# A Planning Tool for COD Flow Optimisation to a Waste Water Treatment Plant

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Abstract: The waste water flows to a typical wastewater treatment plant (WWTP) is comprised from periodic domestic flows and more stochastic industrial flows. Especially variations in the flow of Chemical Oxygen Demand (COD) at the inlet to the WWTP are problematic due to the biological purification process and bio gas production. Traditionally the inlet is un-controlled. A way to reduce variations is to insert a buffer tank near the industrial areas and control the tank outlet according to a prediction of household COD flow. As a first step a planning tool for operator control of the buffer tank outlet 24 hours ahead is designed. The WWTP in the Danish town Fredericia is used as a case. At the moment the only on-line measurement is the inlet flow to the wastewater treatment plant and reliable measurements in the network are difficult to establish. A Model Predictive Control scheme is shown to be able to give considerable reduction in the COD flow variations. To do this two models are introduced; one describing the buffer tank and sewer network from the tank to the WWTP and one describing the daily variations in the household flow. Additionally prediction of the industrial outlet is included. The control scheme has been tested showing good results in a SWMM simulation environment (ProtectionAgency, 2016) based on network architecture and measurements in Fredericia.

## 1 INTRODUCTION

The topic within this paper is to improve the the purification and bio-gas production in wastewater treatment systems by smoothing the COD Flow to a WWTP.

The sewer system drains wastewater from industries and private households. A sewer system network consists of gravity pipes, pressurised pipes, pumps, manholes, weirs etc. making up a complex system, there is no retain tanks in the network. At the moment the inflow to the WWTP is un-controlled. The idea is to insert a retrain tank in the system and control the tank outlet. The first iteration which is in focus in this work is an operator support system making 24 hours ahead plans for outflow from the tank. The planning is based op prediction of industrial and household waste water flow and concentration and potentially precipitation. The execution of the plan is left to the operator. In this work, the sewer network in the Danish city Fredericia with approximately 50000 inhabitants is in focus.

Wastewater is comprised of different pollutants like phosphor, nitrogen and COD. The inlet flow and concentration to the WWTP is varying due to daily variations in household wastewater, varying industrial outlets and different time delays from these sources to the WWTP inlet. In addition, precipitation causes irregular variations. In Fredericia in dry periods approximately 50 % of the wastewater comes from industries.

A detailed model description of all phenomena is extremely comprehensive as seen in e.g. the simulation tool WATS (T. Hvitved-Jacobsen et al., 2013),(DHI, 2017) and is not well suited for controller design. Therefore, a simple model describing the main dynamics is formulated, additionally only flow and COD are taken into account and furthermore it is assumed, that no biological processes takes place in the sewer network.

The sewer system as well as the biological processes are complex and further it is difficult to make on-line measurements of the pollutants. In Fredericia the only available real time on-line measurement is the inlet flow to the WWTP. Off-line measurements of COD flow and concentration are available from October 2017. The average and filtered average of the total flow as well as the COD concentration and COD flow in October 2017 are shown in Fig. 1.

As seen in the figure the shapes of the COD and

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flow inlet show the same tendencies. In (Nielsen and T. S. Pedersen, 2020) a control scheme for minimising the total mass flow variations at the inlet to the WWTP using a buffer tank was developed. In the present work the benefit from including COD measurements is investigated.

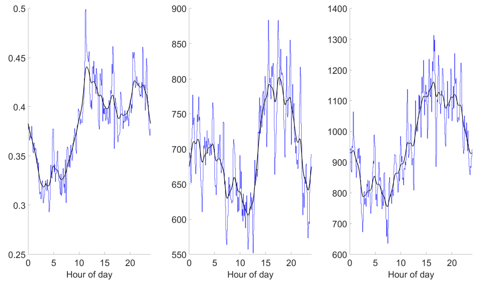

Figure 1: 24 hours average flow [l/s], average COD concentration [mg/l] and average COD flow [mg/s] based on measurements from 30 days at the inlet to Fredericia WWTP (frese.dk, 2018).

