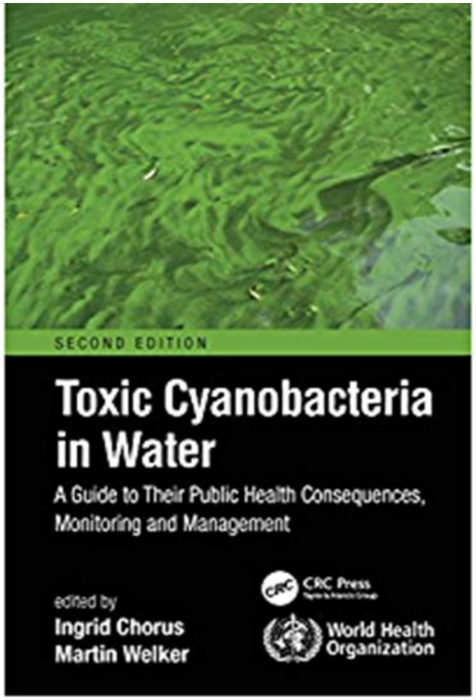
# Cyanotoxins in freshwater fish and shellfish understanding risk assessment and management


UNIVERSITÉ DE GENÈVE

22 march 2022

# WHO TCiW Book launch 2021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**Understanding the hazard**

- **Chapter 2**: Introduction to cyanotoxins
- **Chapter 3**: Introduction to cyanobacteria

**Chapter 5:**

**Preventing hazardous exposure to cyanotoxins**

- **5.1**: Drinking-water
- **5.2**: Recreation and workplace
- **5.3**: Food
- **5.4**: Renal dialysis
- **5.5**: Dietary supplements

**Controlling cyanobacteria and cyanotoxin occurrence**

**Chapter 6**: Assessing & managing risks

**Chapter 7**
**Catchment**

**Chapter 8**
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**Chapter 9**
**Sites of use**

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**Monitoring cyanobacteria and cyanotoxins**

- **Chapter 11**: Planning monitoring programmes
- **Chapter 12**: Site inspection and sampling
- **Chapter 13**: Analysing cyanobacteria and water chemistry
- **Chapter 14**: Analysing cyanotoxins

**Chapter 15**: Public surveillance, communication and participation

# **Introduction** and role of public authorities **(chapters 1** and 15**)**

... Cyanotoxins are **among the most toxic** naturally occurring compounds...

... **widespread occurrence**; contact may be difficult to avoid

... **less public awareness** of risk than for other chemicals

... **control indirect and complex**– through controlling eutrophication: successful approaches need to be site-specific

# **Introduction** and role of public authorities **(chapters 1** and 15**)**

Context of toxic Cyanobacteria – **similar** to other chemicals in water:

... lack of quantitative data (dose estimates) for human exposure...

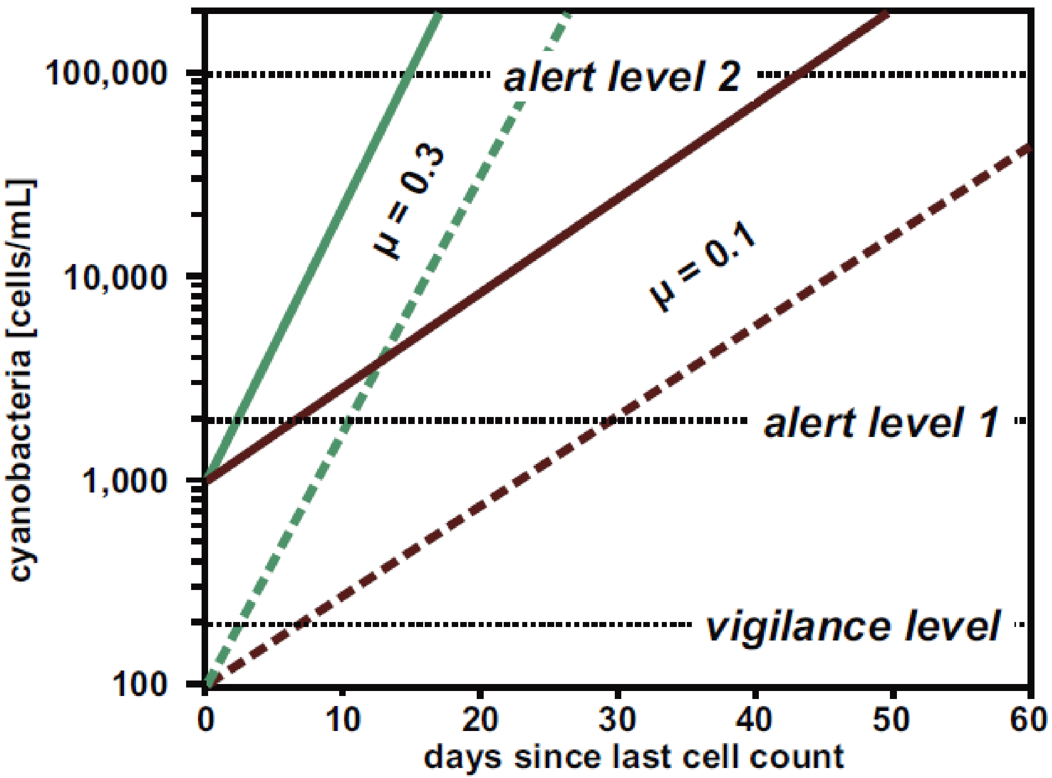
...the contribution of **toxic chemicals in water to morbidity and mortality is rarely acute**, ... impacts on health are less visible and less clearly attributable to chemicals.

... unclear whether cyanotoxins or other hazards were the cause of symptoms reported

... **quite clear data from animal experiments**

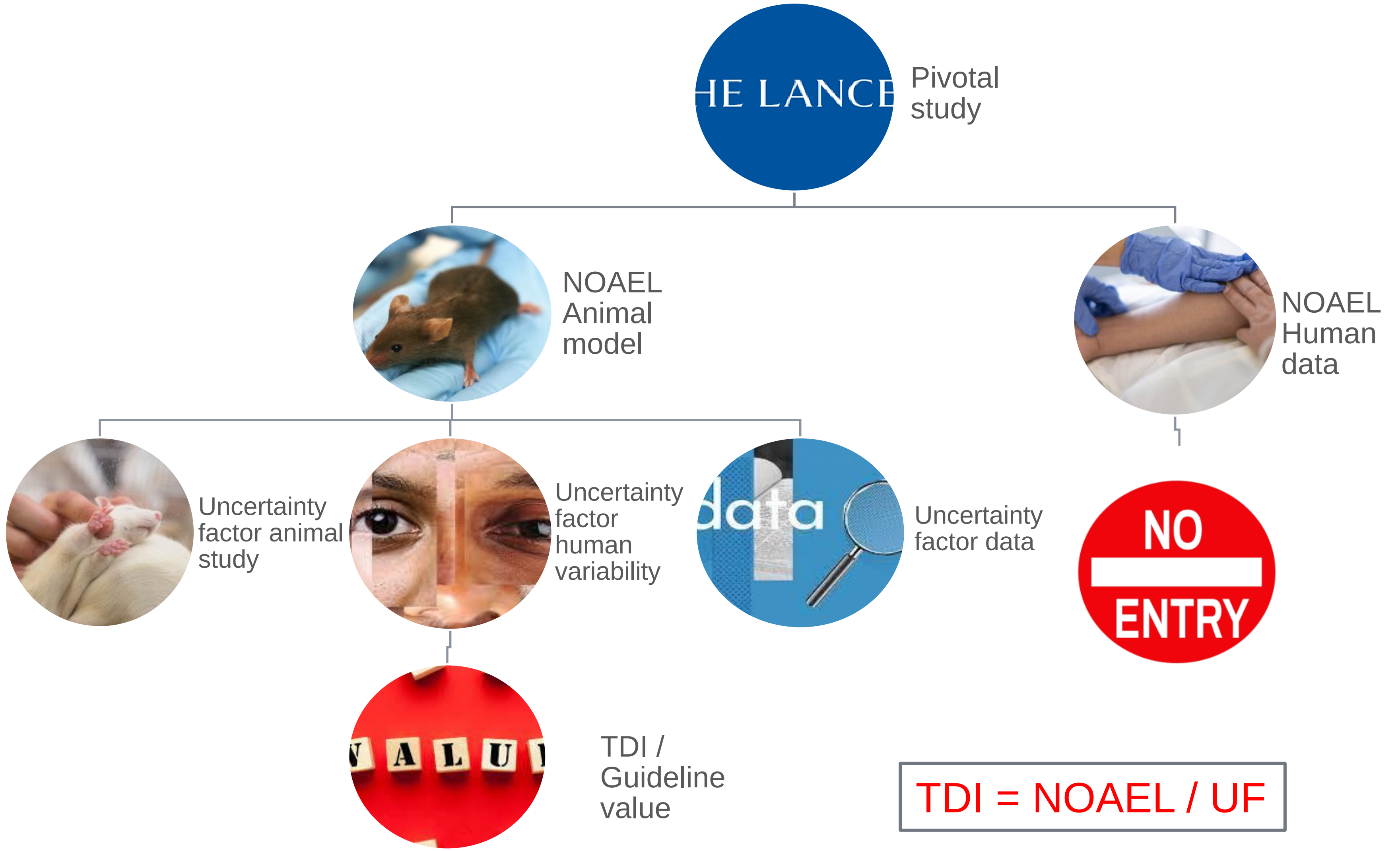
Like for other chemicals in water:

