International “state of the art” of eliminating pharmaceutical residues by wastewater treatment

Michael Cimbritz, Lund University
"Could there be unintended consequences associated with wastewater treatment upgrades?"

Improving the Quality of Wastewater To Tackle Trace Organic Contaminants: Think before You Act!

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‡Institute for the Environment, Brunel University, Uxbridge, UB8 3PH, U.K.
”Uncertainty is not an excuse for inaction”
If the answer is *action* at the wastewater treatment plants...

- What can be done in terms of advanced treatment?

- What have been done in full-scale?
Coming report

- Literature studies
- Study trip to Germany and Switzerland
- Advanced treatment in full-scale
  - Driving forces
  - Technologies and implications
  - Process configurations
  - Costs
Advanced treatment in full-scale

- What is advanced treatment?
  - The fourth treatment step
  - Beyond BOD, N and P in order to remove micropollutants

- What is full-scale treatment?
  - Large-scale pilot tests?
  - Full-flow treatment (at a large or small wastewater treatment plant)
  - Long-term treatment of biologically treated wastewater (in practice corresponding to at least the dry weather flow)
Driving forces – advanced treatment

• Negative effects in the aquatic environment
• Importance of (or need for) end-of-pipe solutions
• The Water Framework Directive and the Watchlist
• Protection of drinking water sources
• The precautionary principle
Conventional wastewater treatment with nitrogen removal

Falás 2012
What about optimization of biological treatment?

• Several substances cannot (today) be removed through (conventional) biological treatment

• Higher sludge age promote removal

• Compared to activated sludge, suspended biofilm carriers results in higher removal capacity for some substances

• But biological treatment is crucial to successful integration of advanced treatment!
Conditions for advanced treatment technologies at municipal WWTP’s

• A broad spectrum of substances should be removed
• Non-wanted transformation or rest products should be avoided
• The function of the WWTP must not be negatively affected (removal of BOD, N, P etc.)
• The measures (costs, energy etc.) should be justified

Abegglen & Siegrist 2012
Principal methods for upgrading

- Physical – membrane processes (nano filtration or reverse osmosis)
- Biological – degradation or transformation
- Oxidative – transformation (for example using ozone or chlorine dioxide)
- Adsorptive – separation by adsorption (for example activated carbon)
- Combined methods

Böhler 2015
Full-scale in Switzerland & Germany

- Ozonation
- Powdered Activated Carbon (PAC)
  - Granular Activated Carbon (GAC)
Switzerland I

• Wastewater treatment plants are significant sources of micropollutants

• Selected plants should be upgraded (100 WWTP’s during a period of 25 year)

• Ozonation and activated carbon considered as suitable and cost effective technologies

• Treatment of micropollutants will results in significant improvements of water quality, also downstreams (Germany etc.)
Switzerland II

- Large treatment plants (>80,000 pe) will be upgraded to reduce the total loading (involves more than 50% of the population)
- Treatment plants designed for at least 24,000 pe will be upgraded to protect certain lakes - drinking water resources
- Treatment plants designed for >8,000 pe with sensitive recipients and insufficient dilution will be upgraded
Switzerland III

• New law 2016
• 80% reduction of certain indicator substances
  • substances that are not affected by biological treatment
  • similar efficiency with ozonation and activated carbon
• 48h sampling and comparison between WWTP influent and effluent
• Number of samples per year (4-24) depends on plants size
### Switzerland IV

- **Selected substances**

<table>
<thead>
<tr>
<th>Grupp</th>
<th>Substans</th>
<th>Typ</th>
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<tbody>
<tr>
<td>1</td>
<td>Amisulprid</td>
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<td>2</td>
<td>Mecoprop</td>
<td>Biocide</td>
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</table>

- **Read more!**

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**Environmental Science & Technology**

*Reducing the Discharge of Micropollutants in the Aquatic Environment: The Benefits of Upgrading Wastewater Treatment Plants*

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3FOEN, Federal Office for the Environment, Water Division, CH-3003, Bern, Switzerland
Ozonation

- Biologically treated wastewater low in TOC preferable
- Transformation of substances
- Biological post-treatment recommended

Abegglen & Siegrist 2012
Transformation products - post treatment

• Doses and retention times are critical factors (Margot et al 2013)
• Toxicity normally reduced following ozonation but there are studies indicating more complex picture (see for example Magdeburg et al 2014)
• Biological post-treatment recommended
  • Sand filtration
  • MBBR, GAC, BAC...
  • Integration with upstream process steps
A compact solution
Powdered Activated Carbon (PAC)

- Adsorption – separation of carbon needed
- Interactions with existing plant
- Rest product – incineration or...?
- Direct dosing to biological treatment under investigation

Abegglen & Siegrist 2012
Integration of PAC: Ulmer-Verfahren
Granular Activated Carbon (GAC)

- Increased interest for the technology – stand-alone or in combination with ozone
Energy use at the WWTP

- Ozonation 0.05-0.1 kWh/m³ corresponding to an increase of 10-30%  
  - Depending upon a number of factors (need for pumping, cooling, source of oxygen etc.)  
  - 0.15 kWh/m³ (Palmowski et al 2015)
- PAC: <0.05 kWh/m³  
  - But production of activated carbon is energy intensive
Costs

• **German** (Hillenbrand et al 2014), **Swiss** (Abegglen & Siegrist 2012) and **Dutch** (Mulder et al 2015) resources – somewhat various starting points

• Economies of scale

• Comparisons tricky – but costs in the order of 0,1-0,3 €/m³
  • What flow?
  • Local infrastructure?
  • Post-treatment?
  • ...?
More about the practice in the report
Full-scale practice in Germany & Switzerland

• Look at:
  • www.koms-bw.de
  • www.masterplan-wasser.nrw.de
  • www.micropoll.ch

• Plants for research and ordinary, daily operation
• Not all plants in operation (stand-by)
Not only in Switzerland and Germany...

• France: ozonation at Saint-Pourcain-Sur-Sioule (15 000 pe) and Sophia Antopolis, Valbonne (26 000 pe). Post-treatment integrated with nitrogen removal
• Netherlands: activated carbon at Horstemeer
• Japan: Ozonation at more than 60 wastewater treatment plants
• Very interesting examples in for example USA and Australia
• World largest ozonation plant under construction at the Jean-R. Marcotte plant in Montreal (2 500 000 m³/d)
The process jigsaw...

- Activated sludge with N-removal and tertiary sand filtration
- How do we integrate ozonation, PAC and GAC into this and other process schemes?
- More about this in the session tomorrow
Design

• Understanding of the existing process for successful integration
  • Sludge treatment?
  • Even more stringent effluent requirements on P and N?

• Recommendations from VSA (Verband Schweizer Abwasser- und Gewässerschutzfachleute)
  • Basis for design is treatment of biologically treated wastewater
  • High flow conditions and mobilization of biocides and other micropollutants highlighted as coming question
Thanks to

• Svenskt Vatten
• Havs- och vattenmyndigheten
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