Control of sewer systems are described in (Marinaki and Papageorgiou, 2005; **?**; Pilgaard and Pedersen, 2018; **?**). A way to minimize the flow variations is to insert buffer tanks in the sewer network and control the outputs from these. At the moment no such tanks are available in the sewer system in Fredericia. Due to large industrial waste water variations a logical place for a buffer tank is close to the industrial outlets. An algorithm to control the outflow from a buffer tank in order to minimize the input flow variations at the WWTP is developed.

To design a controller, models of the buffer tank, the sewer network, the household flows and industrial flows are necessary.

A simple tank model based on a mass balance is used. A dynamic model describing main characteristics of the sewer network is formulated; in (Nielsen and T. S. Pedersen, 2020) it is shown that the Saint-Venant equations under certain assumptions can lead to a delay model for the flow. The flow delay from a buffer tank to the WWTP inlet is found from cross correlation on simulated data. Similarly the COD concentration delay in the network is identified; this delay combined with a linear transfer function constitutes the COD model. The model describing the flows from households to the WWTP is based on measurements.

A Model Predictive Controller (MPC) with a performance function aiming to minimize the variance of inlet COD flow to the WWTP has been formulated given buffer tank volume constraints.

To test the benefit of a buffer tank inserted in the sewer system a realistic simulation describing flow and concentration dynamics in the Fredericia sewer system is developed using the EPA's Storm Water Management Model (SWMM) (ProtectionAgency, 2016).

In section 2 the Fredericia sewer system is described. Section 3 considers the control concept. The SWMM simulator is presented in section 4. The sewer system modelling is described in section 5. Section 6 is a description of the actual control of the buffer tank output. The control concept is tested in SWMM which is described in section 7 and finally the conclusion is in section 8.

## 2 FREDERICIA SEWER SYSTEM

Fredericia wastewater treatment plant covers the town of Fredericia, nearby villages and industrial areas north and west of the town. The total sewer net is among the largest in Denmark. Households and industrial areas north and west of the town dominate the wastewater in Fredericia. The map shows the northern part of Fredericia divided in subareas. A large number of pipes leads to the WWTP. In this work, the pipes from the industrial areas to the WWTP are considered. These are indicated in the map Fig. 2.

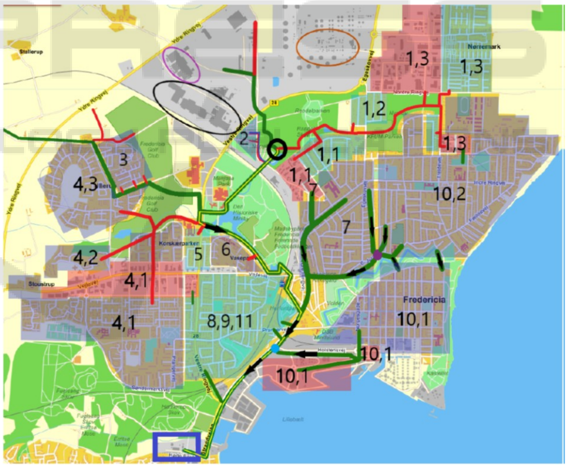

Figure 2: Main sewer system in Fredericia, (Pilgaard and Pedersen, 2018). The blue square is the WWTP, oval shapes are industrial areas, black circle is inlet from industry to the main pipe.

Household wastewater is predictable with regard to flow (Schlutter, 1999). As seen in Fig. 2, the area covered by the wastewater plant is large and the sewer network is split into numerous branches implying that the shape of the inflow from the households to the wastewater treatment plant is influenced by varying delays in flow.

In the WWPT, the quality of the wastewater treatment and biogas production are dependent on the inflow, as the biological processes needs time for scaling. Smoothing the input flow will improve the quality of the WWTP processes.

A case study covering the north part of the area is considered; it comprises the industrial area north to the city, a buffer tank added close to the industrial area, the sewer network from the buffer tank to the WWTP and the residential areas indicated in Fig. 2. A controller is optimising the output flow from the tank.