WHO guideline value not because of widespread cause of illness – but because of significant toxicity and water as relevant exposure pathway


100,000
10,000
1,000
100
0
10
20
30
40
50
60
days since last cell count
cyanobacteria [cells/mL]
alert level 2
alert level 1
vigilance level
μ = 0.3
μ = 0.1


IT'S
ALIVE!

# Derivation GV and TDI




TDI = NOAEL / UF

GV = TDI x bw x P / C

# Analysis of Epidemiological data and Human Reports

**Can individual cases support the derivation of GV?**

- "… *mere co-occurrence of cyanotoxins and unspecific symptoms (skin irritation, gastro-intestinal, etc. …) is not indicative of the known cyanotoxins having caused the symptoms…..*

- Human effects ascribed to the presence of cyanotoxins in the various vectors (drinking- or recreational water, food) such as gastrointestinal illness or skin irritation may well be due to other unknown cyanobacterial metabolites or closely linked to pathogens or other substances associated with the bloom

- Epidemiological studies: i**ndicative value only** because (i) uncertain, retrospective(!) exposure estimates; (ii) other contaminants in surface water; (iii) demographic info is limited

- Important to understand cause–effect relationships and then dose-response relationship (for the quantitative aspects – then role in GV)

**Human & Experimental Toxicology (1999) 18,** 162–167
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http://www.stockton-press.co.uk/het

# The toxicity of cyanobacterial toxins in the mouse: I Microcystin-LR

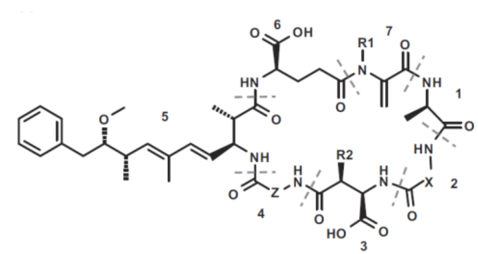
JK Fawell*[,1], RE Mitchell[1], DJ Everett[2] and RE Hill[2]

*[1]WRc National Centre for Environmental Toxicology, Medmenham, Bucks, SL7 2HD, England; [2]Quintiles Toxicology/Pathology Services, Bromyard Road, Ledbury, Herefordshire, HR8 1LH, England*

**Table 3** Thirteen week study – liver microscopic pathology

| *Dose level (µg kg$^{-1}$ bodyweight per day)* | *Control (0)* | NOAEL *40* | LOAEL *200* | *1000* |
|---|---|---|---|---|
| Males | | | | |
| Number examined | 15 | 15 | 15 | 15 |
| Acute inflammation | 0 | 1 | 0 | 0 |
| Chronic inflammation | 1 | 2 | 4 | 15 |
| Congestion | 3 | 0 | 0 | 1 |
| Hepatocyte vacuolation | 5 | 5 | 6 | 3 |
| Haemosiderin deposits | 0 | 0 | 0 | 15 |
| Hepatocyte degeneration | 0 | 0 | 1 | 14 |
| Females | | | | |
| Number examined | 15 | 15 | 15 | 15 |
| Autolysis | 0 | 0 | 0 | 1 |
| Chronic inflammation | 5 | 8 | 8 | 14 |
| Congestion | 0 | 0 | 0 | 1 |
| Hepatocyte vacuolation | 5 | 5 | 11 | 8 |
| Haemosiderin deposits | 0 | 0 | 1 | 14 |
| Hepatocyte degeneration | 0 | 0 | 1 | 9 |

Fawell et al. (1999): Mice of both sexes given MC-LR by gavage at 40 µg/kg bw per day for 13 weeks did not show treatment-related effects in the parameters measured. Only slight hepatic damage was observed at the lowest observed effect level (LOAEL) of 200 µg/kg bw per day in a limited number of treated animals, whereas at the highest dose tested (1 mg/kg bw per day), all the animals showed hepatic lesions, consistent with the known action of MC-LR.



# Derivation provisional TDI MC-LR

$$\mathrm{TDI}_{\mathrm{chronic}} = \frac{\mathrm{NOAEL}}{\mathrm{UF}} = \frac{40}{1000}\ \frac{\mu g}{kg} / d = 0.04\ \frac{\mu g}{kg} / d$$

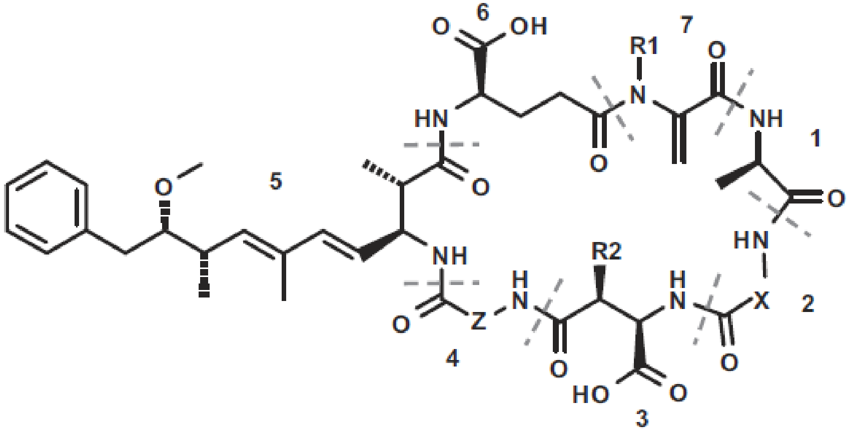
$\mathrm{TDI}_{\mathrm{MC,chronic}}$ = tolerable daily intake for chronic exposure
NOAEL = no-observed-adverse-effect level (40 µg/kg bw per day, based on Fawell et al., 1999)
UF = uncertainty factor (1000 = 10 for interspecies variation × 10 for intraspecies variation × 10 for database deficiencies, including use of a subchronic study)

