Cyanobacterial Problems in South American Reservoirs: Historical Background, Current Status and Prospects for Countermeasures

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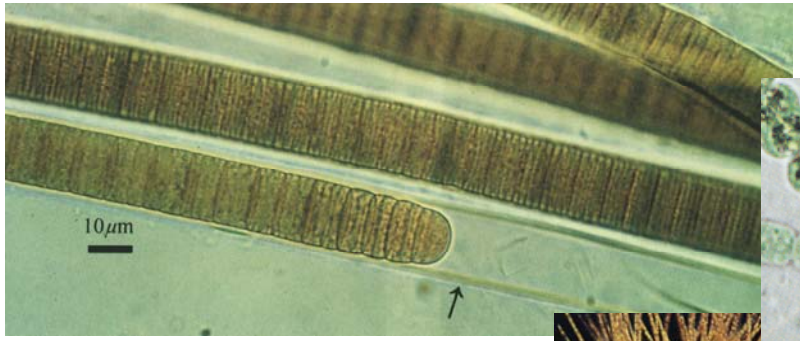
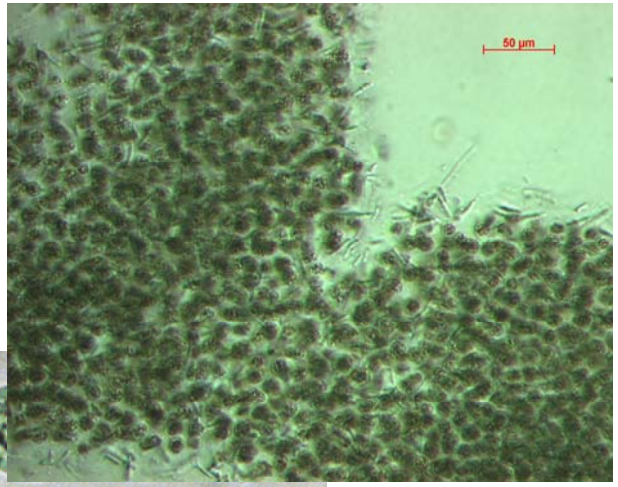
Main questions to be addressed:

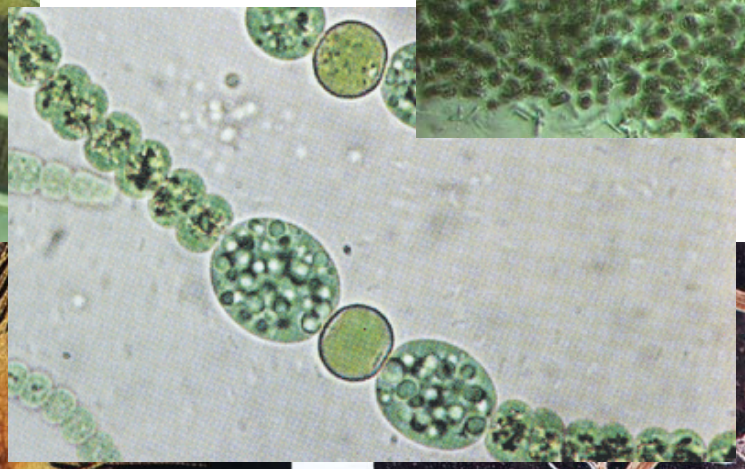
- What are the relationships among cyanobacterial blooms, eutrophication, and climate changes?
- Why are Cyanobacteria a concern in water bodies?
- What are cyanotoxins?
- Which are the features in Latin America that promote toxic cyanobacterial blooms persistence?