## 3 CONTROL CONCEPT

The main goal for the control system is to reduce the COD fluctuations in the inlet, $Y$, to the WWTP. It is assumed that the only measurement is $Y$ and the only controllable variable is the outlet flow $U$ from the buffer tank. The inlet flow from industries to the buffer tank is $Q_i$. $Y_{ref}$ is the WWTP inlet flow reference. The household flows is added to one flow directly to the WWTP inlet. In this work, we look at one buffer tank. The concept for controlling this may easily be extended to more detention tanks. Fig. 3 shows a sketch of the simplified system.

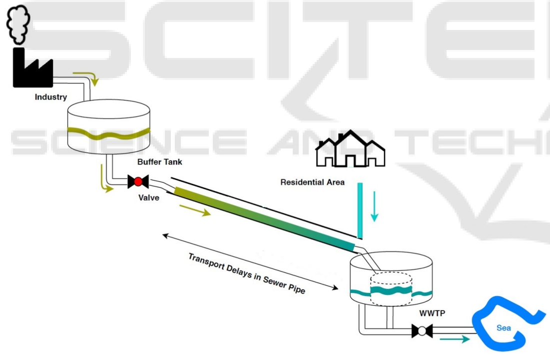

Figure 3: Simplified sewer system with the main components buffer tank, households, sewer pipe and WWTP.

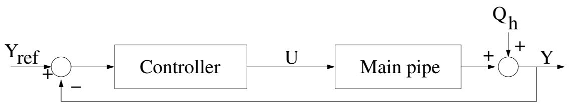

Figure 4: Classical control concept for the problem showing inputs, outputs and disturbances.

A classical control concept is illustrated in Fig. 4. $Q_h$ is the total household flow disturbance and is seen as a flow directly to the WWTP. The model of the main pipe may include a transport delay; therefore, a classic controller will result in a low bandwidth and poor disturbance rejection (Aastrom and Haegglund, 2006; **?**). The disturbance is periodic, see Fig. 1, this periodicity is difficult to take into account in a classic control concept. It is well known from the classical control theory that cascading can improve the performance. More flow measurements in the main pipe will make this possible and up-stream measurements of the household flow could be used as feed forwards. Iterative learning control could be another way to improve a classic controller. A third concept is to use a neural network. In this work it is chosen to use a Model Predictive controller (MPC); the method is based on optimisation from prediction via a plant model. The model can include time delays and it is possible to incorporate knowledge of future disturbances (household flow and potentially precipitation) in the optimisation.

## 4 SWMM MODEL OF FREDERICIA NORD

A realistic simulation model of the main pipes in Fredericia Nord is developed using the EPA's Storm Water Management Model (SWMM) (ProtectionAgency, 2016). SWMM is used for simulations of water runoff quantity and quality. It provides an environment for hydraulic and water quality simulations. The main sewer system in the northern part of Fredericia Fig. 2 is modelled based on information on dimensions and location of pipes, channels, drains, manholes, storage's and pumps. Dominating residential and industrial areas are connected to the main pipe Fig. 5, the household flow from these areas are constructed from typical data from households (Schlutter, 1999) and scaled by the number of inhabitants. In addition to the existing sewer system elements a buffer tank are added close to the industrial area.

The purpose of the model is twofold. Test sequences of flow and concentrations can be applied in the network and corresponding data sets for flow and concentration e.g. at the inlet to the WWTP can be used to investigate propagation rates and filtration for flow and concentration. Additionally evaluation of the control concept can be carried on in the simulation environment.

## 5 MODELLING THE SEWER SYSTEM

A model predictive controller requires development of an appropriate model. The model may consists of a description of the industrial wastewater flow and concentration, a tank model combined with a model of the sewer network from the tank to the WWTP and a

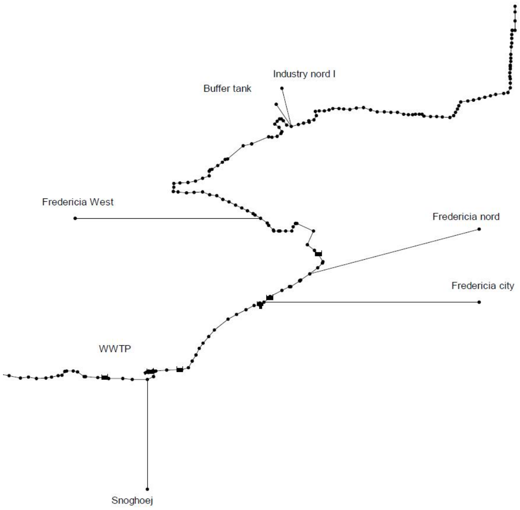

Figure 5: SWMM model of the main sewer system in Fredericia Nord (Pilgaard and Pedersen, 2018).

household flow and concentration disturbance model.

