A risk-based approach to wastewater treatment plant cost-effective permitting

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Motivation

Challenge 1: Increasingly stringent water quality standards
(e.g. Water Framework Directive)

Challenge 2: Carbon reduction commitment
(e.g. CRC Energy Efficient Scheme)

Energy consumption & GHGs emission

Tightening up effluent discharge limits

Challenge 1: Increasingly stringent water quality standards
(e.g. Water Framework Directive)
Motivation

- Sustainable urban design
- Pollution prevention
- Resource recovery and recycling
- Innovative wastewater treatment technologies
- Efficient operation and control of UWWSs
- Safe wastewater disposal

Technological innovation solutions

- Modelling of urban wastewater systems;
- Optimisation of control strategies.

Higher benefit

Less change
Current permitting policy

Stochastic permitting model River Quality Planning (RQP):

Singe objective:
Compliance of the environmental standards

Multi-criteria analysis?
(e.g. environmental risk, cost, GHG emissions)
Methodology

a) Environmental risk function:

![Graphs showing environmental risk function](image)

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Methodology

b) Cost function:

- Dynamic modelling of the WWTP;
- Performance indicators:
  - Operation cost (GHG emissions, cost); and
  - Effluent water quality (in 95%ile).
- Optimisation of WWTP control strategy:
  - Optimal search methods (e.g. Genetic Algorithm); or
  - Scenario analysis.
Methodology

c) Cost-risk analysis:

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Diagram:
- Dynamic model
- RQP+
- Cost function
- Risk function
- Cost-risk analysis

Graph:
- Total operational cost (Million £/year)
- WWTP effluent 95%ile water quality (mg/L)
- Environmental risk (mg/L)

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Case study

A semi-hypothetical case study:

River and rainfall: English Midlands;

Wastewater treatment plant (simulated by SIMBA): Norwich (UK);
Results and discussion

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<table>
<thead>
<tr>
<th>Scenario</th>
<th>Current</th>
<th>Permit</th>
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<tbody>
<tr>
<td>A1</td>
<td>3.9 mg/L</td>
<td>2.1 mg/L</td>
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</tbody>
</table>

However.... Unachievable!
Results and discussion

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'B1' compared to 'A1':
- Effluent 95%ile: 73% lower;
- Operational cost: 8% lower;
- Risk: 75% lower;

'A1' & 'B1':
- Same aeration rate;
- Different sludge pumping rates;

Baseline & optimised sludge pumping rates!
Results and discussion

Scenario analysis to optimise control strategy in WWTP:

Baseline sludge pumping rate: RS- 14400 m$^3$/d, WS- 660 m$^3$/d;
Optimised sludge pumping rate: RS- 24000 m$^3$/d, WS- 240 m$^3$/d;
Results and discussion

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'B1' (current): 1.1 mg/L;
'B2' (cost-effective): 1.5 mg/L;
'B3' (least cost): 1.9 mg/L;
✓ All comply with the WFD;

From 'B1' to 'B2':
✓ Operational cost: 60,000 £/year (8%) saving;
✓ Risk: 0.0016 mg/L (22%) increase;

From 'B1' to 'B3':
✓ Operational cost: 70,000 £/year (9%) saving;
✓ Risk: 0.0034 mg/L (47%) increase;
Conclusions

- **A cost-effective effluent permitting approach** based on **integrated cost-risk analysis**:
  a) Cost function: scenario analysis (based on dynamic models);
  b) Risk function: exploiting information already provided in RQP and by adding a consequence function;

- **Benefits**:
  a) Multi-criteria decision making;
  b) Optimisation of control strategies;
  c) Maximised WWTP performance in an energy and environmental efficient manner;

- **Further work**:
  a) Integrated urban wastewater system;
  b) Real-time control strategy;
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