Demonstration of increasing the capacity of a wastewater treatment plant by process transitions during high flows in Oslo

Demonstration Report

Demonstration of increasing the capacity of a wastewater treatment plant by process transitions during high flows in Oslo

Demonstration Report

Prepared
enabling change

SEVENTH FRAMEWORK PROGRAMME

COLOPHON

Title
Demonstration of increasing the capacity of a wastewater treatment plant by process transitions during high flows in Oslo
Demonstration Report

Report number
PREPARED 2013.036

Deliverable number
D1.3.10

Author(s)
Ragnar Storhaug, Aquateam COWI
Rashid Abdi Elmi, Oslo Water and Sewerage Works

Quality Assurance
Bjarne Paulsrud Aquateam COWI

Document history

Version	Team member	Status	Date update	Comments
2			6.December 2013	
3			15.January 2014	

This report is:
PU = Public

Contents

©PREPARED

1 INTRODUCTION

The climate change will cause increased frequency of high intensity rainfalls, and will strongly influence the operation of municipal sewerage systems transporting both storm water and municipal wastewater (combined sewer systems). During high intensity rainfalls the capacity of the combined sewer systems will be exceeded, resulting in the discharge of combined storm water and untreated wastewater to receiving waters. Combined sewer overflows (CSOs) can introduce high concentrations of pathogenes and other pollutants into the recipient. Generally, CSOs can represent a threat to the public health as a result of contamination of drinking water sources and bathing waters.

This demonstration project focus on how a mechanical, chemical and biological (activated sludge) treatment plant can increase the treatment capacity during high flow events by introducing chemical precipitation in (coagulation + flocculation) the primary settling tanks, to prevent discharge of untreated wastewater to the recipient. The most important aspects of the demonstration project are:

- How peaks in the incoming wastewater flow are handled
- How the removal efficiency of the wastewater treatment plant will vary during the different operational modes

The Bekkelaget WWTP in Oslo, Norway is located approximately 3 kilometres south of the city centre of Oslo. The plant treats wastewater from about 290,000 person equivalents (pe) living in the eastern and south eastern parts of Oslo, and the plant has an average daily flow of 100,000 m^3/d and a maximum capacity of 260,000 m^3/d. The most important goal during high flow situations is to avoid discharge of untreated wastewater via CSOs to the inner part of the Oslofjord close to the city centre.

Oslo municipality owns the treatment plant and Bekkelaget Water Inc. (BEVAS) handles the operation on contract. Bekkelaget Water Inc. is owned by the Swedish company Purac AB. The demonstration project was carried out in close cooperation with the staff at the WWTP, and is a demonstration of a concept that was implemented before the PREPARED project started.

The demonstration project is based on data from 6 operational periods in 2012 and 2013. Bekkelaget WWTP is overloaded compared to the design capacity. This overload situation will from time to time result in different operational problems (e.g. high sludge volume index for the activated sludge), and the treatment capacity will be reduced. According to the plans of the city of Oslo, the treatment capacity of the plant will be extended in the near future. However, during the six operational periods, the process stability was good, and the plant was operated with normal treatment capacity. More details about the demonstration periods can be found in the Annex.

2 FINDINGS

2.1 The demonstration site

Bekkelaget WWTP has mechanical, chemical and biological (activated sludge) treatment steps ,including nitrogen removal (pre-denitrification), simultaneous precipitation with ferrous salts and dual-media filters as a polishing step before the wastewater is discharged at -50 m depth in the Oslofjord. Figure 1 shows a simplified process scheme of the Bekkelaget wastewater treatment plant. A more detailed description is given by Storhaug (2013).