## The Sewer Network and Tank Model

The model of the combined tank and sewer system must be able to show mass flow dynamics and dynamics corresponding to the COD flow in the sewer net from the tank inlet of industrial waste water to the WWTP. Separate models for mass flow and COD concentrations in the network and the tank are developed and combined to one state space description.

The sewer system is dominated by pipes but also consisting of manholes, pumps, minor accumulating tanks etc, Fig. 5. In (Nielsen and T. S. Pedersen, 2020) the connection from the tank to the WWTP is considered not filled pipes and the pipes are described as an open channel. Therefore the flow, the level and the COD content in sewer networks are modelled by the Saint-Vernant equations (Crossley, 1999), (Michelsen, 1976), (Andersen, 1977). A simplified linear model is derived (Nielsen and T. S. Pedersen, 2020) showing that the mass flow in the sewer network can be modelled as a delay. The COD concentration propagation rate is assumed to be the same as for the flow.

In this work a more thorough analysis of the network model is presented. The SWMM model Fig. 5 is used to provide realistic data for the Fredericia sewer system. Average flows and concentration are used as initial values. A mass flow impulse and a COD concentration impulse are used to identify delays from the tank outlet to the WWTP inlet Fig. 6 upper left and lower left. The simulated values are given with a sampling rate $T_s$ of 5 minutes. Even though the outlet from the tank is diluted by mixing the flow and concentration from the remaining part of the net, the figures show clear delays for flow and concentration from the tank to the WWTP.

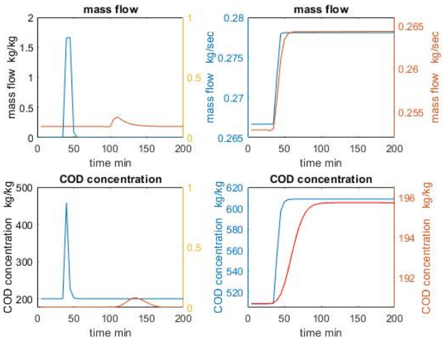

Figure 6: SWMM simulations for pipe responses. Upper left: Impulse mass flow added at the buffer tank (blue) and the flow at the WWTP (red). Lower left: Impulse in COD concentration added at the buffer tank (blue) and the concentration at the WWTP (dotted). Upper right: Mass flow at the buffer tank (blue) and at the WWTP (red). The input is delayed 70 minutes corresponding to 14 samples. Lower right: COD concentration at the buffer tank (blue) and at the WWTP (red). The input is delayed 90 minutes corresponding to 18 samples. At all simulations other inputs are constant.

The delays $T_{d-flow}$ and $T_{d-COD}$ are determined by cross correlation..

$$\begin{aligned} T_{d-flow} &= 14 samples = 70 minutes \\ T_{d-COD} &= 18 samples = 90 minutes \\ T_{d-diff} &= T_{d-COD} - T_{d-flow} \\ &= 4 samples = 20 minutes \end{aligned} \tag{1}$$

To find the transfer functions mass flow and concentration steps are added at the tank outlet. Fig. 6 upper right and lower right shows input steps and corresponding data sets for the inlet to the WWTP; in the figures the tank outputs are staggered by the identified delays. Fig. 6 upper right shows that the dynamics for mass flow is negligible and it will not be taken into account. Fig. 6 lower right is a step in COD concentration. The concentration dynamics are modelled as a second order system. The parameters are identified using the system identification tool SENSTOOL (**?**) giving a function of the type

$$k_{out}(s) = \frac{K\omega^2}{s^2 + 2\zeta\omega s + \omega^2} k(s) \tag{2}$$

In the optimisation algorithm the flow delay $T_{d-flow}$ is handled by shifting the industrial sequences in relation to the household sequences. This shifting is done for both flow and concentration. The additional concentration delay $T_{diff}$ is included in the model.