PROVISIONAL

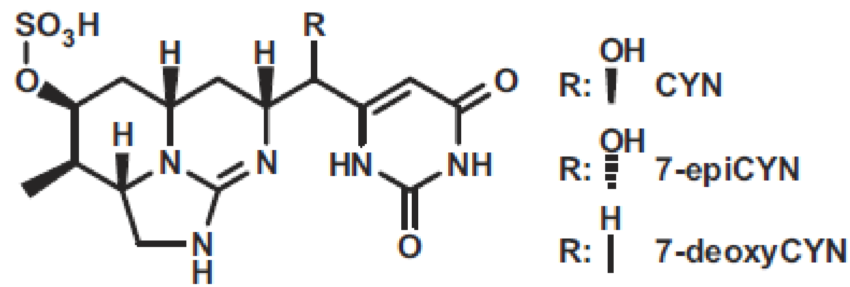
# Derivation provisional life term drinking water GV MC-LR

$$GV_{\text{chronic}} = \frac{\text{NOAEL} * \text{bw} * P}{\text{UF} * C} = \frac{40 * 60 * 0.8}{1000 * 2} \mu g / L = 0.96 \ \mu g / L \ \approx 1 \ \mu g / L$$

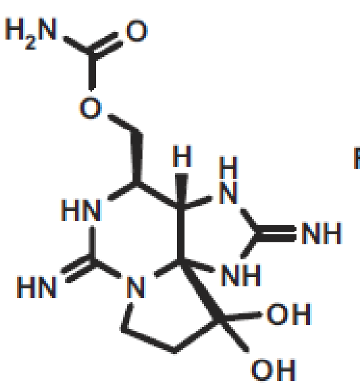
$GV_{\text{chronic}}$ = guideline value for chronic (lifetime) exposure
NOAEL = no-observed-adverse-effect level (40 µg/kg bw per day, based on Fawell et al., 1999)
bw = body weight (default = 60 kg for an adult)
P = fraction of exposure allocated to drinking-water (80%, as other sources of exposure such as air, food and soil are considered minor for lifetime exposure)
UF = uncertainty factor (1000 = 10 for interspecies variation × 10 for intraspecies variation × 10 for database deficiencies, including use of a subchronic study)
C = daily drinking-water consumption (default = 2 L for an adult).



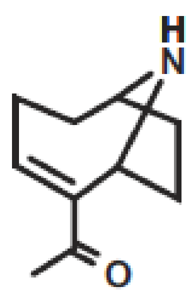
Microcystin



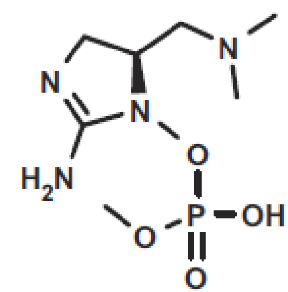

Cylindrospermopsin



Saxitoxin



Anatoxin-a



Anatoxin-a (s)

# Cyanobacterial toxins

## Hepatotoxic cyclic peptides: microcystins and nodularins

- Characteristic Adda amino acid
- > 250 variants for MCYST
- Nomenclature based variable amino acids positions 2 and 4
- Water soluble
- OATP membrane transporter to enter cell (liver)
- Slow detoxication liver
- Inhibtion protein phosphatases, destabilization cytoskeleton
- Tumour promoting

- Producers MCYST across all cyanobacteria, main genera *Microcystis, Planktothrix, Dolichospermum, Nostoc*
- *Nodularia for NODLN*
- Produced via nonribosomal peptide synthetase and polyketide synthase pathway
- Cell quota dependent on temperature, light, pH, N, P, Fe, salinity
- Positive correlation growth rate and MC content
- Tens of µg / L in lakes, up to > 100 mg / L in scums
- Dynamics linked to strain variation

# Cyanobacterial toxins

## Cylindrospermopsin

- Alkaloid
- 4 structural variants
- Hydrophlic
- Various modes action, low dose inhibition protein synthesis, ROS
- Genotoxic
- Unclear whether CYN production constitutive or not
- Species from Nostocales, Oscillatoriales, genera *Raphidopsis (Cylindrospermopsis), Chrysosporum, Aphanizomenon, Anabaena, Umezakia*
- *Planktonic and benthic*
- *Per unit biovolume 0.6 – 3.5 µg / mm3*

- In lake water 10 – 20 µg / L
- Substantial share (up to 90 %) CYN found extracellularly (in contrast MC)
- Environmental conditions change cell quota, ratio between variants and intra vs extracellular

# Cyanobacterial toxins

## Anatoxin-a

- Secondary amine alkaloids
- Anatoxin-a, homoanatoxin, dihydroanatoxin-a
- Pre- and postsynaptic depolarizing agent in nerve cells, increased simulation
- Brain and cardiovascular system target organs
- Muscular paralysis and respiratory failure
- Inadequate data GV, bounding value = provisional health-based reference value, NOAEL 98 µg / kg bw
- Producers *Dolichospermum, Anabaena, Oscillatoria, Planktothrix, Raphidopsis …*

- Environmental factors like light and temperature 2-7 fold variation ATX
- Like MCYST worldwide distribution
- USA concentrations in literature 35 – 1170 µg / L
- Important production benthic cyanobacteria like *Phormidium*

# Cyanobacterial toxins

## Saxitoxins

- Shellfish poisoning toxins (PSP)
- 57 analogues
- Mainly hydrophyllic
- Na, Ca and K channel blocking in neural and cardiac cells, prevents electrical transmission
- Twitching, convulsions, muscle and respiratory paralysis
- LOAEL based upon review human cases PSP: STX = 1.5 µg/kg bw, UF of 3, NOAEL estimated = 0.5 µg/kg bw (acute reference dose)
- Allocation factor drinking water vs food, risk co-incidental exposure
- Produced Nostocales, Oscillatoriales, including..

- *Dolichospermum, Aphanizomenon, Raphidiopsis, Planktothrix, Microseira (Lyngbya)*
- *High cellular content Dolichospermum circinale (Murray-Darling 1000 km bloom)*

§

## Chapters 2.5 – 2.10 – Other toxins and metabolites

E. TESTAI, N. J. OSBORNE, N. CHERNOFF, E.J. FAASEN, D.J. HILL, M. WELKER, T. KALOUDIS, A. HUMPAGE

- 2.5 Anatoxin-a(S) – no GV
- 2.6 Marine dermatoxins – no GV (skin exposure)
- 2.7 β-Methylamino-L-alanine (BMAA)
  - No convincing evidence for the role of BMAA as cause of neurodegenerative disease under realistic exposure scenarios
- 2.8 Cyanobacterial lipopolysaccharides
  - "…cyanobacterial LPS are not likely to pose health risks to an extent known from toxins like microcystins or cylindrospermopsins, in particular, when considering plausible exposure pathways."



World Health Organization

## Chapters 2.5 - 2.10 – Other toxins and metabolites

E. TESTAI, N. J. OSBORNE, N. CHERNOFF, E.J. FAASEN, D.J. HILL, M. WELKER, T. KALOUDIS, A. HUMPAGE

- 2.9 Cyanobacterial taste and odour compounds in water
  - T&O can be used as an early warning for cyanobacteria, but not all cyanobacteria produce T&O
  - No relation between T&O and toxin production
- 2.10 Unspecified toxicity and other cyanobacterial metabolites
  - Compounds produced by cyanobacteria showing bioactivity in various test systems (e.g. peptides)
  - Toxic effects of cyanobacteria extracts that cannot be attributed to the well-known compounds

# Derivation provisional life term drinking water GV MC-LR

$$GV_{chronic} = \frac{NOAEL * bw * P}{\ } \quad \frac{40 * 60 * 0.8}{\ } \quad 1\ \mu g / L$$

$GV_{chronic}$
NOAEL … sed
on Fa…
bw = bo…
P = frac… her
source… for
lifetin…


UF = uncertainty factor (1000 = 10 for interspecies variation × 10 for intraspecies variation × 10 for database deficiencies, including use of a subchronic study)

C = daily drinking-water consumption (default = 2 L for an adult).

