Urban stormwater management: Calibration and validation of an off-line retention tank (RT) dynamic model for water quality

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Université Laval

Ville de Québec
Outline

- Problem statement
- Proposed model
- Calibration method
- Validation results
- Conclusions/Perspectives
Problem statement

BEFORE

Combined sewer → WwTP

Overflow

Receiving body
Problem statement

BEFORE

Combined sewer → WwTP

Overflow

AFTER

Combined sewer → RT → WwTP

Overflow

WwTP performance decrease !!!

Receiving body
Problem statement

Which impact is worse for receiving body?

=> Need for integrated modelling
Problem statement

- Pollutant characterisation in RT
  - Little data during rain events mainly for: effluent quality returned to WWTP, Vs distribution

- RT water quality modelling
  - No existing calibrated nor validated RT model

- RT in IUWS modelling
  - RT models used in IUWS are quite simple: removal rate or linear settling
  - Important for description of wet weather quality
Outline

- Problem statement
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- Calibration method
- Validation results
- Conclusions/Perspectives
Model state variables

Input

CODt

TSS
Model state variables

Literature + respirometry
Proposed model
Outline

- Problem statement
- Proposed model
- Calibration method
- Validation results
- Conclusions/Perspectives
Calibration

Data fit to TSS and COD measurement from the outlet of an off-line RT

Control chamber

Interceptor

Pumping well

Overflow to the receiving water body

Saint-Charles river

Intro

Proposed model

Calibration model

Validation results

Conclusions
Calibration

Initial parameter set

PW layer volumes

$V_{\text{Min}}$, $V_{\text{Mix}}$, $V_{\text{Down}}$

$V_{\text{Up}} = 80 \text{ m}^3$,

($\sim 2.2 \text{ m}$)

$V_{\text{Mix}} = 11 \text{ m}^3$

($\sim 0.4 \text{ m}$)

$V_{\text{Down}} = 13 \text{ m}^3$

($\sim 0.3 \text{ m}$)
Calibration

Initial parameter set

PW layer volumes
$V_{\text{Min}}, V_{\text{Mix}}, V_{\text{down}}$

RT/PW resuspension rates and sludge accumulation
$R_{\text{RT}}, R_{\text{PW}}, A_{\text{PW}}$

No

Yes

$R_{\text{RT},j} = 1000 \text{ h}^{-1}$

$R_{\text{PW},j} = 200 \text{ h}^{-1}$

$A_{\text{PW},j} = 83\%$
Calibration

Initial parameter set

PW layer volumes
\( V_{\text{Min}}, V_{\text{Mix}}, V_{\text{down}} \)

RT/PW resuspension rates and sludge accumulation
\( R_{\text{RT}}, R_{\text{PW}}, A_{\text{PW}} \)

Vs fractionation
\( \text{Vs1, Vs2, Vs3} \)
Classes fractionation (ViCAs)

- Mass of particles with a $V_s$ less than (%)
- Settling velocity $V_s$ (m/h)

- 68%
- 1.6 m/h
Classes fractionation (ViCAs)

Mass of particles with a Vs less than (%)

Class 1

Class 2

Class 3

Settling velocity Vs (m/h)

0.01 0.10 1.00 10.00 100.00
Classes fractionation (ViCAs)

Mass of particles with a $V_s$ less than (%)

Settling velocity $V_s$ (m/h)
Calibration

Initial parameter set

PW layer volumes
$V_{\text{Min}}, V_{\text{Mix}}, V_{\text{down}}$

No

RT/PW resuspension rates and sludge accumulation
$R_{\text{RT}}, R_{\text{PW}}, A_{\text{PW}}$

Yes

Vs fractionation
Vs1, Vs2, Vs3

Yes

One Vs average of ViCAs

One Vs average distribution

<table>
<thead>
<tr>
<th>Number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10-10-80</td>
</tr>
<tr>
<td>2</td>
<td>20-20-60</td>
</tr>
<tr>
<td>3</td>
<td>10-80-10</td>
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<tr>
<td>4</td>
<td>20-60-20</td>
</tr>
<tr>
<td>5</td>
<td>80-10-10</td>
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<tr>
<td>6</td>
<td>60-20-20</td>
</tr>
<tr>
<td>7</td>
<td>33-34-33</td>
</tr>
<tr>
<td>8</td>
<td>15-40-45</td>
</tr>
</tbody>
</table>
Calibration