$$k_{out}(s) = \frac{K\omega^2}{s^2 + 2\zeta\omega s + \omega^2} e^{-T_{dif}s} k(s) \tag{3}$$

The network model is rewritten in state space form and discretised. The discrete form is

$$\begin{bmatrix} x_1(t+T_s) \\ x_2(t+T_s) \\ \vdots \end{bmatrix} = A_{sec} \begin{bmatrix} x_1(t) \\ x_2(t) \\ \vdots \end{bmatrix} + B_{sec} k(t) \tag{4}$$

$$k_{out} = C_{sec} \begin{bmatrix} x_1(t) \\ x_2(t) \end{bmatrix}$$

$x_1$ and $x_2$ is from equation 3, the additional states correspond to the number of samples in $T_{dif}$. In short the state space description for the pipe from the tank to the WWTP is written as

$$X_{net}(t+T_s) = A_{net} X_{net}(t) + B_{net} k(t) \tag{5}$$

$$k_{out} = C_{net} X_{net}(t)$$

The input to the pipes is output from the buffer tank. The tank is illustrated in Fig. 7. Tank inflow is industrial waste water mass flow $m_i$ with the concentration $k_i$, tank output is the mass outflow $m_o$ with concentration $k_o$.

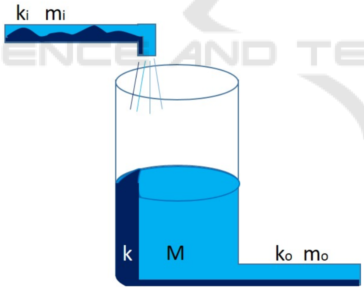

Figure 7: Buffer tank with COD (dark blue) and Water (light blue).

The total mass in the tank is given by:

$$\frac{dM(t)}{dt} = m_i(t) - m_o(t) \tag{6}$$

where $M$ is mass of fluid in the tank.
The COD mass balance is :

$$\begin{aligned} \frac{dM(t)k(t)}{dt} &= m_i(t)k_i(t) - m_o(t)k(t) \\ &= M(t)\frac{dk(t)}{dt} + k(t)\frac{dM(t)}{dt} \end{aligned} \tag{7}$$

where $k$ is COD concentration in the tank defined as

$$k = \frac{kg\ COD\ in\ tank}{mass\ in\ tank} \tag{8}$$

Combining equation 6 and 7 and linearizing gives a model for the MPC

$$\frac{d\hat{M}(t)}{dt} = \hat{m}_i(t) - \hat{m}_o(t) \tag{9}$$

$$\begin{aligned} \frac{d\dot{\hat{k}}(t)}{dt} = &- \frac{\bar{m}_i(\bar{k}_i - \bar{k})}{\bar{M}^2}\hat{M}(t) + \frac{\bar{k}_i - \bar{k}}{\bar{M}}\hat{m}_i(t) \\ &+ \frac{\bar{m}_i}{\bar{M}}\hat{k}_i(t) - \frac{\bar{m}_i}{\bar{M}}\hat{k}(t) \end{aligned} \tag{10}$$

where $\bar{\cdot}$ is the operating point and the small signal value $\hat{\cdot}$ is the deviation from the operating point. To simplify the notation $\hat{}$ is ignored in the succeeding.

The linearised equations 9 and 10 are formulated in a state space description.

Using the state vector $[\hat{M}(t)\ \ \hat{k}(t)]^T$ gives

$$\begin{aligned} \begin{bmatrix} \dot{\hat{M}}(t) \\ \dot{\hat{k}}(t) \end{bmatrix} = &\begin{bmatrix} 0 & 0 \\ -\frac{\bar{m}_i(\bar{k}_i - \bar{k})}{\bar{M}^2} & -\frac{\bar{m}_i}{\bar{M}} \end{bmatrix} \begin{bmatrix} \hat{M}(t) \\ \hat{k}(t) \end{bmatrix} \\ &+ \begin{bmatrix} 1 & 0 & -1 \\ \frac{\bar{k}_i - \bar{k}}{\bar{M}} & \frac{\bar{m}_i}{\bar{M}} & 0 \end{bmatrix} \begin{bmatrix} \hat{m}_i(t) \\ \hat{k}_i(t) \\ \hat{m}_o(t) \end{bmatrix} \end{aligned} \tag{11}$$