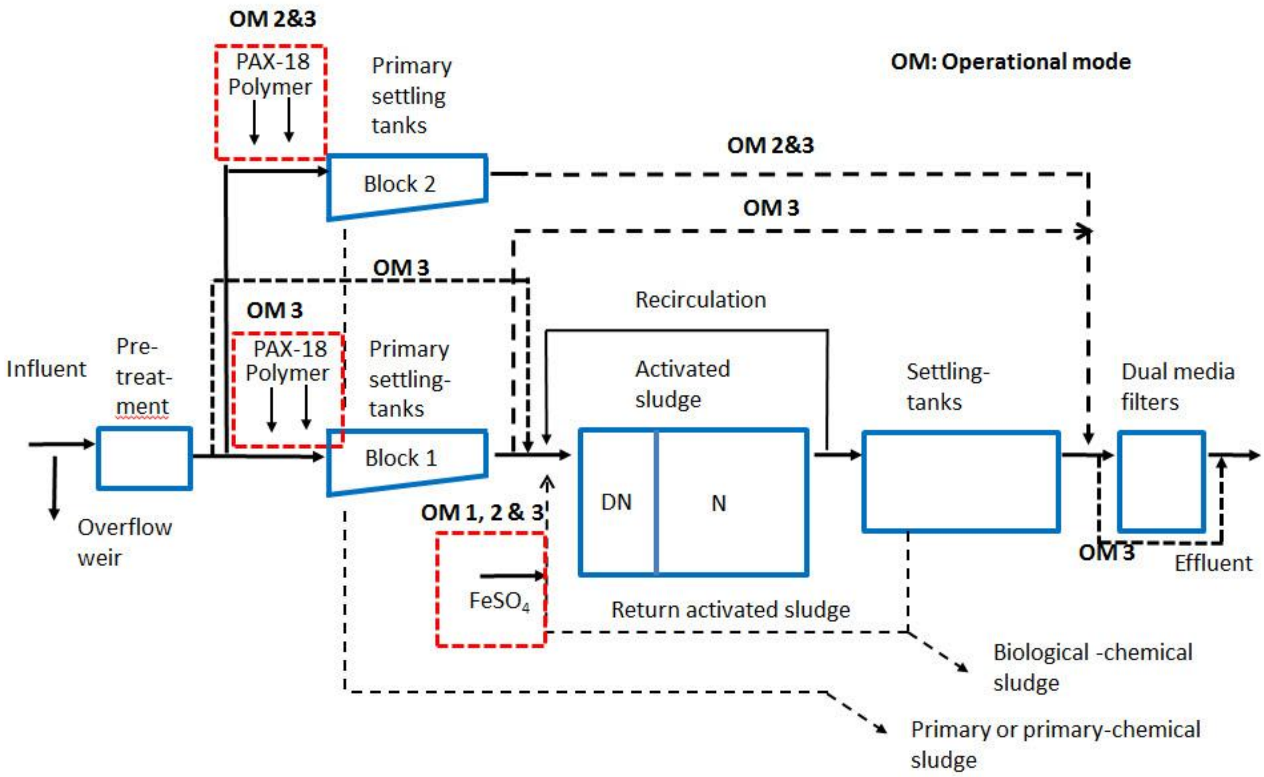

Figure 1. Simplified flow scheme for Bekkelaget WWTP

The process configuration of the plant (Figure 1) includes two primary settling tank blocks (Block 1 and Block 2). Primary settling tank Block 1 and 2 consist of 4 parallel settling tanks (totally 8 settling tanks). Each primary settling tank has a two-compartment flocculation unit at the inlet.

At normal flows (< 1.9 m^3/s) both Block 1 and Block 2 function as primary settling tanks. To increase the treatment capacity of the plant during high flow events, the primary settling tanks are transformed to a chemical precipitation (coagulation + flocculation) step. Consequently, a part of the incoming wastewater undergoes biological - chemical treatment, and a part of the wastewater undergoes only chemical treatment. The transformation of the primary settling tanks into chemical treatment steps prevents discharge of untreated wastewater via the overflow weir upstream the treatment plant.

Depending on the influent flow (Q) to the plant, Bekkelaget WWTP will have 3 modes of operation.

