Harmful Algal Blooms – *Cyanobacteria* occurrence, consequence and management

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Exceeding the limits for eutrophication = Parameters favoring the formation of cyanobacteria-dominated blooms

The occurrence of cyanobacterial blooms - consequences:

Low water quality

- Low transparency
- Low oxygen concentration
- Toxins production:
  - Hepatotoxins (microcystins, nodularyn)
  - Neurotoxins
  - Cytotoxins
  - Dermatotoxins

Are produced by toxigenic cyanobacterial strains

Symptoms of exposure to microcystin:
- allergic reactions, rash, fever, diarrhea, vomiting
- anemia, acute liver damage, liver cancer, colon cancer
HEALTH RISK

CYANOBACTERIAL TOXINS

HEPATOTOXINS
✓ microcystins (-LR, -RR, -YR and the other variants, above 80)
✓ nodularins

NEUROTOXINS
✓ anatoxin-a
✓ anatoxin-a(s)
✓ homoanatoxin-a
✓ saxitoxin
✓ neosaxitoxin
✓ aphanotoxin

CYTOTOXINS
✓ cylindrospermopsins

DERMATOTOXINS
✓ lyngbyatoxin-a
✓ aplysialtoxin

Increase knowledge about cytotoxic and peptidase inhibitory activities of other compounds than main group of cyanobacterial toxins

(Chorus & Bartram, 1999; Mankiewicz et al., 2003; Codd et al. 2005; Žegura et al., 2011)

(Falconer, 2007; Bubik et al., 2008; Sedmak et al., 2008; Mankiewicz-Boczek et al., 2011, Štěpánková et al., 2011)
Accumulation in aquatic animals

Shrimp *Palaemon modestus* (Lake prawn), Lake Chaohu, China, June 2003 daily intakes reached 0.57 mg MC-LR equiv. kg\(^{-1}\) bw (Chen and Xie, 2005)

TDI (tolerable daily intake) value suggested by WHO 0.04 mg kg\(^{-1}\) bw per day for MC-LR (Chorus and Bartram, 1999)

<table>
<thead>
<tr>
<th>Fish name</th>
<th>Wet weight (g)</th>
<th>Liver (µg g(^{-1}) DW)</th>
<th>Kidney (µg g(^{-1}) DW)</th>
<th>Muscle (µg g(^{-1}) DW)(^a)</th>
<th>Total conc. fish(^{-1}) (µg)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Silius glanis</em></td>
<td>1180</td>
<td>ND</td>
<td>ND</td>
<td>0.14</td>
<td>22.4</td>
</tr>
<tr>
<td><em>Carassius auratus</em></td>
<td>120</td>
<td>0.82</td>
<td>ND</td>
<td>0.49</td>
<td>79.4</td>
</tr>
<tr>
<td><em>Cyprinus carpio</em></td>
<td>1818</td>
<td>2.06</td>
<td>ND</td>
<td>0.27</td>
<td>46.3</td>
</tr>
</tbody>
</table>

Human adult weighing 60 kg, who ingests, on average, 429 g *S. glanis*, 123 g *C. auratus*, and 222 g *Cy. carpio* from Lake Suwa will be above TDI limit. (Xie et al., 2007)
Occurrence of cyanobacteria groundwater and accumulation in cultivated plants

as a result: infiltration near water bodies, rainfall events or irrigation of plants

<table>
<thead>
<tr>
<th>Species</th>
<th>Density (cells L⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum</td>
</tr>
<tr>
<td>Cyanobacteria</td>
<td></td>
</tr>
<tr>
<td>Chroococcus minor</td>
<td>4.5 x 10⁵</td>
</tr>
<tr>
<td>Gloeocapsa sp.</td>
<td>0.23 x 10⁶</td>
</tr>
<tr>
<td>Oscillatoria limnetica</td>
<td>68.1 x 10⁵</td>
</tr>
<tr>
<td>Spirulina sp.</td>
<td>0.07 x 10⁶</td>
</tr>
<tr>
<td>Chlorophyta</td>
<td></td>
</tr>
<tr>
<td>Chlorella sp.</td>
<td>1.9 x 10⁵</td>
</tr>
<tr>
<td>Coleomena sp.</td>
<td>0.01 x 10⁵</td>
</tr>
<tr>
<td>Scenedesmus sp.</td>
<td>0.2 x 10⁶</td>
</tr>
</tbody>
</table>

100-g edible leaves and roots would contain from 11 to 36 g MCYSTs
It is about 5–18 times the recommended daily MCYST intake from drinking water

(Mohamed and Shehri, 2009)
Polish water bodies (since 1996)
occurrence of microcystin-producing Cyanobacteria