Available online at www.sciencedirect.com
ScienceDirect
Environmental Pollution 150 (2007) 177–192
ENVIRONMENTAL POLLUTION
www.elsevier.com/locate/envpol

Review

# Accumulation of cyanobacterial toxins in freshwater "seafood" and its consequences for public health: A review

Bas W. Ibelings [a,b,*], Ingrid Chorus [c]

[a] *Eawag, Swiss Federal Institute of Aquatic Sciences and Technology, Centre of Ecology, Evolution and Biogeochemistry, Seestrasse 79, CH-6047 Kastanienbaum, Switzerland*

Tolerable doses to microcystin-LR in relation to frequency and duration of exposure

| Temporal pattern of exposure and ensuing Tolerable Intake (TI) | Assumptions | Tolerable Intake per kg | Tolerable Intake for a 10 kg child | Tolerable Intake for a 75 kg adult | Guideline value for food (μg $kg^{-1}$) | |
|---|---|---|---|---|---|---|
| | | | | | AF = 1 | AF = 0.2 |
| Acute TI | NOAEL of 250 μg/kg and day, extrapolation factors of 100 (Fromme et al., 2000) | 2.5 μg per kg and single exposure | 25 μg per single exposure | 190 μg per single exposure | Adult: 1900, Child: 250 | Adult: 380, Child: 50 |
| Seasonal TDI | NOAEL of 0.4 μg/kg and day, extrapolation factors of 100 (Chorus and Bartram, 1999, adapted) | 0.4 μg per kg and day | 4 μg per day | 30 μg per day | Adult: 300, Child: 40 | Adult: 60, Child: 8 |
| Lifetime TDI | NOAEL of 0.4 μg/kg and day, extrapolation factors of 100 and uncertainty factor of 10 (Chorus and Bartram, 1999) | 0.04 μg per kg and day | 0.4 μg per day | 3 μg per day | Adult: 30, Child: 0.4 | Adult: 6, Child: 0.08 |

# Derivation provisional short term drinking water GV MC-LR

$$GV_{short-term} = \frac{NOAEL * bw * P}{UF * C} = \frac{40 * 60 * 1.0}{100 * 2} \mu g / L = 12 \mu g / L$$

UF = uncertainty factor (100 = 10 for interspecies variation × 10 for intraspecies variation)


WHO: short-term guideline values are necessary to avoid mis-interpretation of lifetime GVs !

# Derivation provisional recreational-waters GV MC-LR

SUM!

$$GV_{recreation} = \frac{NOAEL*bw}{UF*C} = \frac{40*15}{100*0.25}\mu g/L = 24\ \mu g/L$$

$GV_{recreation}$ = guideline value for recreational exposure
NOAEL = no-observed-adverse-effect level (40 µg/kg bw per day, based on Fawell et al., 1999)
bw = body weight (default = 15 kg for a child)
UF = uncertainty factor (100 = 10 for interspecies variation × 10 for intraspecies variation)
C = daily incidental water consumption (default = 250 mL for a child).

Harmful Algae 40 (2014) 63–74

Contents lists available at ScienceDirect

Harmful Algae

journal homepage: www.elsevier.com/locate/hal

# Current approaches to cyanotoxin risk assessment and risk management around the globe

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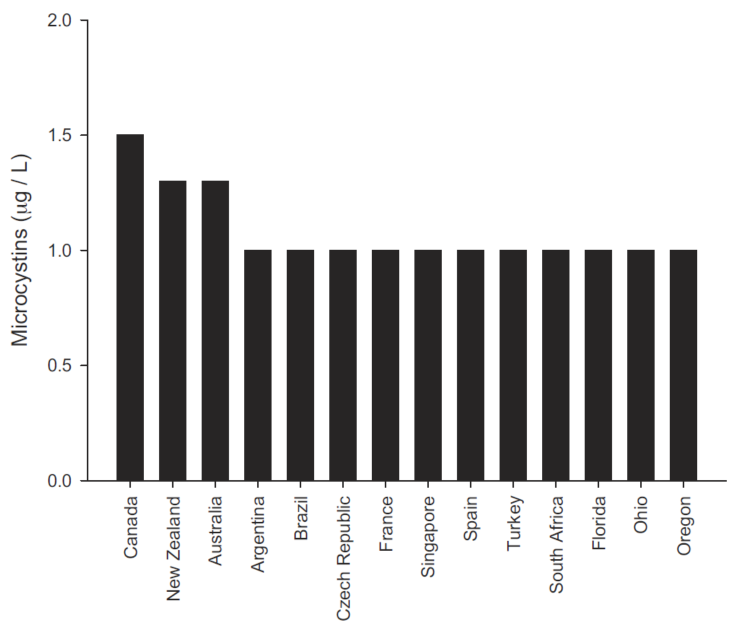
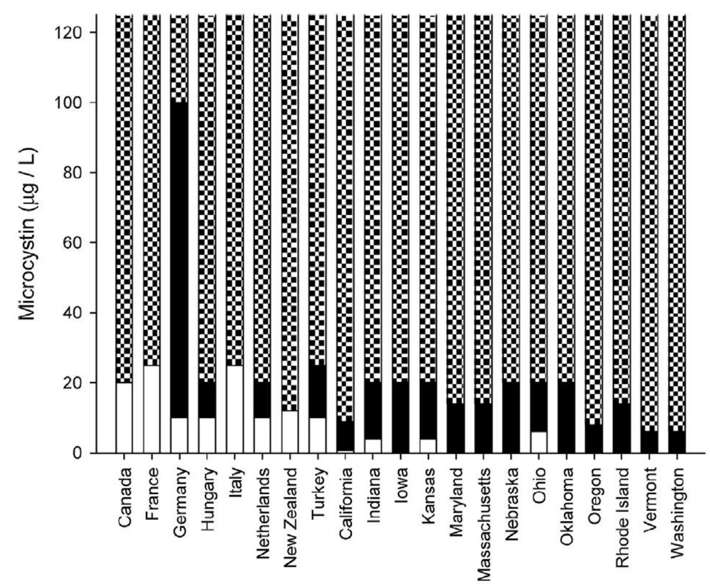



19 mei 2021

*"Setting the alert levels in the Netherlands is the outcome of intensive discussions between scientists, lake managers and policy makers, in a country known for the highly eutrophic state of its lakes (despite successful restoration efforts ...), where stricter alert levels might result in extended closure of many lakes. Safety clearly must come first, but the protocol used in the Netherlands – in addition to health risks – takes into account the promotion of outdoor activities, feasibility, complexity and costs of monitoring or risk control of cyanobacteria, as well as the ease of communication to the public. Given the large uncertainty in the derivation of TDI for cyanotoxins it is not possible to say whether the higher alert levels in the Netherlands truly result in decreased protection. We merely know it is uncertain." (p. 68)*

# The newly derived GV

- GVs be applied to total MCs, total CYNs and total STXs (lack of data for variants)
- Allocation factors: drinking water 80% for life time (!), 100% for short time or recreational
- Life time food or recreation only 20%, short term can be up to 100 %. Adapt AF local circumstances, be mindful other health-effects
- Water intake: 2L for drinking water
- 250 mL for a child as recreational, daily - incidental - water intake
- UF :
  - MC: 1000 LT, 100 ST, 100 Rec
  - CYN: 1000 LT, 300 ST, 300 Rec
  - STX: 3 Acute, 3 Rec
- Provisional: data base deficiency
- Short-term exposure refers to about 2 weeks, until measures can be implemented to achieve concentrations < lifetime GV

## Chapters 2.1 – 2.4
## Guideline values / Health-based reference value*

| | Microcystin | Cylindro-spermopsin | Anatoxin-a | Saxitoxin |
|---|---|---|---|---|
| Drinking water (life time) | 1 | 0.7 | - * | 3 ** |
| Short term value (DW) | 12 | 3 | 30 | - 0.3 |
| Bathing water | 24 | 6 | 60 | 30 |

µg / L

- No comprehensive toxicological data available
  → provisional GV/HBRV Health Based Reference Value
  → no life-time HBRV for anatoxin-a*
- Acute drinking water GV for saxitoxin** (derived from acute seafood poisoning)
- Short term values: exceedance of GV for 2 weeks once in a season
- GV can be applied to the <u>sum of all congeners</u> (MC, CYN, ATX, STX)