The input matrix is divided : $B_i$ acting on the industrial flow and concentration to the tank and $B_o$ acting on the output flow from the tank $\hat{m}_o$. This output flow $\hat{m}_o$ is the controlled signal.

$$\begin{bmatrix} \dot{\hat{M}}(t) \\ \dot{\hat{k}}(t) \end{bmatrix} = A \begin{bmatrix} \hat{M}(t) \\ \hat{k}(t) \end{bmatrix} + B_i \begin{bmatrix} \hat{m}_i(t) \\ \hat{k}_i(t) \end{bmatrix} + B_o \hat{m}_o(t) \tag{12}$$

On discrete form

$$\begin{bmatrix} \hat{M}(t+T_s) \\ \hat{k}(t+T_s) \end{bmatrix} = A_d \begin{bmatrix} \hat{M}(t) \\ \hat{k}(t) \end{bmatrix} + B_{id} \begin{bmatrix} \hat{m}_i(t) \\ \hat{k}_i(t) \end{bmatrix} + B_{od}\hat{m}_o(t) \tag{13}$$

The two equation systems 5 and 13 are combined in series giving a new state space system where the output is the tank mass $\hat{M}(t)$ and the concentration $\hat{k}_{out}(t)$.

$$X(t+T_s) = AX(t) + B_{id} \begin{bmatrix} \hat{m}_i(t) \\ \hat{k}_i(t) \end{bmatrix} + B_{od}\hat{m}_o(t) \tag{14}$$

$$\begin{bmatrix} \hat{M}(t) \\ \hat{k}_{out}(t) \end{bmatrix} = CX(t)$$

$X(t)$ is $\hat{M}$ and $\hat{k}$ in the tank combined with a number of states from the second order system combined with the delays $T_{dif}$.

### The Household Flow and Concentration

Using MPC for optimisation of the COD flow inlet to the WWTP necessitates prediction of the household flow. There is no on-line measurements available. Fredericia WWTP has measured flow and COD concentration at the inlet to the WWTF during October 2017, Fig. 1. This flow is a combination of household waste water, industrial waste water and rain. The industrial outlet is not periodic but it is known that the average industrial flow is approximately 50 % of the inlet to the WWTP during dry periods. Rain raises the flow and lower the concentration. In the network the household flow has different time delays from different parts of the town. Adding waste water from the inhabited areas these delays have to be taken into account when estimating the total flow from the households to the WWTP. In (Nielsen and T. S. Pedersen, 2020) it is shown that it is possible to find a model of the total the household flow based on the frequency spectrum for a large number of measurements. A Kalman filter based on this model and on-line measurements are able to give a prediction of the flow.

Due to the lack of measurements in the sewer-net it is chosen to use filtered and scaled 24-hour variations of the total flow and concentration measured at the inlet to the WWTP as typical average household waste water values. The optimisation is based on small signal values, therefore the mean value of flow and concentration are subtracted. Test sequences including e.g. weather forecast information can be added to the mentioned average flow. The small signal values of the household flow is $\hat{m}_h$ and the concentration is $\hat{k}_h$.

## 6 CONTROL OF THE BUFFER TANK OUTPUT

The aim of the optimisation is to minimise the variation of the COD-inlet flow to the WWTP.

The total discrete linearised inlet flow $\hat{Y}$ to the WWTP at time $j$ is

$$\begin{aligned}\hat{Y}(j) =&\bar{k}_{out}\hat{m}_o(j)+\bar{m}_o\hat{k}_{out}(j)+\bar{k}_h\hat{m}_h(j+T_d-1)\\&+\bar{m}_h\hat{k}_h(j+T_d-1)-\hat{\mu}\end{aligned} \tag{15}$$

where $\bar{k}_h$ is the average household concentration and $\hat{m}_h$ is the household flow variation, $\bar{m}_h$ is the average household flow and $\hat{k}_h$ is the household concentration variation. $\hat{\mu}$ is the mean value variation.

