013. The parameters for this spike are a low sludge concentration of 2,9g/l, a short retention time of eight hours and a high dissolved oxygen level of 3,5mg/l. The development of COD in the effluence during this spike is shown in figure 9.

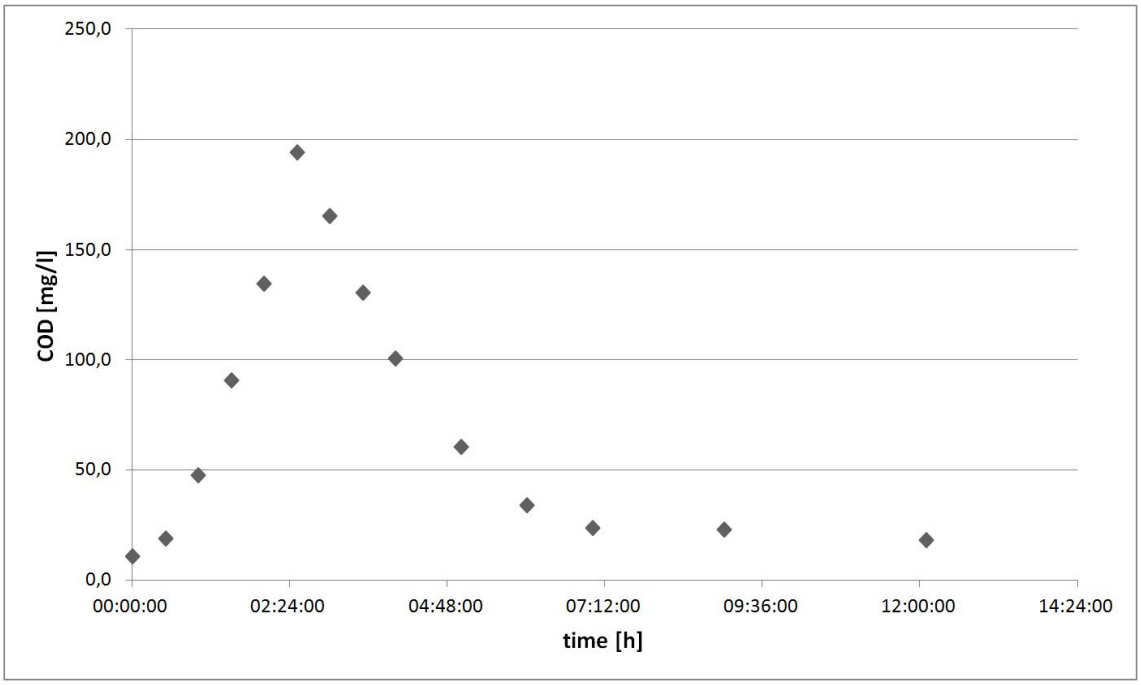

Figure 9: COD development, spike 17.06.2013

After adding 300ml concentrate synthetic wastewater or 9g of COD the development goes straight up to a peak value of nearly 200mg/l after 2,5 hours. Afterwards the trend is falling down and after around seven hours it is back to the normal amount like it was before. An integral with the whole surplus of COD in the effluence can give information how well the bacteria react on an overfeeding. In every experiments according to the parameter cube shown in figure 4 (chapter 4.1.1) the progress works good and a development back to the normal level of COD in the effluent has been observed. The amount and the time of the peak are changing from spike to spike. By comparing all spikes with all different parameters it is

possible to find out which parameter is significant or which interactions of the parameters are the most important ones. Software like Mathcad and MODDE could be helpful.