# Potential exposure routes

**5.1 Drinking-water** and the Alert Levels Framework (ALF): now includes the *short-term guideline* values

**5.2 Recreational exposure** and the related ALF. Emphasis is on adapting ALF locally or regionally.

**5.3 Food exposure**: emphasis to the need of good quality data for assessing exposure

**5.4 Renal dialysis**: less frequent exposure but at high risk (susceptible subpopulation and kinetics)

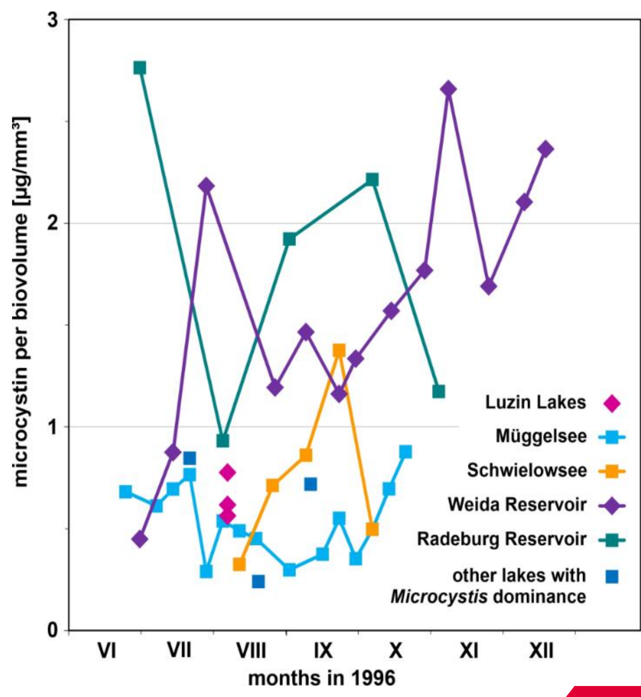
**5.5 Dietary supplements**: increasing consumption expected - good quality data needed

# Alert Levels Framework (ALF)

An Alert Levels Framework (ALF) is a **monitoring and management action sequence** (“**decision tree**”), which can be used to provide a rapid response to a cyanobacterial bloom

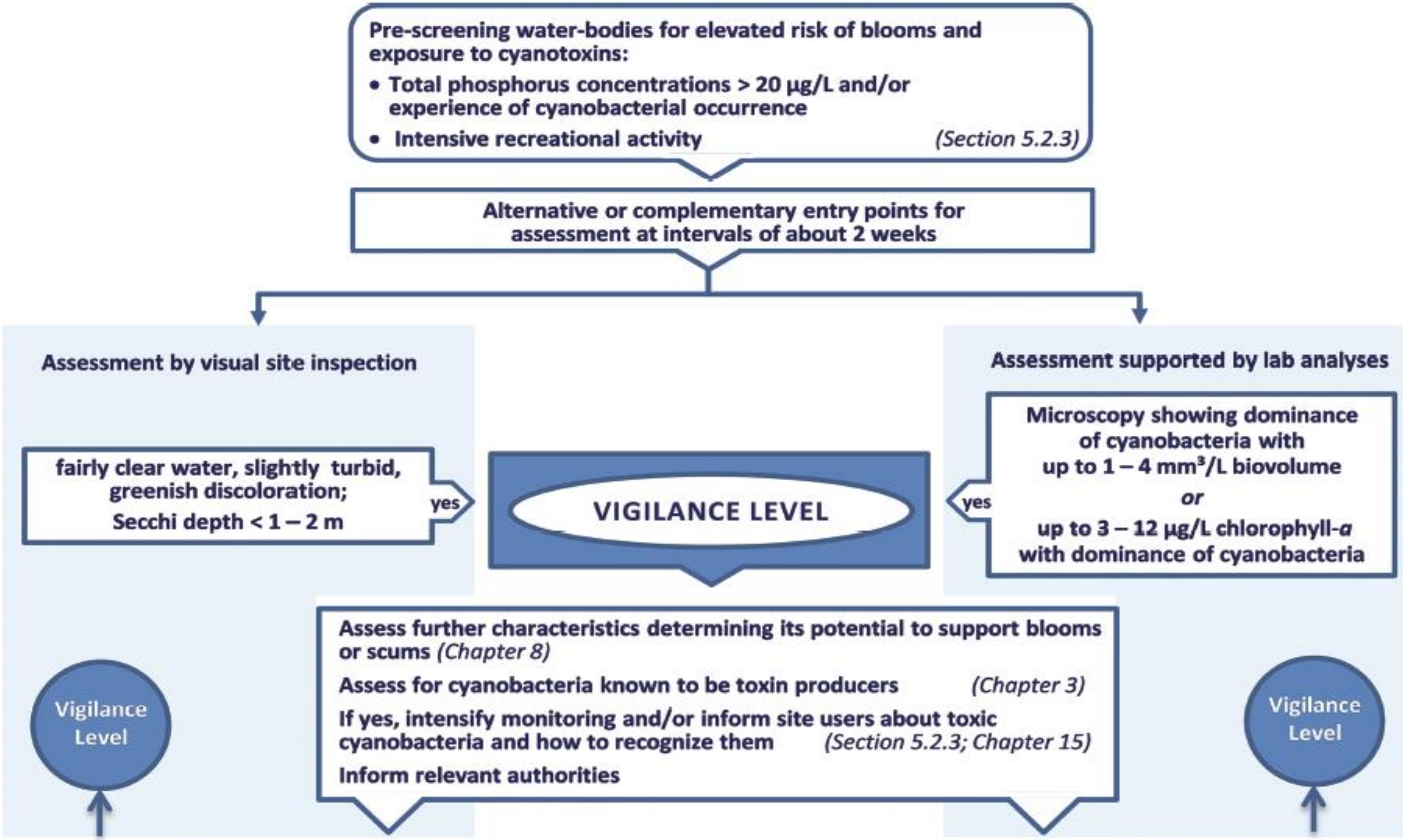
**Adapt ALF to local conditions**:

- Parameters used to trigger alerts (e.g. visual assessment, turbidity readings, quantification of cyanobacterial biomass- either biovolume or pigment concentrations-, cell number, cyanotoxin levels)
- Providing they are periodically “calibrated” against toxin levels.
- Indeed, the toxin/biomass ratios can vary not only between waterbodies but also between years for one-and-the-same waterbody



# Adapting the ALF to local situation

- Extent and duration of cyanotoxin exposure in relation to other hazards: when pathogens are present and cyanobacterial blooms are short-lived events, a decision might be to tolerate somewhat higher concentrations (as an interim solution) in order to prioritize available capacity and resources on controlling hazards causing the highest risks
- The amount of drinking-water consumed and the fraction of cyanotoxin allocated to uptake through drinking-water in relation to other exposure pathways. (GV were derived with an allocation factor=1, assuming each of these exposure to be the dominant source during the short duration)
- Meteorological data, indication of drought or heavy rainfall (often associated to cyanobacterial blooms) should be recorded and considered when following the ALF
- Local adaptation : consumption freshwater seafood




# ALF recreational waters

no

**Pronounced greenish turbidity; feet barely visible when standing knee-deep in water**

*(Fig. 5.7)*

**possibly minor thin green film *or* streaks on parts of the surface**

*(Fig. 5.6)*

**Secchi depth < 0.5 – 1 m**

yes

**Alert Level 1**


no

**Visible, thick cyanobacterial scums covering most of the water surface in areas used for recreation**

**Secchi depth < 0.5 – 1 m**

yes

## ALERT LEVEL 1

**Watch for scums**

**Investigate further (if possible, conduct toxin analysis)**

**Inform site users to watch for scums and avoid activities that can lead to uptake through mouth or nose, particularly for children; if this cannot be controlled keep children out of the water**