Mode 1: Dry weather flow	Q < 1.9 m^3/s	Primary settling in Block 1 and Block 2
Mode 2: Medium flow	1.9 m^3/s < Q< 3.0 m^3/s	Chemical precipitation in Block 2, primary settling in Bock 1
Mode 3: Maximum flow	3.0 m^3/s < Q<4.0 m^3/s	Chemical precipitation in both Block 1 and Block 2

The discharge requirements for Bekkelaget WWTP are :

- Average annual removal rate for total nitrogen: 70 %
- Average annual removal rate for total phosphorus: 90 %
- Discharges via two overflow weirs close to the plant have to be included in the calculation of the removal rates

The maximum mass transport of nitrogen and phosphorus via the overflow weirs must not exceed 2 % of the total mass transport to the plan

2.2 The concept of process transformation

A general increase of the treatment capacity for all process steps in the plant to make it possible to meet the discharge requirements during all flow situations, is very costly. An alternative to this strategy has been to introduce a process layout that easily can be changed during high flow events. During normal flow, the total flow to the plant undergoes the standard treatment scheme for the plant (operational mode 1)

During high flow events, the standard treatment scheme is changed and a part of the flow to the plant undergoes only chemical precipitation.

Chemical precipitation (coagulation and flocculation) has two main effects on the wastewater:

- Removal of soluble substances, primarily phosphorus
- Removal of colloids and small particles resulting in removal of organic matter, phosphorus, heavy metals, organic micropollutants and bacteria. Normally more than 90 % removal of total suspended solids (TSS) and total phosphorus can be expected. According to Norwegian experiences (Ødegaard, 1999), approximately 70 % of the organic matter in undiluted municipal wastewater will be colloids and small particles. Consequently a removal rate of 70- 80 % for organic matter (BOD and COD) can be expected for chemical precipitation (Ødegaard, 1999)

During high flows, the incoming wastewater is diluted, and such high removal rates as for undiluted wastewater will not be attainable by chemical precipitation. However, the removal rates are significant and represent a big improvement compared to discharge of untreated wastewater to receiving waters via storm water overflow weirs.

2.3 Results from the demonstration periods

During the 6 operational periods that are included in the demonstration project, the total flow to the plant received the following treatment (Table 1):

Table 1.Overview of wastewater treatment in the demonstration periods

Operational mode	Wastewater volume (m^3)	% of total wastewater volume (%)
1. Mechanical, chemical and biological treatment	25,072,534	86.4
2. and 3. Chemical treatment	3,544,638	12.2
Discharged via overflow weir	386,990	1.4

Totally 11.8 % of the wastewater was treated during operational mode 2 (chemical precipitation in primary settling tanks, Block 2), and 0.4 % of the wastewater was treated during operational mode 3 (chemical precipitation in primary settling tanks Block 1 and 2).