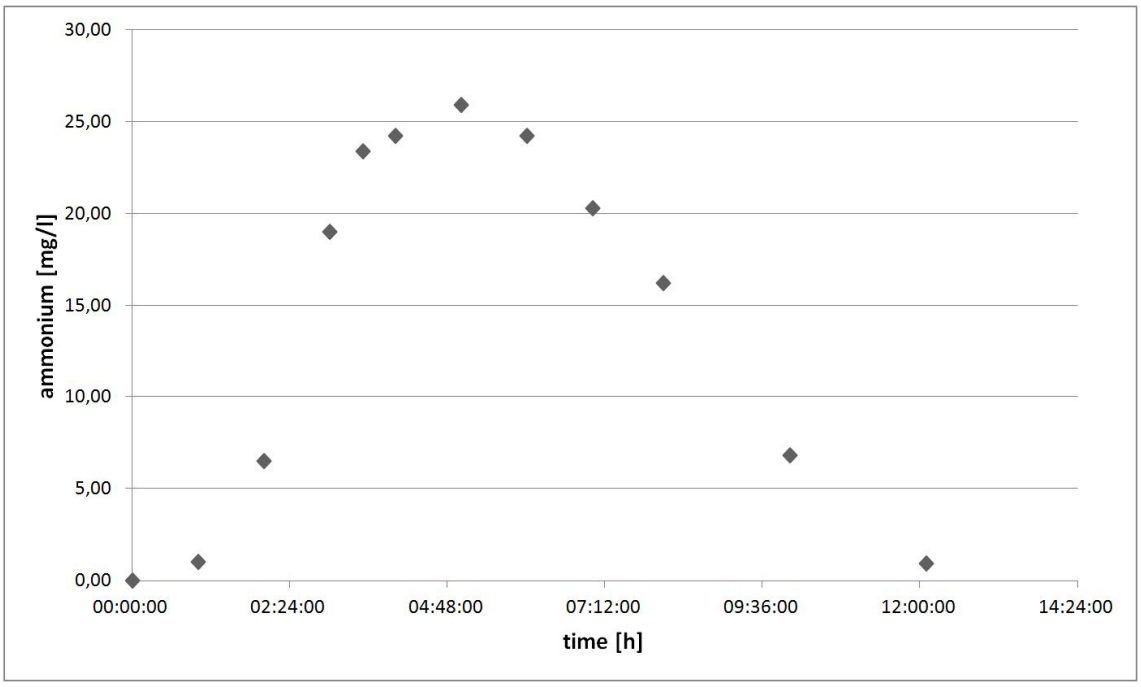

Figure 10: ammonium development, spike 17.06.2013

The ammonium curve of this spike shows nearly the same result. The ammonium concentration starts at zero and goes up to 26mg/l after around five hours. The whole development of ammonium in contrast to COD is delayed. It needs a long time (more than twelve hours) to get back to the origin amount.

An interesting think is shown in the following figure 11. It represents the pH and lime milk consumption courses.

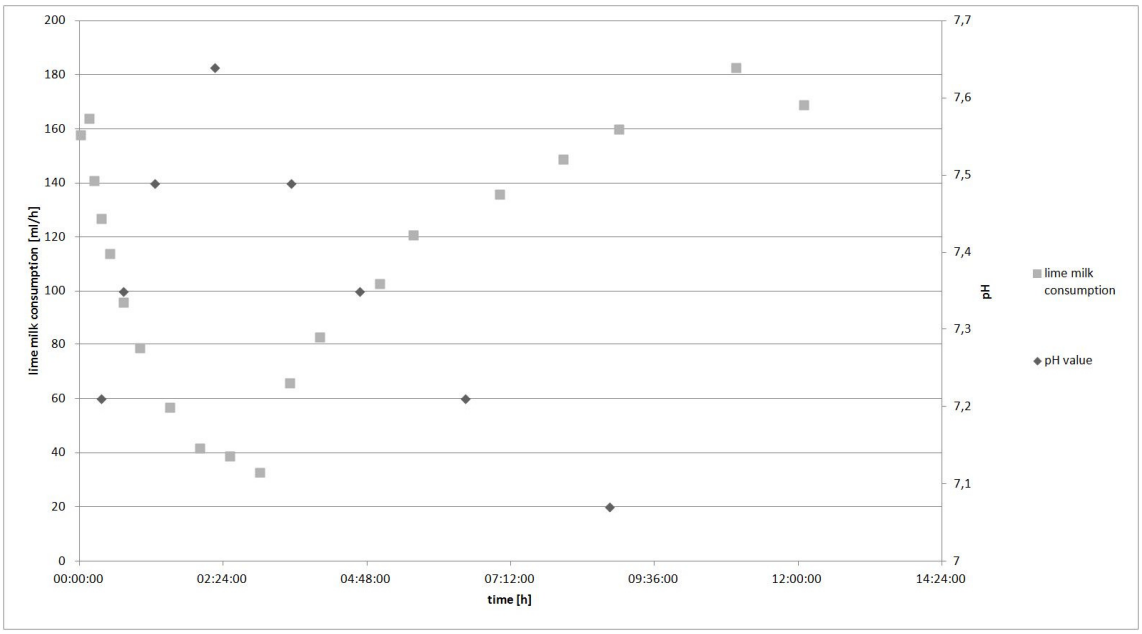

Figure 11: pH and lime milk consumption, spike 17.06.2013

Immediately after starting the spike the pH increases and as a consequence the lime milk consumption regresses. At around three hours the pH has reached a limit of over 7,6 and is falling rapidly down after this. The consumption of lime milk goes up at the same point. Everything that comes after that is the regulation of the process control to the origin level which is going to take a while.