**Inform relevant health authorities**

## ALERT LEVEL 2

**Immediate action to prevent contact with scums; possible temporary prohibition of swimming and other water contact activities**

**Inform site users to stay out of the water and to avoid sports activities that can lead to scum contact, particularly uptake through mouth or nose; keep children out of scum**

**Inform relevant authorities**

**Public health follow-up investigation**

no

yes

**Cyanobacterial biovlume up to 4 – 8 mm³/L**

***or***

**up to 12-24 µg/L chlorophyll-*a* with dominance of cyanobacteria**

**If toxins are analysed:**
**≤ 24 µg/L MCs *or***
**≤ 6 µg/L CYNs *or***
**≤ 60 µg/L ATXs *or***
**≤ 30 µg/L STXs**

**Alert Level 1**

no

yes

**Cyanobacterial scum and**
**> 24 µg/L MCs *or***
**> 6 µg/L CYNs *or***
**> 60 µg/L ATXs *or***
**> 30 µg/L STXs**

# Alert Levels for biovolume and chlorophyll-a

- The proposed values are derived on the basis of *conservative* – “worst case” - assumptions on ratios of MCs to either biovolume or chlorophyll-*a*
- Available data on low concentrations of CYN, ATX and STX found in water indicate that the toxin/biomass ratios derived for MCs can be assumed valid for the other cyanotoxins.
- For ATX, GVs are much higher i.e. much less toxic – MCs valid
- However, when Alert Level 2 is exceeded, careful with respect CYN (box 5.1) and STXs: toxin concentrations should be determined for blooms when STX- or CYN-producing species are dominant

*Table 5.2* Conservative values for parameters of cyanobacterial biomass indicative of possible occurrence of cyanotoxin concentrations reaching guideline values

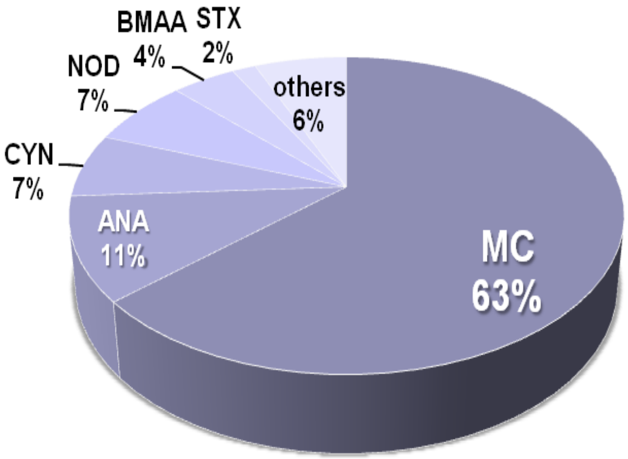
| *Alert Level* | *Biovolume* *MC/BV≤3/1 [μg/mm³]* | *Chlorophyll-a* *MC/Chl.a≤1:1 [μg/μg]* | *Basis for conservative estimate*[a] *of toxin/biomass* |
|---|---|---|---|
| Alert Level 1 in drinking-water ALF | 0.3 mm³/L | 1 μg/L | $GV_{chronic}$ for MCs in drinking-water: 1 μg/L |
| Alert Level 2 in drinking-water ALF | 4 mm³/L | 12 μg/L | $GV_{short\text{-}term}$ for MCs in drinking-water: 12 μg/L |
| Alert Level 2 in recreational ALF | 8 mm³/L | 24 μg/L | $GV_{recreational}$ for MCs: 24 μg/L |

**If these Alert Levels are not exceeded, the MCs concentrations are highly unlikely to exceed the respective GVs**

# Exposure through food


- The great majority of papers deal with MC, and more specifically to MC-LR
- Little availability of robust analytical methods for matrices other than water
- Covalently bound MC
- Only about 25% of the available studies applied reliable analytical methods (especially dated studies do not report recovery, matrix effects etc…)
- Food preparation (cleaning) important, cooking inefficient

**Occurrence data: distribution among toxins**




Testai et al, EFSA Supporting Publications 13(2):998 (2016)

# Cyanotoxins in food: potential sources

- Animals grown in aquaculture or harvested as food in freshwater or brackish rivers and lakes
- Blue-green algal food supplements
- Food prepared with contaminated water
- Crops irrigated with contaminated water

# Cyanotoxin concentrations in various food sources

*Table 5.5 (Continued)* Examples of cyanotoxin concentrations in foods

| A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|
| *Organism* | *Organs or tissue* | *Cyanotoxin* | *Content [µg/kg ww]* | *Max. [µg] ingested with serving of 0.1 kg* | *% of TI for DW short term (MC; CYN) or acute (STX) exposure* | *Study type* | *Reference* |
| **Fish** | | | | | | | |
| *Aristichthys nobilis* | Muscle | MC-RR, MC-YR, MC-LR | 177[a] | 17.7 | 74 | Field | Chen et al. (2007) |
| *Hypophthalmichthys molitrix* | Muscle | MC-RR | 0.4[a] | 0.0 | 0.2 | Field | Chen et al. (2009b) |
| *Hypophthalmichthys molitrix* | Muscle | MC-RR, MC-LR | ND–249[c] (mean: 39.4) | 24.9 | 104 | Field | Chen et al. (2006) |
| *Pomoxis nigromaculatus* | Muscle | MC-LR | ND–70 | 7.0 | 29 | Field | Schmidt et al. (2013) |
| *Cyprinus carpio* | Muscle | MC-LR | ND–4 | 0.4 | 2 | Field | Schmidt et al. (2013) |
| *Cyprinus carpio* | Muscle | MC-RR | 0.6[b] | 0.1 | 0.3 | Field | Chen et al. (2009b) |
| *Oreochromis niloticus* | Muscle | MC-LR[b] | 4.2–5.2 | 0.5 | 2 | Field | Greer et al. (2017) |
| *Geophagus brasiliensis* | Muscle | $STX_{eq}$ | 12–20 | 2.0 | 7 | Field | Clemente et al. (2010) |

For contextualising the health risk due to these concentrations, column "F" relates to the amount of toxin ingested with a serving of 0.1kg to the percentage of the *tolerable intake for short-term (MCs, CYN) or acute (STX) exposure* (TI calculated from the NOAEL, UF and bodyweight of 60 kg as given in Chapter 2). Note that these short-term GVs were derived assuming drinking-water to be the major source of exposure to these cyanotoxins, not leaving a proportion to other sources, and that this comparison is intended merely to give a rough estimate of the health relevance of concentrations found in food, not for defining safe levels for food. This table does not take into account the relative toxicities of microcystin congeners.

ND = not detected above the detection limit. $STX_{eq}$ = saxitoxin toxicity equivalents.

[a] When applied with equal amounts of MC; without MC accumulation was fourfold lower.
[b] Secondary technique (i.e., MMPB, ELISA) indicated higher levels may have been present.
[c] Converted to wet weight using a wet-to-dry weight ratio of 5.