Inflow: June 6th 2010: 2 periods → 2 Vs distributions

Time boundary between wash-off/dilution
Calibration

Initial parameter set

Yes

PW layer volumes

$V_{\text{Min}}$, $V_{\text{Mix}}$, $V_{\text{down}}$

No

RT/PW resuspension rates and sludge accumulation

$R_{\text{RT}}$, $R_{\text{PW}}$, $A_{\text{PW}}$

Yes

Vs fractionation

$V_s1$, $V_s2$, $V_s3$

Yes

One average of ViCAs

Two ViCAs

(wash-off/dilution)

One Vs average distribution

<table>
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<tr>
<td>8</td>
<td>15-40-45</td>
</tr>
</tbody>
</table>

Two Vs distributions

<table>
<thead>
<tr>
<th>Wash-off (%)</th>
<th>Dilution (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-40-45</td>
<td>45-25-30</td>
</tr>
</tbody>
</table>

Same Vs
Calibration

Initial parameter set

PW layer volumes
\( V_{\text{Min}}, V_{\text{Mix}}, V_{\text{down}} \)

No

RT/PW resuspension rates and sludge accumulation
\( R_{\text{RT}}, R_{\text{PW}}, A_{\text{PW}} \)

Yes

Vs fractionation
\( V_{s1}, V_{s2}, V_{s3} \)

Yes

No, Yes

RT/PW hydrolysis rates
\( k_{h1}, k_{h2}, k_{h3} \)

Yes

No

\( k_{h1} = 2 \text{ h}^{-1} \)

\( k_{h2} = 1.5 \text{ h}^{-1} \)

\( k_{h3} = 0.5 \text{ h}^{-1} \)
Calibration
Laboratory experiment data vs. simulation data

RT

Composite sample

Experiment
Closed-top
Completely mixed

Measurements
CODt
CODs

Concentration (gO2/m³)

Time (h)

CODs sim
CODt sim
CODs obs
CODt obs
Calibration

Initial parameter set

PW layer volumes
\( V_{\text{Min}}, V_{\text{Mix}}, V_{\text{down}} \)

RT/PW resuspension rates and sludge accumulation
\( R_{\text{RT}}, R_{\text{PW}}, A_{\text{PW}} \)

Vs fractionation
\( V_{s1}, V_{s2}, V_{s3} \)
One average of ViCAs
Two ViCAs (wash-off/dilution)

RT/PW hydrolysis rates
\( k_{h1}, k_{h2}, k_{h3} \)

Yes
No

CALIBRATED MODEL
Calibration

July 27th 2009

[Graphs showing concentration and Q out over time]
Calibration

September 27\textsuperscript{th} 2009

Obs TSS Q out

Obs CODt Q out

Time (h)

Concentration (g/m\textsuperscript{3})

Q (m\textsuperscript{3}/h)

Concentration (g/m\textsuperscript{3})

0

1000

1100

1200

200

400

600

800

1000

1200

1400

1600

1800

0

200

400

600

800

1000

1200

1400

1600

1800

0

200

400

600

800

1000

1200

1400

1600

1800

0
Outline

- Problem statement
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Validation

July 13\textsuperscript{th} 2010: 2 periods of emptying
Outline

- Problem statement
- Proposed model
- Calibration method
- Validation results
- Conclusions/Perspectives
Conclusions

- A new fast RT model describing the TSS and total COD fluxes, both in the tank and in the pumping well
  - Settling
  - Hydrolysis

- It takes into account the settling velocity distribution variation depending on the inflow TSS concentration

- As far as known, model calibration and validation performed for the first time
Perspectives

- Propose an integrated model “sewer – RT – primary clarifier”
- Validate the Vs distribution dynamics (3 classes)
- Carry on a parameter sensitivity analysis
Questions

Acknowledgements

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