Treatment of micropollutants in municipal wastewater: Ozone or activated carbon?

J. Margot1, C. Kienle1, A. Magnet2, M. Weil1, L. Rossi1, L.F. de Alencastro1, C. Abeggl1, D. Thonne1, N. Chèvre3, M. Schärer3, D.A. Barry1

1 École Polytechnique Fédérale de Lausanne (EPFL), Switzerland (jonas.margot@epfl.ch); 2 Swiss Centre for Applied Ecotoxicology, Eawag/EPFL, Switzerland; 3 Wastewater treatment plant of Lausanne, Switzerland; 4 ECT Oekotoxikologie GmbH, Germany; 5 Swiss Federal Institute of Aquatic Science and Technology (Eawag), Switzerland; 6 University of Lausanne, Switzerland; 7 Federal Office for the Environment (FOEN), Switzerland

Introduction & Objectives

Pharmaceuticals
Pesticides
Other:
- Detergents
- Additives
- Personal care products

Micropollutant treatment is necessary

Aquatixicity
Drinking water contamination

Pilot plants at Lausanne municipal WWTP, Switzerland

Ozonation – sand filter (SF) pilot system (capacity 100 l/s)

Objectives

- To evaluate the efficiency of:
  - Ozonation
  - Activated carbon adsorption
- To reduce wastewater micropollutant concentrations and toxicity, at large scale, in real conditions

Figure 1. Ozone, produced from pure oxygen, is injected into wastewater to oxidize organic substances (contact time: > 20 min, dosage: 1 to 15 mg O2/l). The reactor is followed by a biologically active sand filter (SF) to remove the readily biodegradable reaction products

Powdered activated carbon–ultrafiltration system (PAC-UF) (capacity 10 l/s)

Figure 2. PAC slurry is introduced into wastewater (10 to 20 mg/l) to absorb the micropollutants. After a sufficient contact time (> 30 min), water is filtered with either ultrafiltration membrane (pore size of 30 nm) or sand filter and the retained PAC is reinjected in the contact reactor to obtain a sludge age of 2 d. Saturated PAC is finally incinerated with the adsorbed pollutants

Efficiency monitoring

- 28 sampling campaigns before and after each treatment during 1 y
- 58 potentially problematic substances (36 pharmaceuticals, 13 biocides and pesticides, 2 corrosion inhibitors and 7 endocrine disruptors) analysed
- A large battery of ecotoxicological tests performed before and after each treatment performed:
  - 16 in vitro assays: mutagenicity, genotoxicity, estrogrenicity and other hormonal effects
  - 9 in vivo assays: acute toxicity on bacteria and fish (Vibrio fisheri, Danio rerio), chronic toxicity on algae, aquatic plants, crustaceans, gastropods, worms and fish (Pseudokirchneriella subcapitata, Lemna minor, Ceriophpha dubia, Gammarus fossarum, Potamopyrgus antipodarum, Lumbricillus variegatus, Oncorhyncus mykiss)

Results & Discussion

Figure 3. Elimination of micropollutants between the WWTP entrance and the outlet of either the ozonation (3 to 7 mg O2/l), top chart) or the PAC-UF treatment (10 to 20 mg PAC/l, bottom chart). Boxplot with the minimum/maximum, the quartile and the mean (±) of 12 analyses. The diamond (♦) represents optimized operational conditions (6.7 mg O2/l or 20 mg PAC/l).

- On average, same efficiency for both treatments (> 80% removal)
- Some substances better eliminated with one or the other treatment
- Some substances not well eliminated with both treatments in the tested conditions: e.g. X-ray contrast media or gabapentin
- Clear toxicity decrease during ozonation and PAC-UF for most of the bioassays

Effluents of the advanced treatments are not toxic in most of the tests

Comparison: Ozone & Activated Carbon

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Ozone + SF</th>
<th>PAC + UF</th>
<th>PAC + SF</th>
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<tbody>
<tr>
<td>Measured/estimated on the pilot systems</td>
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<td>Micropollutants removal (2)</td>
<td>&gt; 80% on average (with 5.5 g O2/l); Substances not completely degraded (by-product formation)</td>
<td>&gt; 80% on average (with 10 to 20 g PAC/m3). If PAC is incinerated, substances are completely destroyed</td>
<td></td>
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<td>Toxicity reduction (3)</td>
<td>Good (&gt; 80% in all in vitro bioassays)</td>
<td>Very good (&gt; 90% in all in vitro bioassays)</td>
<td>Not tested</td>
</tr>
<tr>
<td>Water disinfection</td>
<td>Yes, partially</td>
<td>Yes, totally</td>
<td>No</td>
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<tr>
<td>Improving other water quality parameters</td>
<td>Yes, due to the sand filter</td>
<td>DOC reduction due to the PAC and strong global improvement due to the membranes</td>
<td>DOC reduction due to the PAC and global improvement due to the sand filter</td>
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<td>Waste production</td>
<td>No</td>
<td>Increase by 10% the sludge production of the WWTP</td>
<td></td>
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<td>Electricity consumption</td>
<td>0.11 kWh/m3</td>
<td>0.50 – 0.90 kWh/m3 (3)</td>
<td>0.08 kWh/m3</td>
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<td>Operation cost (COP)</td>
<td>ca. 3 to 4 cents/m3</td>
<td>ca. 20 to 30 cents/m3 (3)</td>
<td>ca. 4 to 5 cents/m3</td>
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<tr>
<td>Investment cost (CIP)</td>
<td>ca. 10 cents/m3</td>
<td>ca. 15 to 30 cents/m3</td>
<td>ca. 7 to 10 cents/m3</td>
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<tr>
<td>Footprint</td>
<td>ca. 1000 m2/m3</td>
<td>ca. 5000-7000 m2/m3 (3)</td>
<td>ca. 1400 m2/m3 (3)</td>
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General considerations

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<tr>
<th>Risks for the staff</th>
<th>Need trained staff (toxic substance). Safety system required</th>
<th>Low risk</th>
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<tr>
<td>Risks for the environment</td>
<td>Risk of forming potentially toxic by-products</td>
<td>Technique unusable in case of land application of the sewage sludge. PAC production can have significant environmental impacts</td>
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Type of WWTP that can use this process

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<th>Need permanent and trained staff</th>
<th>Implementation possible in all types of WWTP</th>
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Conclusions

- Both processes (ozonation and PAC addition) are effective in reducing the toxicity and the release of micropollutants into surface waters
- Ozonation–SF and PAC-SF proved to be feasible in terms of implementation and operation at large-scale in WWTP, for relatively similar investment and operation costs
- The energy requirement and the cost of the global wastewater treatment would increase by 20 to 30%.
- Each process has its advantages and disadvantages. The selection of one solution should be made case by case for each WWTP depending on the local constraints (space, security, energy cost, sludge disposal process, size of the plant, need for disinfection, wastewater composition, effluent quality, etc.)


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