# Cyanotoxin concentrations in various food sources

*Table 5.5* Examples of cyanotoxin concentrations in foods

| A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|
| *Organism* | *Organs or tissue* | *Cyanotoxin* | *Content [µg/kg ww]* | *Max [µg] ingested with serving of 0.1 kg* | *% of TI for DW short term (MC; CYN) or acute (STX) exposure* | *Study type* | *Reference* |
| **Crops** | | | | | | | |
| *Lactuca sativa* | Leaf | MC-LR | 2.4–147 | 14.7 | 61 | Lab | Cordeiro-Araújo et al. (2017) |
| *Lactuca sativa* | Unknown | MC-YR, MC-RR | ND–108 | 10.8 | 45 | Field | Li et al. (2014) |
| *Ipomoea aquatica* | Unknown | MC-RR, MC-LR | ND–68 | 6.8 | 29 | Field | Li et al. (2014) |
| *Brassica oleracea* | Unknown | MC-RR | ND–20 | 2.0 | 9 | Field | Li et al. (2014) |
| *Brassica rapa* var. *Parachinensis* | Unknown | MC-RR | ND–40 | 4.0 | 17 | Field | Li et al. (2014) |
| *Brassica oleracea var. Sabellica* | Leaf | CYN | 3.1 | 0.3 | 5 | Lab | Kittler et al. (2012) |
| *Brassica juncea* | Leaf | CYN | 4.0 | 0.4 | 7 | Lab | Kittler et al. (2012) |
| *Lactuca sativa* | Leaf | CYN | 3.1–8.2 | 0.8 | 13 | Lab | Cordeiro-Araújo et al. (2017) |
| *Eruca sativa* | Leaf | CYN | 5.5–11.5 | 1.1 | 18 | Lab | Cordeiro-Araújo et al. (2017) |
| *Spinacea oleracea* | Leaf | CYN | 9.5–120 | 12.0 | 200 | Lab | Llana-Ruiz-Cabelo et al. (2019)[a] |
| *Lactuca sativa* | Leaf | CYN | 2.4–42 | 4.2 | 70 | Lab | Llana-Ruiz-Cabello et al. (2019)[a] |

(*Continued*)

# Cyanotoxin concentrations in various food sources

*Table 5.5 (Continued)* Examples of cyanotoxin concentrations in foods

| *A* | *B* | *C* | *D* | *E* | *F* | *G* | *H* |
|---|---|---|---|---|---|---|---|
| *Organism* | *Organs or tissue* | *Cyanotoxin* | *Content [µg/kg ww]* | *Max. [µg] ingested with serving of 0.1 kg* | *% of TI for DW short term (MC; CYN) or acute (STX) exposure* | *Study type* | *Reference* |
| **Molluscs** | | | | | | | |
| *Mytilus galloprovincialis* | Whole | dmMC-RR[b] | ND–39 | 3.9 | 16 | Field | Rita et al. (2014) |
| *Patinopecten yessoensis* | Whole | MC-LR | ND–4.3 | 0.43 | 2 | Field | Cui et al. (2018) |
| *Crassostrea virginica* | Whole | MC-RR, MC-LR | ND–9.8 | 1.0 | 4 | Field | Cui et al. (2018) |
| *Mytilus galloprovincialis* | Whole | CYN | 28.1–41.6 | 4.2 | 70 | Lab | Freitas et al. (2016) |
| *Anodonta cygnea* | Whole | CYN | 247 | 24.7 | 412 | Lab | Saker et al. (2004) |
| *Anodonta cygnea* | Whole | $STX_{eq}$ | 160–220 | 22 | 73 | Lab | Pereira et al. (2004) |
| *Alathyria condola* | Muscle | $STX_{eq}$ | 144–179 | 18 | 60 | Lab | Negri & Jones (1995) |
| **Crustaceans** | | | | | | | |
| *Astacus astacus* | Head/ thorax | [Asp$^3$,Dhb$^7$]MC-LR, [Asp$^3$]MC-RR, [Asp$^3$,Dhb$^7$]MC-RR | 10 | 1.0 | 4 | Field | Miles et al. (2013) |
| *Astacus astacus* | Tail | [Asp$^3$,Dhb$^7$]MC-LR, [Asp$^3$]MC-RR, [Asp$^3$,Dhb$^7$]MC-RR | <1 | <0.1 | <1 | Field | Miles et al. (2013) |
| *Procambarus clarkii* | Abdomen | MC-RR, MC-LR | 1.4–17.1 | 1.7 | 7 | Field | Ríos et al. (2013) |
| *Cherax quadricarinatus* | Muscle | CYN | 205 | 20.5 | 342 | Field | Saker & Eaglesham (1999) |

*(Continued)*

# Checklist assessing risk cyanotoxin exposure food

- Blooms potentially toxic species present?
  - Toxin content cyanobacteria
  - Recent period?
- Are organisms harvested?
  - Filter feeders?
  - Viscera removed?
- Are crops irrigated?
  - Cyanobacterial cells present on surface?
- Toxins likely from other sources (drinking water)
- Seasonal or year round? Amounts consumed local setting?
- Clarify possible toxin dose
  - Necessary to restrict access to food contaminated food?
- Measures for protection?
- Raise public awareness

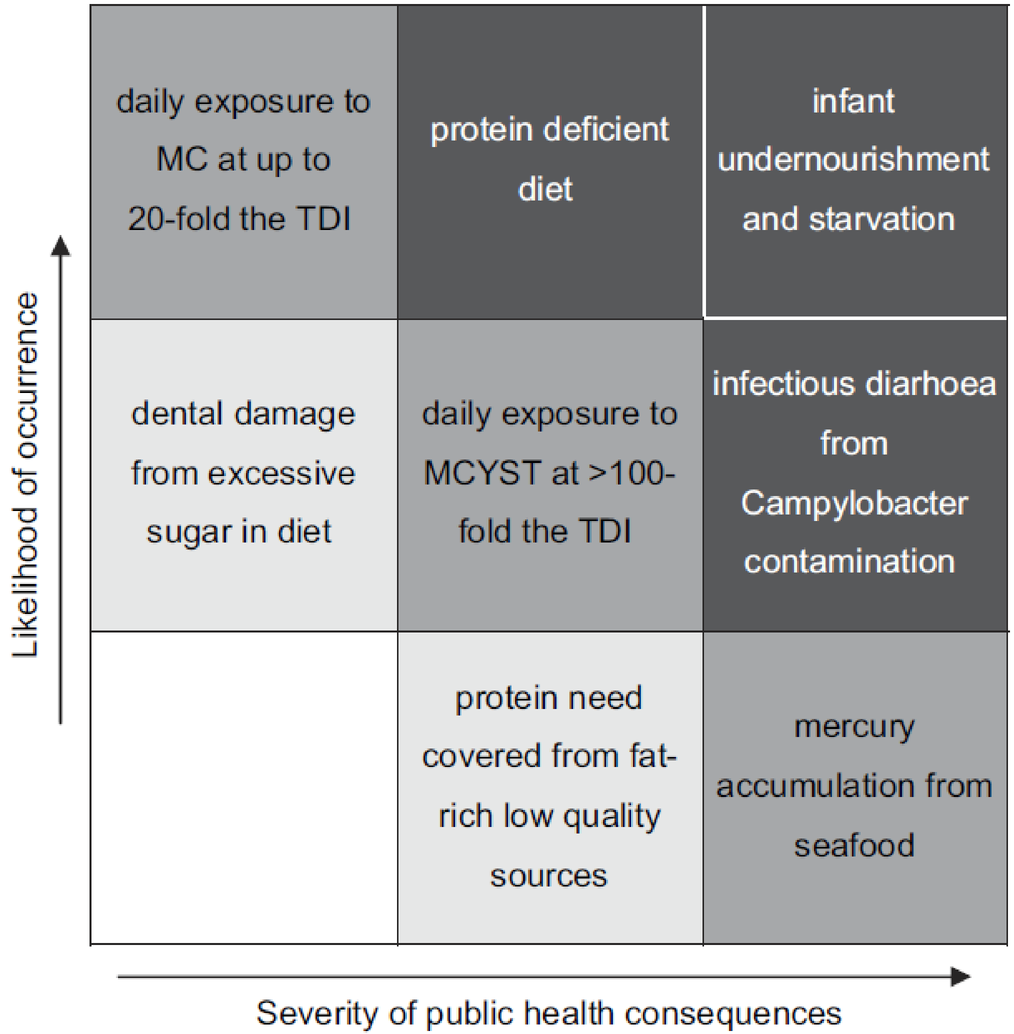
# Guideline values food


- MCYST 5.6 µg / kg bw fish and 51 µg / kg bw molluscs (France)
- CYN 18 µg / kg bw (AUS), 70 µg / kg bw  (California)
- STX 800 µg / kg bw (AUS, CAN), 5000 µg / kg bw (Calfornia)

