Retention of heavy metals and Poly-Aromatic Hydrocarbons from road water in a constructed wetland and the effect of de-icing

Karin Tromp, Ana T. Lima, Arjan Barendregt and Jos T.A. Verhoeven
Outline

• Road runoff
  • Polycyclic Aromatic Hydrocarbons (PAHs)
  • Heavy metals

• 1.8 ha of motorway collected water at gully pots

• Constructed wetland to complement runoff contaminant retention

• Monitored PAHs and Heavy metals for 1.5 years

• Major considerations and recommendations
Road water infiltration facility

- Retention basin
- Vertical-flow wetland with Common reed
- Infiltration ditch

10 m
Research Questions

• (1) What are the reductions in concentrations going from road runoff via the sewer system (gully pots) towards the wetland and finally to the groundwater recharge point?
• (2) What are the effects of road management measures (sweeping, de-icing)?
• (3) What is the ‘best practice’ for the road and wetland management?
Research Questions

• (1) What are the reductions in concentrations going from road runoff via the sewer system (gully pots) towards the wetland and finally to the groundwater recharge point?

• (2) What are the effects of road management measures (sweeping, de-icing)?

• (3) What is the ‘best practice’ for the road and wetland management?
Research Questions

• (1) What are the reductions in concentrations going from road runoff via the sewer system (gully pots) towards the wetland and finally to the groundwater recharge point?

• (2) What are the effects of road management measures (sweeping, de-icing)?

• (3) What is the ‘best practice’ for the road and wetland management?
Main drivers

Rainfall and Salt

Rainfall (mm/month) vs. C load (kg/ha)

- February 2003
- April 2003
- June 2003
- Jul-Aug 2003
- September 2003
- November 2003
- January 2004
- March 2004
- May 2004
- Jun-Jul 2004
- August 2004

Rainfall
Cl input

0 1000 2000 3000 4000 5000 6000 7000 8000
0 20 40 60 80 100 120 140 160 180 200

Red: Rainfall
Blue: Cl input
<table>
<thead>
<tr>
<th></th>
<th>Runoff (μg/L)</th>
<th>Influent (μg/L)</th>
<th>Effluent (μg/L)</th>
<th>Dutch Standards (μg/L) *</th>
<th>EU Standards (μg/L) †</th>
<th>EPA standards (μg/L) ‡</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min.</td>
<td>Average</td>
<td>Max.</td>
<td>Min.</td>
<td>Average</td>
<td>Max.</td>
</tr>
<tr>
<td>Cd</td>
<td>0.1</td>
<td>0.6 ± 1.2</td>
<td>5.5</td>
<td>0.1</td>
<td>0.4 ± 0.4</td>
<td>1.3</td>
</tr>
<tr>
<td>Cr</td>
<td>0.8</td>
<td>4.1 ± 2.8</td>
<td>10.5</td>
<td>1.0</td>
<td>2.7 ± 1.3</td>
<td>6.1</td>
</tr>
<tr>
<td>Cu</td>
<td>21.7</td>
<td>117.1 ± 101.8</td>
<td>445</td>
<td>36</td>
<td>103.5 ± 89</td>
<td>405</td>
</tr>
<tr>
<td>Ni</td>
<td>1.3</td>
<td>3.8 ± 2.7</td>
<td>12.5</td>
<td>1.1</td>
<td>2.1 ± 0.9</td>
<td>5.1</td>
</tr>
<tr>
<td>Pb</td>
<td>7.4</td>
<td>29.3 ± 18</td>
<td>71.7</td>
<td>2.7</td>
<td>7.1 ± 4.1</td>
<td>19.8</td>
</tr>
<tr>
<td>Zn</td>
<td>115</td>
<td>289.8 ± 171</td>
<td>602</td>
<td>62</td>
<td>115.3 ± 44</td>
<td>256</td>
</tr>
<tr>
<td></td>
<td>Runoff (μg/L)</td>
<td>Influent (μg/L)</td>
<td>Effluent (μg/L)</td>
<td>Dutch Standards (μg/L)</td>
<td>EU Standards (μg/L)</td>
<td>EPA standards (μg/L)</td>
</tr>
<tr>
<td>-------</td>
<td>---------------</td>
<td>----------------</td>
<td>----------------</td>
<td>------------------------</td>
<td>--------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td></td>
<td>Min.</td>
<td>Average</td>
<td>Max.</td>
<td>Min.</td>
<td>Average</td>
<td>Max.</td>
</tr>
<tr>
<td>Cd</td>
<td>0.1</td>
<td>0.6 ± 1.2</td>
<td>5.5</td>
<td>0.1</td>
<td>0.4 ± 0.4</td>
<td>1.3</td>
</tr>
<tr>
<td>Cr</td>
<td>0.8</td>
<td>4.1 ± 2.8</td>
<td>10.5</td>
<td>1.0</td>
<td>2.7 ± 1.3</td>
<td>6.1</td>
</tr>
<tr>
<td>Cu</td>
<td>21.7</td>
<td>117.1 ± 101.8</td>
<td>445</td>
<td>36</td>
<td>103.5 ± 89</td>
<td>405</td>
</tr>
<tr>
<td>Ni</td>
<td>1.3</td>
<td>3.8 ± 2.7</td>
<td>12.5</td>
<td>1.1</td>
<td>2.1 ± 0.9</td>
<td>5.1</td>
</tr>
<tr>
<td>Pb</td>
<td>7.4</td>
<td>29.3 ± 18</td>
<td>71.7</td>
<td>2.7</td>
<td>7.1 ± 4.1</td>
<td>19.8</td>
</tr>
<tr>
<td>Zn</td>
<td>115</td>
<td>289.8 ± 171</td>
<td>602</td>
<td>62</td>
<td>115.3 ± 44</td>
<td>256</td>
</tr>
</tbody>
</table>

