The use of UV-VIS spectrometer probes to estimate additional loads drained by the central storage tunnel (CST) Graz to the WWTP Graz, Austria from the CST MONITORING Project

10.06.2017

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Challenges for WWTP Graz

High population growth

Increase of flowrates and pollution loads due to new Central Storage Tunnel (CST)

Capacity of 500,000 PE (last expansion 2007 based on 2001)
max $Q_{dwf} = 1.6 \text{ m}^3/\text{s}$; max $Q_{d,dwf} = 90,000 \text{ m}^3/\text{d}$
max $Q_{wwf} = 3.2 \text{ m}^3/\text{s}$; max $Q_{d,wwf} = 276,480 \text{ m}^3/\text{d}$
Challenge 1: Population growth

- 2001: 225,000
- 2017: 287,000
- 2034: 329,000

Current loading (2016): 560,000 PE (BOD) and 480,000 PE (COD)

No problems regarding carbon removal but sometimes problems with nitrification and the NH4-N threshold values during winter season

(Stadt Graz, Referat für Statistik, 2015)
Challenge 2: Central Storage Tunnel (CST)

- Collection and temporal storage of \(3 + 16 = 19\) CSOs from 35 CSO along river Mur

- Routing and treatment of the temporal stored volumes at WWTP Graz

- 94 000 m³ additional storage volume in the sewer system
Central Storage Tunnel Graz

- In total 8.4 km (3.2 km + 5.2 km)
- In total 94 000 m³ (25 000 m³ + 69 000 m³)
- Slope: 0.16%
- 7 cascades equipped with movable weirs to activate volume

CST II: Under construction: 2017 – 2022

CST I: In operation since 2016
Goals for CST-MONITORING Project

- Influence of additional pollution loads resulting from the CST I+II on the purification capacity of WWTP Graz => iCST-Project (2015)

- Calibration and validation of the integrated iCST-model

- Estimation of the additional pollution loads routed by the CST I+II to WWTP Graz

- => Online-Monitoring in CST and at WWTP Graz (since 2015)
Installed Sensor Network
MS-CST-KS01 failed due to clogging 😞

⇒ Clogging the sensors due to fixed installation in the CST 😞
Installed Sensor Network
MS-WWTP-inflow (2015) failed due to sand and grit in the old flume 😞

=> Sand and grit in the flume 😞
Inflow sampling points at WWTP
Quality-Station – „WWTP-inflow“ 😊
Bypass-installation (Flume)

System „uni-pass“
(Fa. unimon GmbH)
Volume = 120 L
Q = 2 L/s
v = 3 cm/s
A = 600 cm²
Quality-Station – „WWTP-inflow“

Bypass-operation

Measurement interval: 2 min

- Bypass-operation
  - Automatic emptying and backwashing of the flume each 6 hours.

- Automatic sensor-cleaning
  - By compressed air:
    - Interval: 300 s
    - Duration: 3 s
    - Pressure: 6,0 bar
  - By wiper (Turbidity probe from Fa. Hach)

- Additional manual cleaning of the flume and the sensors:
  - Approx. once a week
Measurement campaigns and maintainance

WWTP-inflow
# Measurement campaigns and maintainance

<table>
<thead>
<tr>
<th>KW-Woche</th>
<th>Mo</th>
<th>Di</th>
<th>Mi</th>
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<tr>
<td>KW 17 25.04. - 01.05.</td>
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</table>

- **K**: Campaigns for local calibration
- **S**: Special campaigns
- **W**: Maintainance
Local calibration – „WWTP-inflow“
Spectrometer probes → COD

\[ y = 1.78 \times x - 88.31 \]
\[ R^2 = 0.95 \]
64 Stichproben

\[ y = 2.78 \times x - 139.35 \]
\[ R^2 = 0.94 \]
64 Stichproben

=> Local COD all weather calibration based on 74 reference samples
Local calibration – „WWTP-inflow“
Spectrometer probes → TSS

=> Local TSS (and BOD$_5$) all weather calibration based on 50 reference samples
Results I