For the discretised and linear system dynamics, the MPC problem can be formulated as

$$\begin{aligned}\min_{m_o} \mathcal{J} = \sum_{j=0}^{H_p-1}&(\bar{k}_{out}\hat{m}_o(j)+\bar{m}_o\hat{k}_{out}(j)+\bar{k}_h\hat{m}_h(j+T_{dif}-1)\\&+\bar{m}_h\hat{k}_h(j+T_{dif}-1)-\hat{\mu})^2+(W_M\hat{M}(j))^2\end{aligned} \tag{16}$$

subject to :

$$x(j+1) = A_d x(j) + B_d m_o(j) \tag{17}$$

$W_M$ is a weight.

The constraints are given by the buffer tank size and the outflow capacity

$$\begin{aligned}0 \le M(j) \le M_{max}\\ 0 \le m_o(j) \le m_{o,max}\end{aligned} \tag{18}$$

Future values for $\hat{m}_o$, $\hat{k}$, $\hat{m}_h$ and $\hat{k}_h$ is part of the performance. The mean value $\mu$ is $\hat{\mu}+\bar{\mu}$ where $\hat{\mu}$ typically is 0, $\bar{\mu}$ is

$$\bar{\mu} = \frac{\sum_{j=1}^{H_p} k_h(j+T_{dif})m_h(j+T_{dif})+k_i(j)m_i(j)}{H_p} \tag{19}$$

The pipe model includes a delay $T_{d-flow}$ represented as 14 states, eq. (1). The off-line use of the optimisation makes it possible to to streamline the optimization code by reducing the pipe model order using time shifting. The tank out flow is shifted $T_{d-flow}$ in relation to the household sequences. This shifting is done for both flow and concentration. The additional industrial concentration delay $T_{diff}$ is included in the model.

The performance function is now

$$\begin{aligned}\mathcal{J} = \sum_{j=0}^{H_p-1}&(\bar{k}\hat{m}_o(j)+\bar{m}_o\hat{k}(j)+\bar{k}_h\hat{m}_h(j)+\bar{m}_h\hat{k}_h(j)-\hat{\mu})^2\\&+(W_M\hat{M}(j))^2\end{aligned} \tag{20}$$

The optimisation problem is solved in (Nielsen. and Pedersen, 2021) using the technique mentioned in (Maciejowski, 2002) and the MATLAB function *quadprog*.

## 7 TEST OF THE OPTIMISATION STRATEGY

Two different tests of the optimisation strategy are tested in this section. First the concept is tested using a simple model of the sewer network where the liquid flow from the tank to the WWTP is approximated by a delay and the concentration propagation rate is approximated by a delay combined with second order system. Secondly the optimisation algorithm is tested using the SWMM model of the Fredericia Nord sewer system in combination with a buffer tank (Pilgaard and Pedersen, 2018).

### 7.1 Test using a Simple Sewer Network Model

Here the control algorithm is tested using a model of the sewer network based on one delay for the mass flow and another delay combined with a second order transfer function for the COD concentration.

Fig. 8 shows the input sequences for the simulation. The household flow and concentration is based on measurements from Fredericia; The industrial flow and the concentrations are constructed test signals. COD flows are calculated.

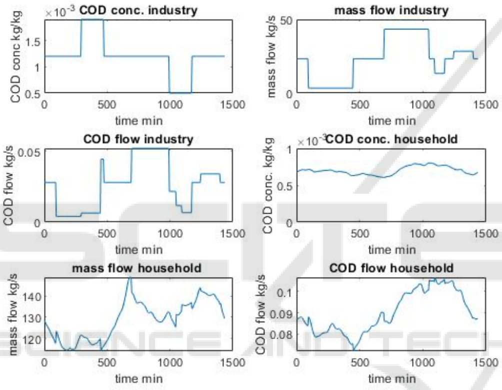

Figure 8: Inputs to the test. Upper left is COD concentration from industry, upper right is mass flow from industry, mid left is COD flow from industry, mid right is COD concentration from households, lower left is mass flow from households and lower right is COD flow from households.

