Suspended solids and nutrient retention in rural constructed wetlands in cold climate

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Long-term automatic monitoring of constructed wetlands
Aerial photograph of the Hovi wetland

Catchment
Area: 12 ha
Land use: 100% agricultural

Wetland
Area: 0.6 ha
(5% of the catchment)
Established 1998

Automatic monitoring since autumn 2007

Photo: Natural Resources Institute Finland (Luke)
Hovi wetland in agricultural landscape

Photo: Natural Resources Institute Finland (Luke)
Aerial photograph of the Rantamo-Seitteli wetland

**Catchment**
- Area: 1920 ha
- Land use: 40% agricultural

**Wetland**
- Area: 24 ha
- (1.2% of the catchment)
- Established 2009

Connection channel

Seitteli

Rantamo

Lake Tuusulanjärvi

Outflow

Inflow

Dam

Automatic monitoring since spring 2010

Photo: Esko Kuusisto
Aerial photograph of the Tarvaala wetland

**Catchment**
- Area: 140 ha
- Land use: 16% agricultural

**Wetland**
- Area: 1.4 ha
- (1.0% of the catchment)
- Established 2012

Lake Summasjärvi

Monitoring point

Outflow

Inflow

Monitoring point

Kosteikolle tulevan veden iatkuvatoiminen

Pohjoinen kosteikko 1,34 ha

Eteläinen kosteikko 1,4 ha

Evälannoitus okeet (suunnittella)
An innovative weir design – Oivanki wetland in Kuusamo

Catchment
Area: 383 ha
Land use: 27% agricultural

Wetland
Area: 15 ha
(3.9% of the catchment)
Established 2012
"Oxygen weir" improving the oxidization of water in the Oivanki wetland

- High DRP retention: 54%
- Decrease in mean concentrations in 2014–2015 (11 sample pairs)

Photo: Pekka Rasimus

min. 1.5 m water depth
S::can sensors used in automatic monitoring of Hovi and Rantamo-Seitteli wetlands

Data recorded at 1-h (Hovi) and ½-h (Rantamo-Seitteli) intervals at inflow and outflow
Hourly time series of turbidity and NO3-N as measured with s::can sensors at the Hovi wetland in 2013–2015
Hourly time series of turbidity and NO3-N as measured with s::can sensors at the Rantamo-Seitteli wetland in 2013–2015.
Conversion equations to obtain total P concentration (y) from calibrated turbidity (x)

<table>
<thead>
<tr>
<th>Measurement site</th>
<th>Conversion equation (R²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hovi inflow</td>
<td>y=60.7+1.13·x (0.90)</td>
</tr>
<tr>
<td>Hovi outflow</td>
<td>y=52.6+1.26·x (0.92)</td>
</tr>
<tr>
<td>Rantamo-Seitteli inflow</td>
<td>y=32.0+1.40·x (0.88)</td>
</tr>
<tr>
<td>Rantamo-Seitteli outflow</td>
<td>y=38.9+1.07·x (0.90)</td>
</tr>
</tbody>
</table>

High coefficients of determination (R²)

⇒ Reliable conversions from turbidity to Ptot (and TSS)
Dissolved reactive P concentration in the Hovi wetland in 2013–2015

DRP concentration (µg/l)

Time

DRP IN
DRP OUT

Mean 67 µg/l
Mean 12 µg/l
Dissolved reactive P concentration in the Rantamo-Seitteli wetland in 2013–2015

Mean 19 µg/l
Mean 11 µg/l

DRP IN
DRP OUT

Time

DRP concentration (µg/l)
Total suspended solids retention in the studied wetlands in 2013–2015

<table>
<thead>
<tr>
<th>Wetland</th>
<th>Mean TSS retention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hovi</td>
<td>79 % 12 194 kg/ha</td>
</tr>
<tr>
<td>Rantamo-S.</td>
<td>6 %    2 097 kg/ha</td>
</tr>
<tr>
<td>Tarvaala</td>
<td>50 %   1 419 kg/ha</td>
</tr>
</tbody>
</table>
Phosphorus retention in the studied wetlands in 2013–2015