Daily dry weather pollutographs

WWTP-inflow
Daily dry weather pollutographs
WWTP-inflow

Criteria for dry weather definition:
- **Criterion 1:** Maximum flowrate $Q_{\text{max}} < 1 400 \text{ L/s}$
- **Criterion 2:** Maximum daily flow volume $Q_d < 80.000 \text{ m}^3/\text{d}$

Monitoring-period:
- 30.04.2016 – 30.04.2017 (366 days, 361 proofed to be valid)
- Dry weather days: 238 days
  - Working days: 174 days
  - Weekend days: 64 days
- Wet weather days: 128 days
WWTP inflow: Daily dry weather pattern

Flowrates (Data base: 172 working and 64 weekend days)

Flowrates Q (L/s) – Dry weather flow

Time (hours/day)
WWTP inflow: Daily dry weather pattern
COD (Data base: 172 working and 64 weekend days)
WWTP inflow: Daily dry weather pattern

\( \text{BOD}_5 \) (Data base: 238 dry weather days)
WWTP inflow: Daily dry weather pattern

**TSS** (Data base: 238 dry weather days)
WWTP inflow: Daily dry weather pattern

**NH4-N** (Data base: 166 dry weather days)
Results II

Estimation of additional loads resulting from CST I+II emptying to WWTP Graz
Method: Load Estimation

Method based on:

Loadrate – without adjustment
L (kg/min)

Loadrate – with adjustment
L (kg/min)

=> Additional load due to emptying

Daily dry weather pattern
(Statistics)

Measurements

Fitting before
Fitting after
Event loads resulting from CSO tanks and CST I emptying

# 55 Rain events from 30.04.2016 – 30.04.2017

# 7 Rain events with measurable emptying loads from CSO tanks and CST I

- Emptying event 02: 08.02.2017 08:00 – 09.02.2017 06:30
- Emptying event 04: 01.03.2017 05:39 – 01.03.2017 15:22
- Emptying event 05: 05.04.2017 09:11 – 05.04.2017 19:15
- Emptying event 07: 23.05.2017 00:36 – 24.05.2017 20:00
**Event loads resulting from CSO tanks and CST I emptying**

Estimation for COD and BOD$_5$ loads

- Currently maximum activatable storage volume = 23 000 m$^3$
  - CSO tank: 12 000 m$^3$
  - CST I: 11 000 m$^3$ (volume which could be emptied by the already installed CSO tank pumps)

<table>
<thead>
<tr>
<th>Event #</th>
<th>Emptying Duration</th>
<th>Water level CSO tank</th>
<th>Emptied Volume</th>
<th>Emptied load COD (kg)</th>
<th>Emptied EMC COD (mg/L)</th>
<th>Emptied load BOD (kg)</th>
<th>Emptied EMC BOD (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>780</td>
<td>65</td>
<td>16 500</td>
<td>5 000</td>
<td>303</td>
<td>2 600</td>
<td>158</td>
</tr>
<tr>
<td>02</td>
<td>1350</td>
<td>80</td>
<td>21 300</td>
<td>7 600</td>
<td>357</td>
<td>4 600</td>
<td>216</td>
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<tr>
<td>03</td>
<td>800</td>
<td>60</td>
<td>15 200</td>
<td>7 900</td>
<td>520</td>
<td>3 800</td>
<td>250</td>
</tr>
<tr>
<td>04</td>
<td>582</td>
<td>55</td>
<td>13 200</td>
<td>7 700</td>
<td>583</td>
<td>3 200</td>
<td>242</td>
</tr>
<tr>
<td>05</td>
<td>603</td>
<td>50</td>
<td>12 300</td>
<td>7 000</td>
<td>569</td>
<td>2 800</td>
<td>228</td>
</tr>
<tr>
<td>06</td>
<td>753</td>
<td>57</td>
<td>15 300</td>
<td>2 900</td>
<td>190</td>
<td>1 500</td>
<td>98</td>
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<td>07</td>
<td>2603</td>
<td>90</td>
<td>23 000</td>
<td>6 100</td>
<td>265</td>
<td>4 000</td>
<td>174</td>
</tr>
</tbody>
</table>

32 mm prec.
Event loads resulting from CSO tanks and CST I emptying
Estimation for COD and BOD$_5$ loads