The results of optimisation is shown in Fig. 9. The upper left figure shows the outflow from the tank, the upper right is the COD flow from the tank, the lower left plot shows the COD flow at the inlet to the WWTP and the lower right flow is the COD flow to the WWTP without a tank. It is seen that the algorithm is capable of smoothing changes in the inputs.

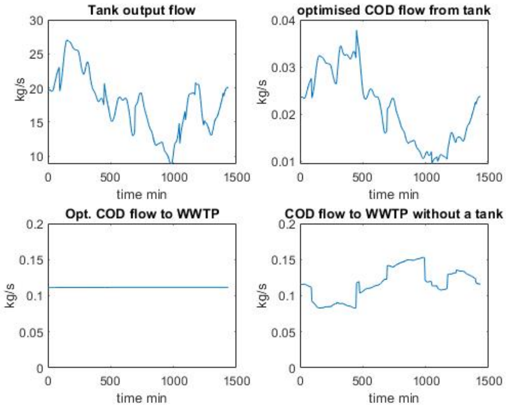

Figure 9: Optimisation results. Upper left is the outflow from the tank, upper right is the optimised COD flow the tank, lower left is the COD inflow to the WWTP using optimisation and lower right is the COD inflow to the WWTP without a tank.

### 7.2 Test using EPA SWMM

At the moment no tank has been established in Fredericia, therefore the control strategy is tested using the EPA SWMM model of Fredericia Nord sewer network with a tank added at the industrial area. Fig. 10 upper plot shows the COD flows from the household (yellow) and from industry (blue). The household COD flow is based on measured data, the industrial input is a test sequence. Additionally the optimised COD outflow from the buffer tank (red) is shown. Fig. 10 lower is the COD inflows to the WWTP corresponding to the wastewater flows in the upper figure. The blue curve is the inlet to the WWTP corresponding to the existing situation without a tank, the red curve is the result of inserting a tank and optimisation of the outlet. As seen the flows is significantly smoothened using the optimisation.

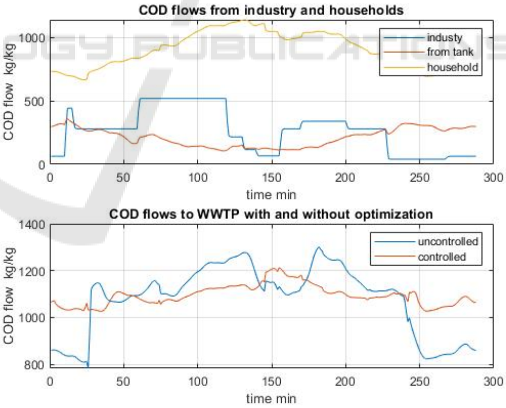

Figure 10: Upper:COD-flows from households(yellow) and industry (blue) used in the EPA SWMM simulation. Additionally the optimised COD outlet (red) from the tank is shown. Lower: COD flows at the inlet to the WWTP without a tank (blue) and with optimised tank outlet (red).

## 8 CONCLUSION

The aim of this work is to improve the purification and bio gas production in WWTPs by securing a smooth COD flow at the inlet. This is done by inserting a buffer tank in the sewer network and develop a optimisation algorithm for control of the tank outlet. As a transition from manual control with few interaction possibilities to full automation is difficult, an operator support system to assist in control of the tank is developed. The control system tends to optimise the output from the tank with respect to COD flow variations at the inlet to the WWTP using MPC. The MPC is based on knowledge on average household waste water mass flow and COD concentration, prediction of industrial mass flow and concentration and a model of the sewer network. Under linear assumptions it is shown that the mass flow model results in a time delay and the COD concentration propagation can be described as another delay model combined with a second order filter. The output from the MPC is the tank outlet flow. As the result of the work is part of the basis for building a buffer tank in Fredericia the system is tested on a simplified network model and on a realistic model for Fredericia Nord sewer network implemented in EPA SWMM (ProtectionAgency, 2016). Tests are showing good results for planning up to 24 hours ahead.

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