**Total P**

<table>
<thead>
<tr>
<th>Wetland</th>
<th>Mean Total P retention</th>
<th>kg/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hovi</td>
<td>61%</td>
<td>11,7</td>
</tr>
<tr>
<td>Rantamo-S.</td>
<td>22%</td>
<td>11,0</td>
</tr>
<tr>
<td>Tarvaala</td>
<td>23%</td>
<td>3,5</td>
</tr>
</tbody>
</table>

Puustinen et al. (2007):

\[
\text{TP-ret.} = 3.2 \times \text{W/C ratio}^{0.57}
\]

- Hovi 58%
- Rantamo-S. 27%
- Tarvaala 23%

**DRP**

<table>
<thead>
<tr>
<th>Wetland</th>
<th>Mean DRP retention</th>
<th>kg/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hovi</td>
<td>83%</td>
<td>2,7</td>
</tr>
<tr>
<td>Rantamo-S.</td>
<td>27%</td>
<td>1,5</td>
</tr>
<tr>
<td>Tarvaala</td>
<td>77%</td>
<td>1,9</td>
</tr>
</tbody>
</table>
Nitrogen retention in the studied wetlands in 2013–2015

**Total N**

<table>
<thead>
<tr>
<th>Wetland</th>
<th>Mean Total N retention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hovi</td>
<td>66 % 167</td>
</tr>
<tr>
<td>Rantamo-S.</td>
<td>14 %  83</td>
</tr>
<tr>
<td>Tarvaala</td>
<td>NO RET. NO RET.</td>
</tr>
</tbody>
</table>

**NO3-N**

<table>
<thead>
<tr>
<th>Wetland</th>
<th>Mean NO3-N retention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hovi</td>
<td>62 % 157</td>
</tr>
<tr>
<td>Rantamo-S.</td>
<td>7 %  33</td>
</tr>
<tr>
<td>Tarvaala</td>
<td>NO RET. NO RET.</td>
</tr>
</tbody>
</table>
Systea – Micromac 1000 portable analyzer for continuous dissolved P monitoring

- Uses wet chemistry methods normally used in laboratories
- Was tested for dissolved P in laboratory and in the wetland at Tarvaala
- Worked without technical problems in situ
- Gave reliable results in lab., particularly at higher concentration levels

<table>
<thead>
<tr>
<th>Control solution DRP concentration (µg/l)</th>
<th>Uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>16 %</td>
</tr>
<tr>
<td>30</td>
<td>7 %</td>
</tr>
<tr>
<td>50</td>
<td>4 %</td>
</tr>
<tr>
<td>100</td>
<td>3 %</td>
</tr>
<tr>
<td>300</td>
<td>3 %</td>
</tr>
</tbody>
</table>
Discussion and conclusions

Factors behind **high per cent retentions at Hovi**
- High wetland-to-catchment area ratio
- High percentage of agricultural land in the upstream catchment
- Biological activity (woody and herbaceous vegetation, algae, microbes)
- Fe- and Al-rich soil

Factors behind **moderate per cent retentions at Rantamo-Seitteli**
- Rather low percentages of wetland-to-catchment area ratio and agricultural soil in the upstream catchment
- Large areas without vegetation
- Wind-induced erosion of the shorelines
- Bioturbation of the wetland bottom by fish in the Seitteli part

Factors behind **varying per cent retentions at Tarvaala**
- Rather low percentages of wetland-to-catchment area ratio and agricultural soil in the upstream catchment (-, nutrients)
- Ditching and earthworks at the wetland during the study period (-, N)
- Abundant, partly woody vegetation (+, P)
- Coarse soil type in the catchment (+, TSS)
Conclusions (cont.)

- On the base of our results, CWs can be recommended as water protection measures in Finnish rural areas

- However
  - Generous dimensioning, like in Hovi, often reduces the willingness of the landowners to build them
  - Small absolute size, like in Hovi, means that there must be quite many such wetlands, in order to have perceptible influence in downstream watercourses

- The current incentive system created to promote wetlands to Finland’s rural areas has not been very effective
  - The number of wetlands constructed through so-called non-productive investment support is far below target
  - more wetlands have been established through independent projects (particularly by hunters)

- Wetlands have other benefits beyond water protection, such as
  - Improved landscape
  - Increased biodiversity
  - Possibilities for recreation, education, hunting, etc.

- Portable analyzers based on wet chemistry offer a promising alternative for continuous dissolved P analysis in wetland studies
THANK YOU!

Photo: Pinja Kasvio