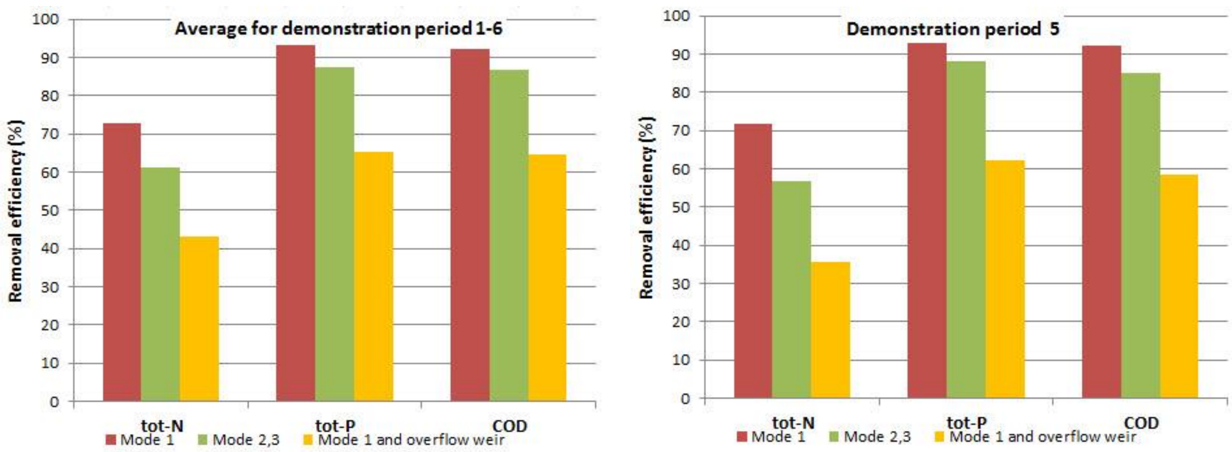

Figure 2 . Average removal efficiency for tot-N, tot-P and COD for all demonstration periods (left) and for demonstration period 5 (right)

Figure 2 shows average removal efficiency for three different situations

- Operational mode 1 (brown)
- Operational mode 2 and 3 (green)
- Operational mode 1 and including discharge via overflow weir (yellow)

The left part of Figure 2 shows the average removal efficiency for all 6 demonstration periods. The right part of the figure shows the removal efficiency for demonstration period 5. The brown columns show over all treatment efficiency for Bekkelaget WWTP in operational mode 1. The green columns shows the over all treatment efficiency in operational mode 2 and 3. On average the treatment efficiency for tot-N drops from 72.7 % to 61.0 % in operational mode 2 and 3. For tot-P the treatment efficiency drops from 93.3 % to 87.5 % and for COD the treatment efficiency drops from 92.2 % to 86.9 %.

The yellow columns show the removal efficiency without the flexibility to use operational mode 2 and 3. That means that the maximum capacity for the plant will be 1.9 m^3/s. The surplus flow has to be discharged via the overflow weir. Consequently, the reduction in removal efficiency will be considerably higher.

The right part of Figure 2 shows the removal efficiency in demonstration period 5. During this period, operational mode 2 and 3 were activated several times, and still the reduction in removal efficiency are acceptable compared to the option of using the overflow weirs (yellow columns).

Table 2 shows the average removal efficiency for the settling tank blocks during the operational modes 1 and 2 and 3.

Table 2.Average removal efficiency in the primary settling tanks during operational mode 1 and operational modes 2 and 3

Parameter		Removal efficiency for operational mode	
		1	2 and 3
tot-N	%	18.5	31.6
tot-P	%	35.6	83.6
COD	%	59.2	83.3

Chemical precipitation represents a considerable quality improvement of the effluent from the settling tanks. Depending of the flow, the effluent is discharged to the Oslofjord via the dual-media filters or directly to the fjord.

During operational mode 2 and 3, the average chemical dose was 10.0 g Al/m^3 (110g PAX-18/m^3). The average dosage of polymer was 0.5 g/m^3.

3 CONCLUSIONS AND RECOMMENDATIONS

Due to an expected increased frequency of heavy rain falls in the future, the risk of pollution from discharges via storm water overflow weirs will increase. Consequently, it will be of major importance to utilize the treatment capacity of the wastewater treatment plants as far as possible. Norwegian experiences shows that chemical precipitation (coagulation + flocculation) removes particles and soluble phosphorous to a great extent. However chemical precipitation has a minor effect on the removal of nitrogen. Based on the experiences from Bekkelaget WWTP and this demonstration project, the following conclusions and recommendations can be made:

- The process at Bekkelaget WWTP has three operational modes:
  Mode 1 Dry weather flow: $Q < 1.9\ m^3/s$
  Mode 2 Medium flow: $1.9\ m^3/s < Q < 3\ m^3/s$
  Mode 3 Maximum flow: $3\ m^3/s < Q < 4\ m^3/s$

  During mode 2 and mode 3, a part of the wastewater undergoes only chemical precipitation. This process flexibility has proved to reduce the volume of wastewater that has to be discharged through the storm water overflow weir.