Jurczak et al., Chromatographia 2004, 59, 571-578
Mankiewicz et al., Envirin. Toxicol. 2005, 20, 499-506
Izydorczyk et al., J. Plankton Res. 2008, 30, 394-400
Mankiewicz-Boczek et al., Environ, Toxicol. 2011, 26(1): 10–20
Microcystis blooms in SU

Fot. Izydorczyk, Skowron
Microcystis blooms in SU

Fot. Skowron, Gągała, Frątczak
IDENTIFICATION of key abiotic (physico-chemical) parameters affecting the development of toxic cyanobacterial blooms

METHODS ELABORATION for monitoring of toxic cyanobacteria (application of molecular methods for risk assessment and early warning system)

OPTYMISATION of biological structure of Pilica river floodplain for selfpurification enhancement and REDUCTION of diffusive and point sources pollution in the Pilica basin

IDENTIFICATION of the impact of biotic parameters and interactions on the trail: cyanobacteria / cyanophages / bacteria / cyanoabcterial toxins / other organisms

DEVELOPMENT OF TOOLS for better assessment of the overall threat from cyanobacterial blooms (cellular biosensors for detection and evaluation of novel mechanisms of noxious bioactivity of cyanobacteria)
**Proposed integral procedure of microcystin-producing cyanobacteria monitoring for bathing water quality**

**Spring/Summer**
Determination of physico-chemical parameters including nutrients concentration:
- P-PO$_4$, TP (>0.1 mg/l*)
- N-NO$_3$, N-NH$_4$, TN (>1.5 mg/l*)
- Chlorophyll a (> 10 μg/l**)

Phytoplankton analysis

**Occurrence of** *Microcystis, Planktothrix, Anabaena*
Detection of toxigenic (potentially toxic) strains of cyanobacteria
- PCR amplification of *mcy* genes
  - (polymerase chain reaction)

**Occurrence of microcystins**
Application of screening tests:
- determination of microcystins concentration – ELISA
  - (enzyme-linked immunosorbent assay)
- determination of microcystins toxicity – PPIA
  - (protein phosphatase inhibition assay)

**Confirmation of microcystins if ELISA showed > 2.5 μg/l**
Quantitative and qualitative analysis of microcystins – HPLC
  - (high performance liquid chromatography)

**Transdisciplinary interpretation of results**
Following the first and second principle of **Ecohydrology**, the identification of cause-effect relationship with comparative studies of the lake/reservoir typology, hydrochemistry, phytoplankton diversity and water toxicity are fundamental for developing a **strategy to reverse eutrophication**.

(Zalewski 2000; Wagner et al. 2009)

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Note: * critical values for eutrophication recommended by OECD (1983); ** relatively low probability of adverse health effect recommended by WHO (2003)
Objectives of ecohydrology

- Assessment of threats
- Hydrology
- Hydrochemistry
- Ecological succession driver

Strategy elaboration for Cost Efficiency Restoration

Photo by I.Gagala
Elaboration of system solutions

Demonstration zone in Zarzecin: reduction of groundwater POLLUTION WITH PHOSPHORUS COMPOUNDS, by strengthening the plant ecotone zone with geochemical barrier based on limestone.

Critical level for occurrence of cyanoabcterial blooms

GEOCHEMICAL BARRIER

Phosphates concentration [mg/l]

3.09.2010
30.09.2010
3.11.2010
9.12.2010
19.01.2011

(www.geoportal.gov.pl)
Increasing the efficiency of the buffer zone by incorporation of geochemical barrier

Phosphates concentration in groundwater (mgPO₄/ℓ)

Before barrier: high concentration of phosphates in groundwater

After barrier: low concentration of phosphates in groundwater

www.ekorob.pl

Izydorczyk et al. 2013, Ecohydrology & Hydrobiology
**EH: Sequential Sedimentation-Biofiltration System**  
*(Zalewski 2008)*

- **Stormwater inflow** into SBS
- **Enhanced sedimentation zone**
- **Geochemical barrier enhanced by geotextile curtains**
- **Filtering bed regeneration system**
- **Outflow purified stormwaters**

**Graphs:**
- **TOTAL SUSPENDED SOLIDS**
- **TOTAL PHOSPHORUS**
Sequential filtration of pollutants

1 Phase
Limstone zone

2 Phase
Coal zone

3 Phase
Sawdust zone

4 Phase
Wetland with macrophytes

Mean TP reduction: 26%
Max. TP reduction 76%

Mean TN reduction: 48%
Max. TN reduction 97%

(Kiedrzyńska E. et al., in preparation)
The final effect of implementation of Ecohydrology for enhancement ecosystems services in small urban catchment (Jurczak, Zalewski in preparation)

The recent ecological and recreational status

SSBS

The Past
Thank you for your attention