The conclusion of this could be a stop of nitrification directly after adding the concentrated wastewater and because of the slow regulation possibilities the pH is increasing fast on the basis of the high lime milk flow. Reasons for this could be a substrate surplus inhibition (for example by NH_4^+ / NH_3) or a too high salt concentration [14]. More precise statements require additional studies in this field.

List of Figures

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[1] online: http://www.novia.fi/about-novia/

[2] online: http://www.mare-purum.eu/background.html

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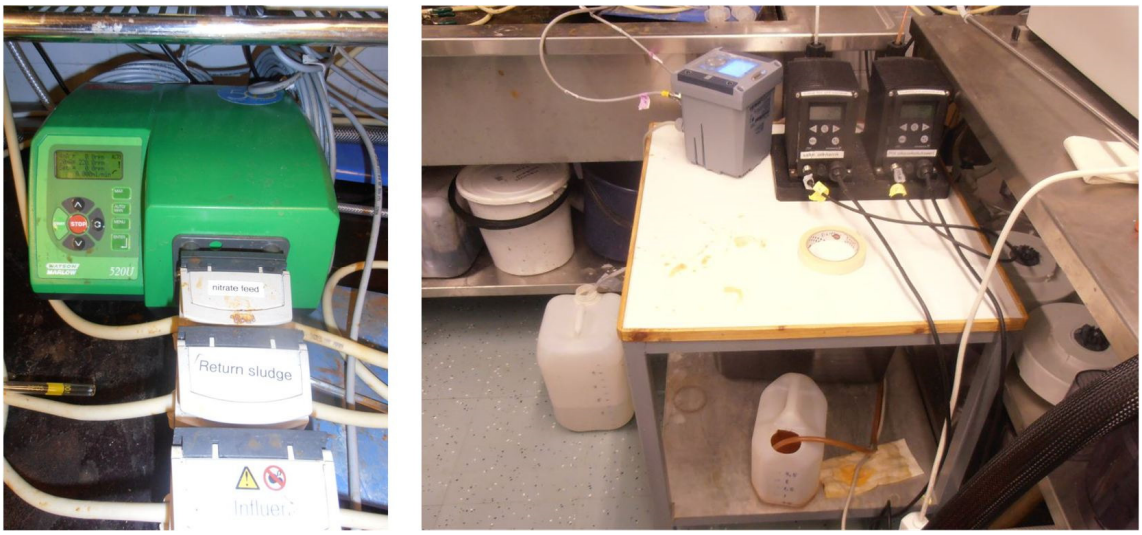
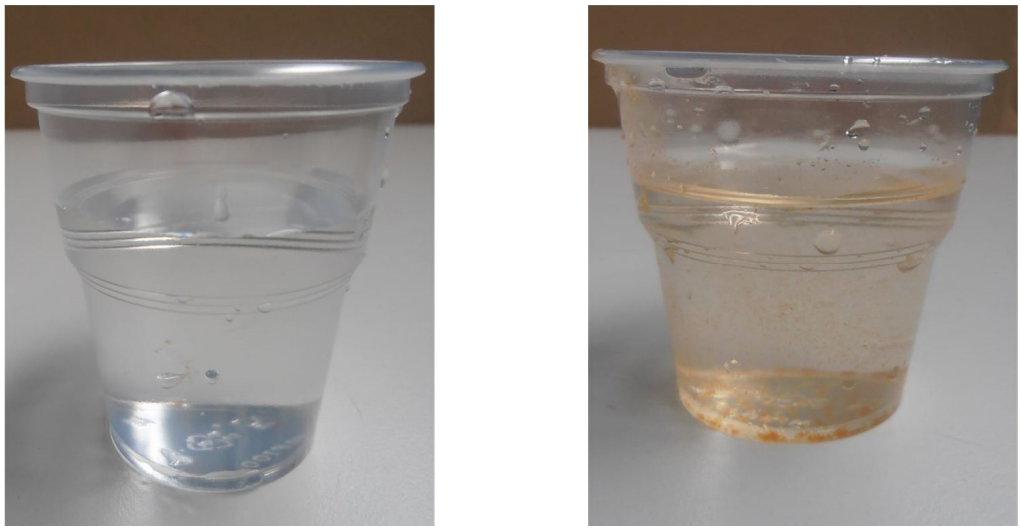
Annex

plant Putsari in process (left), PLC (right)

clarifier in process from above (left), basins in process from above (right)



pumps for influent, return sludge and nitrate feed (left), pumps for lime milk and PIX solution (right)



cubs with influent/ synthetic wastewater (left) and effluent/ cleared water (right)

cubs with lime milk (left) and PIX- solution (right)