Dynamics of pollutant discharge in combined sewer systems during rain events: chance or determinism?

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Context

• Importance of urban wet weather pollution;

• Negative impact of TSS (main vector of certain contaminants);

• High temporal variability of TSS concentrations and fluxes not only during event but also between events;

• Some studies have observed some spatial homogeneity between sites, as regards fluxes and concentrations (Kafi Benyahia et al. 2008: Spatial variability of the characteristics of combined wet weather pollutant loads in Paris. Water Research 42, 539-549)

• Conventional sampling methods on samples collected during rain events:
  ▪ limited number of samples per event
  ▪ some events can be sampled

• Continuous turbidity measurement in sewer systems:
  ▪ indirect access to the dynamics of particulate pollution
SOERE URBIS databases (A long-term Observation System for research and Experimentation on urban environment)

- Statistically representative databases for continuous water flow and turbidity measurements at the outlet of:
  - two embedded catchments in Paris (Quais and Clichy)
  - one in Lyon (Ecully)
  - hundreds of rainfall events and dry weather days

- Aim of this study
  - Assessment of the variability of TSS fluxes and concentrations observed at the outlet of these catchments during both wet and dry weather periods
### Description of the sites

<table>
<thead>
<tr>
<th>Land uses</th>
<th>Quais</th>
<th>Clichy</th>
<th>Outside Quais</th>
<th>Ecully</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface area (ha)</td>
<td>402</td>
<td>942</td>
<td>540</td>
<td>245</td>
</tr>
<tr>
<td>Runoff coefficient (-)</td>
<td>0.64</td>
<td>0.68</td>
<td>0.71</td>
<td>0.15</td>
</tr>
<tr>
<td>Active surface (ha)</td>
<td>257</td>
<td>641</td>
<td>383</td>
<td>37</td>
</tr>
<tr>
<td>Median slope (%)</td>
<td>0.14</td>
<td>0.10</td>
<td>0.10</td>
<td>2.7</td>
</tr>
</tbody>
</table>

- Quais catchment is totally embedded in the Clichy catchment complementary fraction of the “Quais” catchment denoted “Outside Quais”
- Ecully’s characteristics are quite different vs. Parisian sites: low population density, residential area with steep slopes, and no street cleaning
- Paris sewer network is known for its high deposit level but this is not the case for Ecully
@ each site: 2 redundant turbidity sensors, 1 flow-rate sensor & 1 conductivity sensor

Flow-rate, turbidity and conductivity measurements: time step: 1 minute @ Quais & Clichy (2006), 2 minutes @ Ecully (2004→2008))

Turbidity-TSS average relationship was applied

Available data set

<table>
<thead>
<tr>
<th></th>
<th>Quais</th>
<th>Clichy</th>
<th>Common events</th>
<th>Ecully</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry weather</td>
<td>221</td>
<td>215</td>
<td>209</td>
<td>180</td>
</tr>
<tr>
<td>Wet weather</td>
<td>74</td>
<td>88</td>
<td>70</td>
<td>239</td>
</tr>
</tbody>
</table>
RESULTS AND DISCUSSION

- Volumes, masses and concentrations at the level of rainfall events and dry days

<table>
<thead>
<tr>
<th></th>
<th>Wet weather</th>
<th>Dry weather</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ecully</td>
<td>Outside Quais</td>
</tr>
<tr>
<td>Volumes (m$^3$/act.ha)</td>
<td><img src="image1" alt="Box plot comparison" /></td>
<td><img src="image2" alt="Box plot comparison" /></td>
</tr>
<tr>
<td>Mass (Kg/act.ha)</td>
<td><img src="image3" alt="Box plot comparison" /></td>
<td><img src="image4" alt="Box plot comparison" /></td>
</tr>
<tr>
<td>Concentration (mg/l)</td>
<td><img src="image5" alt="Box plot comparison" /></td>
<td><img src="image6" alt="Box plot comparison" /></td>
</tr>
</tbody>
</table>
RESULTS AND DISCUSSION

- Volumes, masses and concentrations at the level of rainfall events

Correlations between sites for common rainfall events

(a) Volume (m$^3$/active ha) $R^2 = 0.83$

(b) Mass (Kg/active ha) $R^2 = 0.80$

(c) EMC (mg/l) $R^2 = 0.90$

(a) Volume (m$^3$/active ha) $R^2 = 0.66$

(b) Mass (Kg/active ha) $R^2 = 0.59$

(c) EMC (mg/l) $R^2 = 0.74$
CONTRIBUTION OF SOURCES

- Contribution of different sources to mass results for each rain event

- 3 distinct origins of event load during a rain event ($M_{\text{Outlet}}$):
  - Wastewater ($M_{\text{WW}}$),
  - Surface runoff ($M_{\text{SR}}$)
  - Sewer deposits ($M_{SD}$)

$$M_{SD} = M_{\text{Outlet}} - M_{\text{WW}} - M_{\text{SR}}$$
RESULTS AND DISCUSSION

• Contribution of different sources to mass results for all rainfall events

Absolute contribution

Relative contribution

<table>
<thead>
<tr>
<th>Distribution</th>
<th>Absolute contribution (kg/act.ha)</th>
<th>Relative contribution (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WW</td>
<td>Quais</td>
<td>Clichy</td>
</tr>
<tr>
<td>SR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Differences $d_{10}$-mean-$d_{90}$
RESULTS AND DISCUSSION

- Contribution of different sources to mass results for common rainfall events

Correlations between sites (Quais & Clichy)

(a) WW contribution (Kg/act.ha) \( R^2 = 0.72 \)

(b) SR contribution (Kg/act.ha) \( R^2 = 0.70 \)

(c) SD contribution (Kg/act.ha) \( R^2 = 0.74 \)
Conclusions

• The results confirmed obtained for other Paris sites with similar land uses;
• Masses and concentrations for different rain events are correlated between sites with similar land uses
• The correlation between the concentrations is unexpected and may be a clue for some deterministic processes
• Regarding urban water discharges, wastewater is a decisive factor for two reasons:
  ▪ Wastewater generates straightforwardly a significant part of the total event load
  ▪ deposits contribution is also comparatively substantial;
• substantial contribution of sewer deposits is not specific to sewer systems like the Paris sewer network (low slope, coarse sewer deposits)
THANK YOU FOR YOUR ATTENTION

Questions?