Max. – referring to the periods of de-icing
# Heavy metal retention efficiencies

## Heavy metals removal % in sewer system

<table>
<thead>
<tr>
<th></th>
<th>Cd</th>
<th>Cr</th>
<th>Cu</th>
<th>Ni</th>
<th>Pb</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>40</td>
<td>39</td>
<td>13</td>
<td>48</td>
<td>76</td>
<td>60</td>
</tr>
<tr>
<td>Particulate</td>
<td>57</td>
<td>79</td>
<td>77</td>
<td>85</td>
<td>85</td>
<td>81</td>
</tr>
<tr>
<td>Dissolved</td>
<td>32</td>
<td>-33</td>
<td>-15</td>
<td>11</td>
<td>-14</td>
<td>34</td>
</tr>
</tbody>
</table>

## Heavy metals removal % in the wetland

<table>
<thead>
<tr>
<th></th>
<th>Cd</th>
<th>Cr</th>
<th>Cu</th>
<th>Ni</th>
<th>Pb</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>-74</td>
<td>51</td>
<td>-11</td>
<td>-213</td>
<td>28</td>
<td>42</td>
</tr>
<tr>
<td>Particulate</td>
<td>30</td>
<td>34</td>
<td>47</td>
<td>-13</td>
<td>67</td>
<td>84</td>
</tr>
<tr>
<td>Dissolved</td>
<td>-105</td>
<td>49</td>
<td>-15</td>
<td>-337</td>
<td>-37</td>
<td>24</td>
</tr>
</tbody>
</table>
## PAHs overview

<table>
<thead>
<tr>
<th>PAH</th>
<th>Runoff (μg/L)</th>
<th>Influent (μg/L)</th>
<th>Effluent (μg/L)</th>
<th>Dutch Standards (μg/L) *</th>
<th>EU Standards (μg/L) †</th>
<th>EPA standards (μg/L) ‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anthracene</td>
<td>0.004</td>
<td>0.021 ± 0.02</td>
<td>0.08</td>
<td>0</td>
<td>0.003 ± 0.002</td>
<td>0.009</td>
</tr>
<tr>
<td>Phenanthrene</td>
<td>0</td>
<td>0.20 ± 0.22</td>
<td>0.77</td>
<td>0</td>
<td>0.08 ± 0.12</td>
<td>0.39</td>
</tr>
<tr>
<td>Fluoranthen</td>
<td>0</td>
<td>0.78 ± 0.95</td>
<td>3.65</td>
<td>0</td>
<td>0.06 ± 0.07</td>
<td>0.24</td>
</tr>
<tr>
<td>Benzo(a)anthracene</td>
<td>0.04</td>
<td>0.19 ± 0.2</td>
<td>0.89</td>
<td>0</td>
<td>0.02 ± 0.02</td>
<td>0.07</td>
</tr>
<tr>
<td>Chrycene</td>
<td>0.09</td>
<td>0.44 ± 0.51</td>
<td>2.17</td>
<td>0</td>
<td>0.05 ± 0.04</td>
<td>0.16</td>
</tr>
<tr>
<td>Benzo(k)fluoranthen</td>
<td>0.03</td>
<td>0.12 ± 0.12</td>
<td>0.46</td>
<td>0.004</td>
<td>0.02 ± 0.01</td>
<td>0.05</td>
</tr>
<tr>
<td>Benzo(a)pyrene</td>
<td>0.06</td>
<td>0.25 ± 0.23</td>
<td>0.84</td>
<td>0.009</td>
<td>0.03 ± 0.02</td>
<td>0.11</td>
</tr>
<tr>
<td>Benzo(g,h,i)perylene</td>
<td>0.09</td>
<td>0.36 ± 0.34</td>
<td>1.27</td>
<td>0.01</td>
<td>0.06 ± 0.05</td>
<td>0.19</td>
</tr>
</tbody>
</table>
# PAH retention efficiencies