- For existing wastewater treatment plants with primary settling tanks, an option will be to use all or a preselected number of the settling tanks for chemical treatment during high flows to the plant. This option requires that the necessary channel and pipe connections are available.

- For planning of new wastewater treatment plant, the option of turning a part of the normal treatment process into a simpler process for particle removal (e.g. chemical precipitation) with direct discharge to the recipient should be considered. During high flow events, the overall removal efficiency of the plant will be reduced, but discharges via the storm water overflow weirs will be limited.

4 REFERENCES

BEVAS (2013). Annual report 2012, 15/03/2013

Storhaug, R. (2013). Integrated real time control of sanitation systems in Oslo, PREPARED report no. PREPARED 2013.016, May 2013

Ødegaard, H. (1999). The influence of wastewater characteristics on choice of wastewater treatment method. Proc. Nordic conference on: Nitrogen removal and biological phosphate removal, Oslo, Norway' 2.-4. February 1999.

ANNEX

Table I Wastewater flow in the demonstration periods

Demon-stration period (No)		Operational mode 1	Operation al mode 2	Operational mode 3	Overflow weir	Total flow
1	Flow (m³)	2,615,408	274,778	16,771	42,451	2,949,408
	% of tot.flow (%)	88.7	9.3	0.6	1.4	-
2	Flow (m³)	4,203,293	416,180	8,918	0	4,628,391
	% of tot.flow (%)	90.8	9.0	0.2	0	-
3	Flow (m³)	6,244,313	275,581	4,566	0	6,524,460
	% of tot.flow (%)	95.7	4.2	0.1	0	-
4	Flow (m³)	1,913,622	50,825	1,904	0	1,966,351
	% of tot.flow (%)	97,3	2,6	0,1	0,0	-
5	Flow (m³)	7,892,712	2,080,566	82,784	319,548	10,375,610
	% of tot.flow (%	76.1	20.1	0.8	3.1	-
6	Flow (m³)	2,203,186	319,399	12,366	24,991	2,559,942
	% of tot.flow (%)	86,1	12.5	0.5	1.0	-

Table II Influent and effluent concentrations for COD, tot-N and tot-P in the demonstration periods

Demonstration period (No)		Influent			Effluent		
		COD	tot-N	tot-P	COD	tot-N	tot-P
		(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
1	Count	20	20	20	20	20	20
	Average	452	32.0	4.02	41	9.5	0.44
	Median	480	32.3	4.19	40	9.3	0.42
	Max	608	37.9	4.85	57	13.6	0.58
	Min	248	18.8	2.18	30	7.5	0.32
2	Count	30	30	30	30	30	30
	Average	443	29	4.03	42	8.7	0.54
	Median	424	29	4.09	40	8.8	0.47
	Max	632	37	5.13	63	11.6	0.93
	Min	314	22	2.85	32	6.8	0.36
3	Count	54	54	54	54	54	54
	Average	437	31	4.16	38	8.0	0.38
	Median	452	32	4.43	38	7.9	0.33
	Max	567	40	5.24	56	11.4	0.69
	Min	285	18	2.67	25	5.8	0.15
4	Count	17	17	17	17	17	17
	Average	437	31	4.30	23	8.8	0.07
	Median	437	31	4.26	22	8.9	0.06
	Max	537	38	5.11	40	12.5	0.18
	Min	336	25	3.30	17	5.9	0.05
5	Count	63	63	63	63	63	63
	Average	371	27	3.57	30	8.2	0.16
	Median	336	28	3.48	26	7.9	0.15
	Max	661	42	6.13	73	18.4	0.83
	Min	169	14	1.77	21	4.8	0.07
6	Count	20	20	20	19	19	19
	Average	405	28	3.99	25	8.4	0.11
	Median	424	31	4.37	25	6.7	0.11
	Max	657	40	5.93	35	13.5	0.17
	Min	178	14	1.37	15	4.8	0.07