Tolerable doses to microcystin-LR in relation to frequency and duration of exposure

| Temporal pattern of exposure and ensuing Tolerable Intake (TI) | Assumptions | Tolerable Intake per kg | Tolerable Intake for a 10 kg child | Tolerable Intake for a 75 kg adult | Guideline value for food (µg $kg^{-1}$) | |
|---|---|---|---|---|---|---|
| | | | | | AF = 1 | AF = 0.2 |
| Acute TI | NOAEL of 250 µg/kg and day, extrapolation factors of 100 (Fromme et al., 2000) | 2.5 µg per kg and single exposure | 25 µg per single exposure | 190 µg per single exposure | Adult: 1900, Child: 250 | Adult: 380, Child: 50 |
| Seasonal TDI | NOAEL of 0.4 µg/kg and day, extrapolation factors of 100 (Chorus and Bartram, 1999, adapted) | 0.4 µg per kg and day | 4 µg per day | 30 µg per day | Adult: 300, Child: 40 | Adult: 60, Child: 8 |
| Lifetime TDI | NOAEL of 0.4 µg/kg and day, extrapolation factors of 100 and uncertainty factor of 10 (Chorus and Bartram, 1999) | 0.04 µg per kg and day | 0.4 µg per day | 3 µg per day | Adult: 30, Child: 0.4 | Adult: 6, Child: 0.08 |

# What defines a risk?



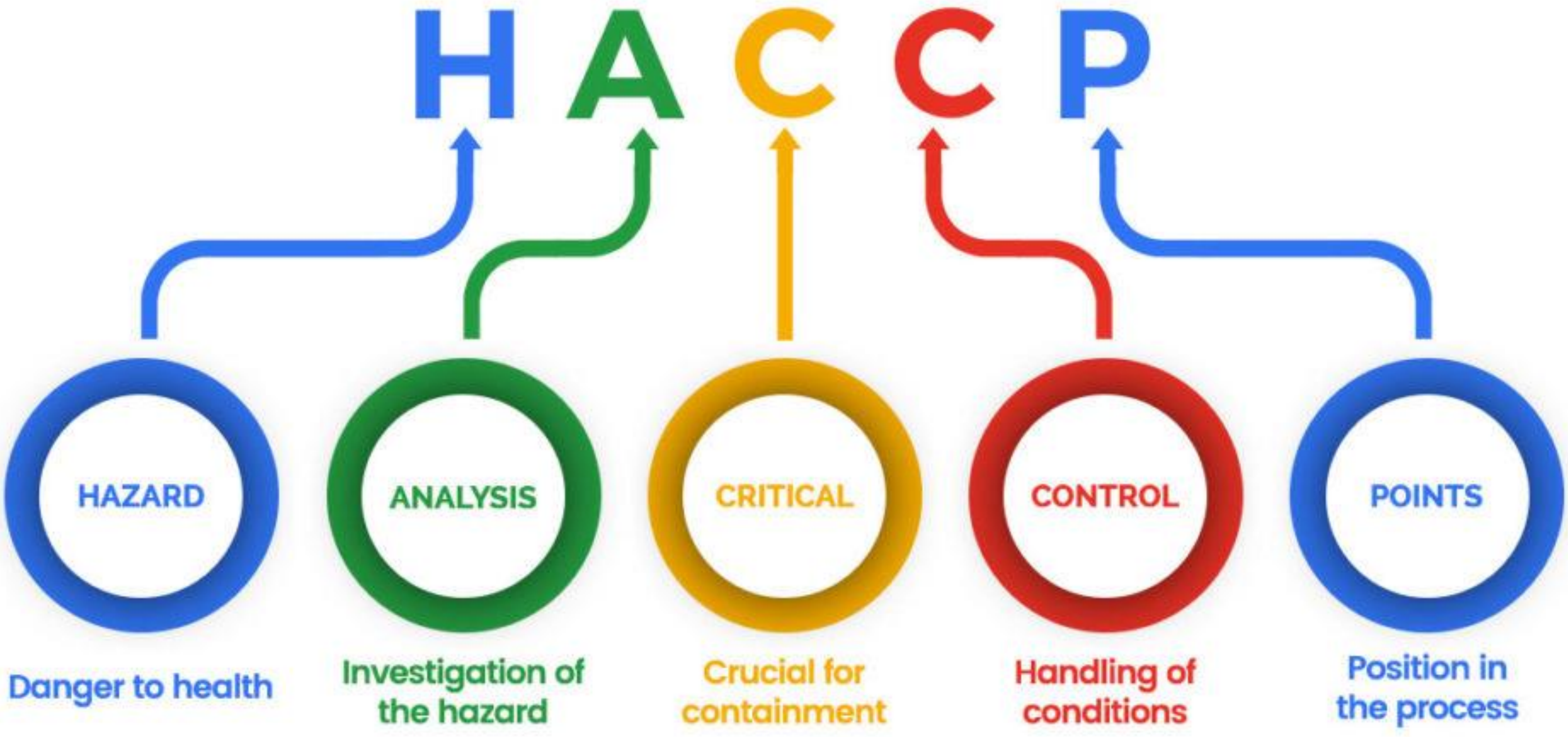
# Multiple Barriers

- Common element in many National and International Water Quality Guides
  - HCCAP
  - Water Safety Plans
  - Drinking Water Guidelines
  - Water Quality Guidelines


- "Catchment to Tap"
  - Systematically assess hazards, risk and control measures

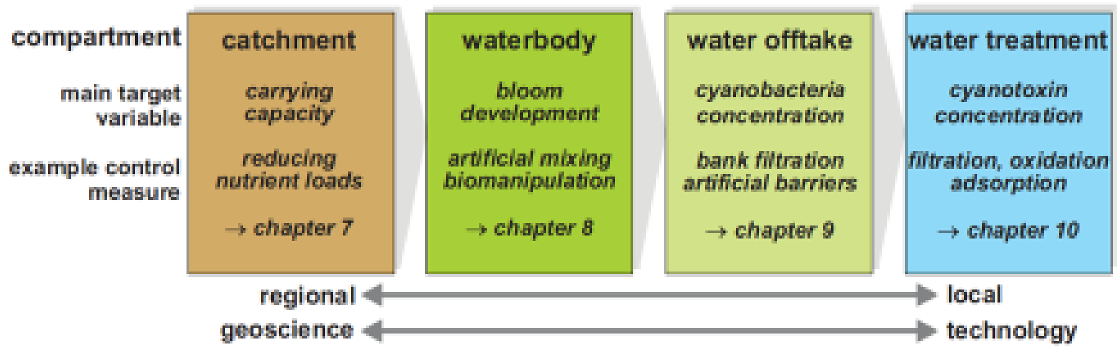
- ***Toxic cyanobacteria in water*** (2nd edition) provides a comprehensive guide to inform state and national guidelines, assess situations and manage risk

# HACCP CERTIFICATION



# Critical control points and control measures

- ***Toxic cyanobacteria in water*** (2nd edition) outlines critical control points and control measures




- Advice to tailor control measures to the local situation and the cyanobacterial risk



World Health Organization


WARNING!
BLUE-GREEN ALGAE
BLUE-GREEN ALGAE HAS BEEN DETECTED IN THE WATER AND ON THE FORESHORE OF THIS AREA.
AVOID DIRECT CONTACT
AS THIS ALGAE CAN CAUSE SKIN EYE, OR RESPIRATORY IRRITATION.
RECREATION HAZARD
Blue-green algae hazard
WARNING
Current Recreation Hazard
Uiminen kielletty
Danger
Baignade interdite
Algues bleu-vert abondantes
ÉVITEZ DE TOUCHER OU DE BOIRE L'EAU
Québec
Achtung Algenblüte
Vergiftungsgefahr
Baden verboten
Hunde an der Leine führen