## PAH removal % in sewer system

<table>
<thead>
<tr>
<th>Phen</th>
<th>Anth</th>
<th>Fla</th>
<th>Pyr</th>
<th>B(a)A</th>
<th>Chry</th>
<th>B(b)F</th>
<th>B(k)F</th>
<th>B(a)P</th>
<th>DIB(a,h)A</th>
<th>B(g,h,I)P</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>86</td>
<td>92</td>
<td>87</td>
<td>89</td>
<td>89</td>
<td>87</td>
<td>85</td>
<td>88</td>
<td>82</td>
<td>84</td>
<td>86</td>
</tr>
</tbody>
</table>

## PAH removal % in the wetland

<table>
<thead>
<tr>
<th>Phen</th>
<th>Anth</th>
<th>Fla</th>
<th>Pyr</th>
<th>B(a)A</th>
<th>Chry</th>
<th>B(b)F</th>
<th>B(k)F</th>
<th>B(a)P</th>
<th>DIB(a,h)A</th>
<th>B(g,h,I)P</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>69</td>
<td>70</td>
<td>94</td>
<td>91</td>
<td>94</td>
<td>88</td>
<td>93</td>
<td>91</td>
<td>94</td>
<td>93</td>
<td>87</td>
<td>87</td>
</tr>
</tbody>
</table>
Road management results

• The engineered system along the motorway of the sewer system (+ gully pots) and the remediation wetland facility retained PAHs and heavy metals

• Salts added to the road for de-icing increased heavy metal release from:
  • The sewer system
  • Wetland

• Although most metal concentrations were below the standards post treatment, Cu, Zn, Cd and Ni showed a dramatic increase during salt de-icing

• High release of Cu (65 higher than the standard)
Road management results

- The facility retained the PAHs very well, with retention efficiencies of 90–95%.

- Environmental standards for water quality were never surpassed after the wetland filtering for PAHs.
Research Questions

• (1) What are the reductions in concentrations going from road runoff via the sewer system (gully pots) towards the wetland and finally to the groundwater recharge point?
• (2) What are the effects of road management measures (sweeping, de-icing)?
• (3) What is the ‘best practice’ for the road and wetland management?
Management recommendations

• Modify the hydraulic management of the system to let the road water bypass it during de-icing

• PAHs and metals were well retained by the system during the rest of the year and reduce point source emissions

• Sediment and root mat of the wetland facility will have to be treated as hazardous waste at the end of its life time of 25 years.
Retention of heavy metals and poly-aromatic hydrocarbons from road water in a constructed wetland and the effect of de-icing

Karin Tromp a,1, Ana T. Lima b, Arjan Barendregt c, Jos T.A. Verhoeven a,∗

a Ecology and Biodiversity, Department of Biology, Utrecht University, Padualaan 8, 3584 CA Utrecht, The Netherlands
b Geochemistry, Dept. of Earth Science, Utrecht University, P.O. Box 80021, 3508 TA Utrecht, The Netherlands
c Interfacultary Institute for Risk Assessment Science, Toxicology Division, Utrecht University, P.O. Box 80177, 3508 TD Utrecht, The Netherlands
Thank you for your attention

Questions?

Ana Teresa Lima – lima.at@gmail.com
Jos Verhoeven – j.t.a.verhoeven@uu.nl