- Currently maximum activatable storage volume = 23 000 m$^3$
  - CSO tank: 12 000 m$^3$
  - CST I: 11 000 m$^3$ (volume which could by emptied by the already installed pumps)

<table>
<thead>
<tr>
<th>Event #</th>
<th>Emptying Duration (min)</th>
<th>Water level CSO tank (%)</th>
<th>emptied Volume (m$^3$)</th>
<th>COD Emptied load (kg)</th>
<th>Emptyed EMC COD (mg/L)</th>
<th>BOD Emptied load (kg)</th>
<th>Emptyed EMC BOD (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>12 300</td>
<td>2 900</td>
<td>190</td>
<td>1 500</td>
<td>98</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>16 700</td>
<td>6 300</td>
<td>398</td>
<td>3 200</td>
<td>195</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
<td>23 000</td>
<td>7 900</td>
<td>583</td>
<td>4 600</td>
<td>250</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Shown minimum, maximum and mean values are independent!
Event loads resulting from CSO tanks and CST I+II emptying (careful extrapolation!)

- Maximum activatable storage volume = 106 000 m³
  - CSO tank: 12 000 m³
  - CST I+II: 94 000 m³
- Current daily mean loads to WWTP during dry weather: 58 000 kg COD/d and 33 000 kg BOD/d

<table>
<thead>
<tr>
<th></th>
<th>COD (mg/L)</th>
<th>Emptied EMC</th>
<th>Emptied load (kg)</th>
<th>% of current mean COD load to WWTP</th>
<th>BOD (mg/L)</th>
<th>Emptied EMC</th>
<th>Emptied load (kg)</th>
<th>% of current mean BOD load to WWTP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Minimum load</strong></td>
<td>190</td>
<td>106 000</td>
<td>20 100</td>
<td>35%</td>
<td>98</td>
<td>10 400</td>
<td>31%</td>
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<tr>
<td><strong>Mean load</strong></td>
<td>398</td>
<td>106 000</td>
<td>42 200</td>
<td>73%</td>
<td>195</td>
<td>20 700</td>
<td>63%</td>
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<tr>
<td><strong>Maximum load</strong></td>
<td>583</td>
<td>106 000</td>
<td>61 800</td>
<td>107%</td>
<td>250</td>
<td>26 500</td>
<td>80%</td>
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</table>
Estimation of mean COD concentration from CSO R05

CSO R05:
- $A_{\text{total}} = 456$ ha (ca. 8 %)
- $A_{\text{imp}} = 126$ ha (ca. 4 %)
- Inhabitants: 19,500
Estimation of mean COD concentration from CSO R05

- CSO R05 has to be connected to CST II
- Data base: 47 CSO events

<table>
<thead>
<tr>
<th>47 CSO events into river Mur</th>
<th>Duration of overflow (min)</th>
<th>Overflow volume (m³)</th>
<th>Overflow load (kg)</th>
<th>EMC COD (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum value</td>
<td>14</td>
<td>11</td>
<td>3</td>
<td>108</td>
</tr>
<tr>
<td>Mean value</td>
<td>83</td>
<td>2 113</td>
<td>433</td>
<td>292</td>
</tr>
<tr>
<td>Maximum value</td>
<td>291</td>
<td>15 229</td>
<td>3 097</td>
<td>921</td>
</tr>
</tbody>
</table>

Shown minimum, maximum and mean values are independent!

Based on mean EMC for COD => 106 000 m³ * 292 mg/L => 31 000 kg (53%)
Summary so far

- We failed so far with direct quality measurements in the CST.
- The installed sensor network in the influent of the WWTP is suitable to measure the quality dynamics resulting from CST emptying.
- With the proposed method we are able to estimate even the additional loads which should be treated at the WWTP.
- First results and careful extrapolations for the total CST show very challenging additional loads for the WWTP.
- These first results have to be confirmed by more emptying events especially during the summer period.
- If you can provide the i::scan with a comprehensive sample of good reference samples it is delivering comparable results as the UV/VIS spectrometer.
Acknowledgements

The presenters would like to thank all colleagues from Holding Graz Water Management for funding and supporting this project. Special gratitude we want to express to the staff people from WWTP Graz and to the lab and IT team of our institute.

Thank you for your attention!

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