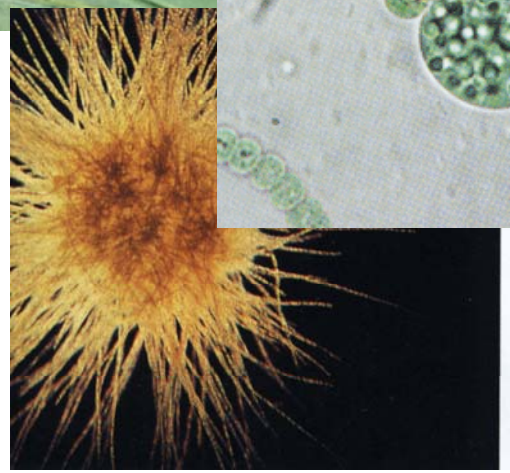
Cyanobacteria: High diverse group

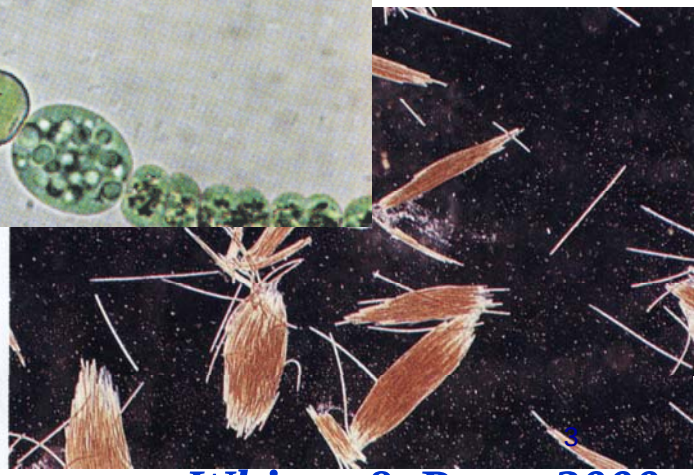
- Shape and cell size;
- Ecological strategies;
- Secondary metabolites.







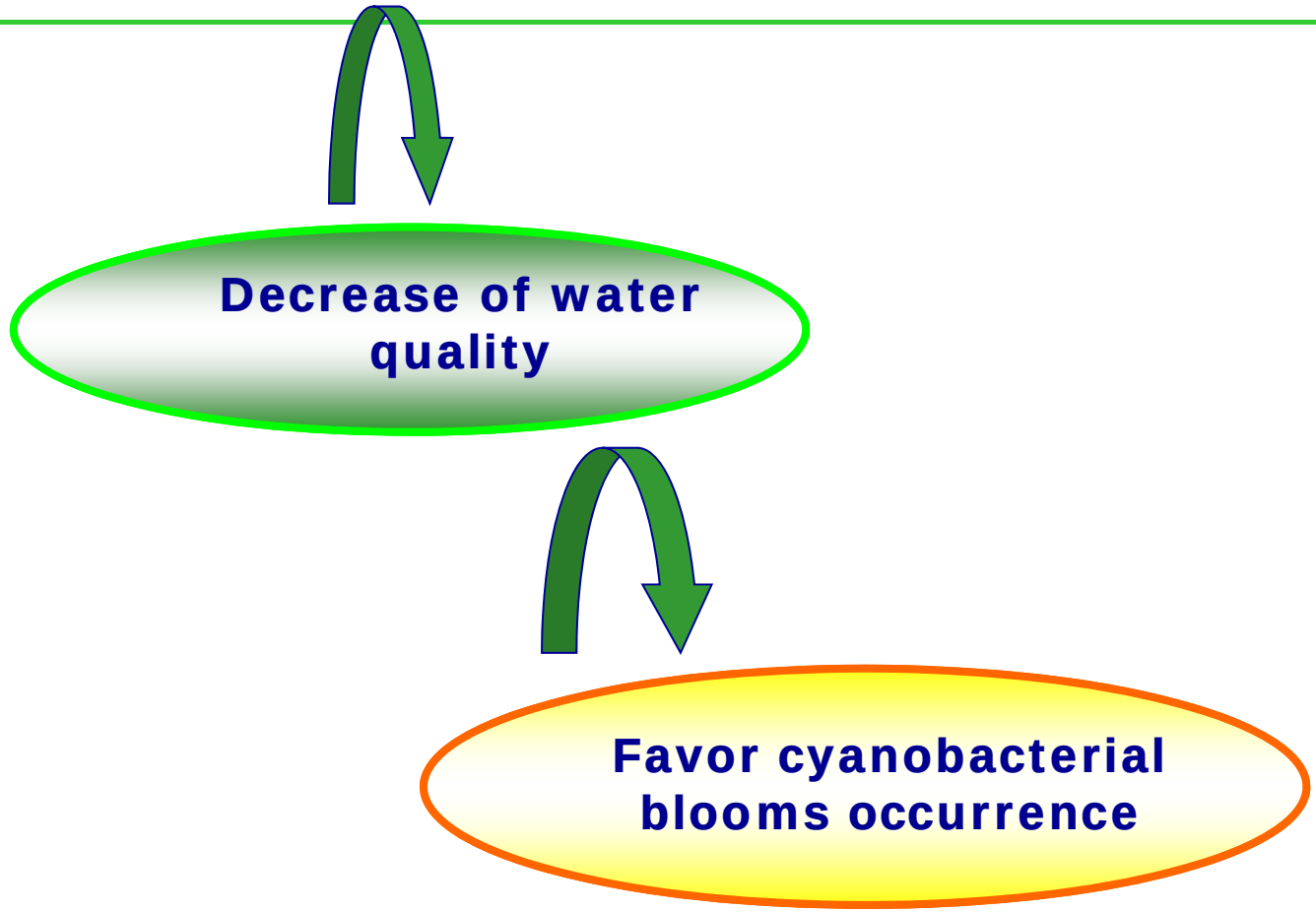


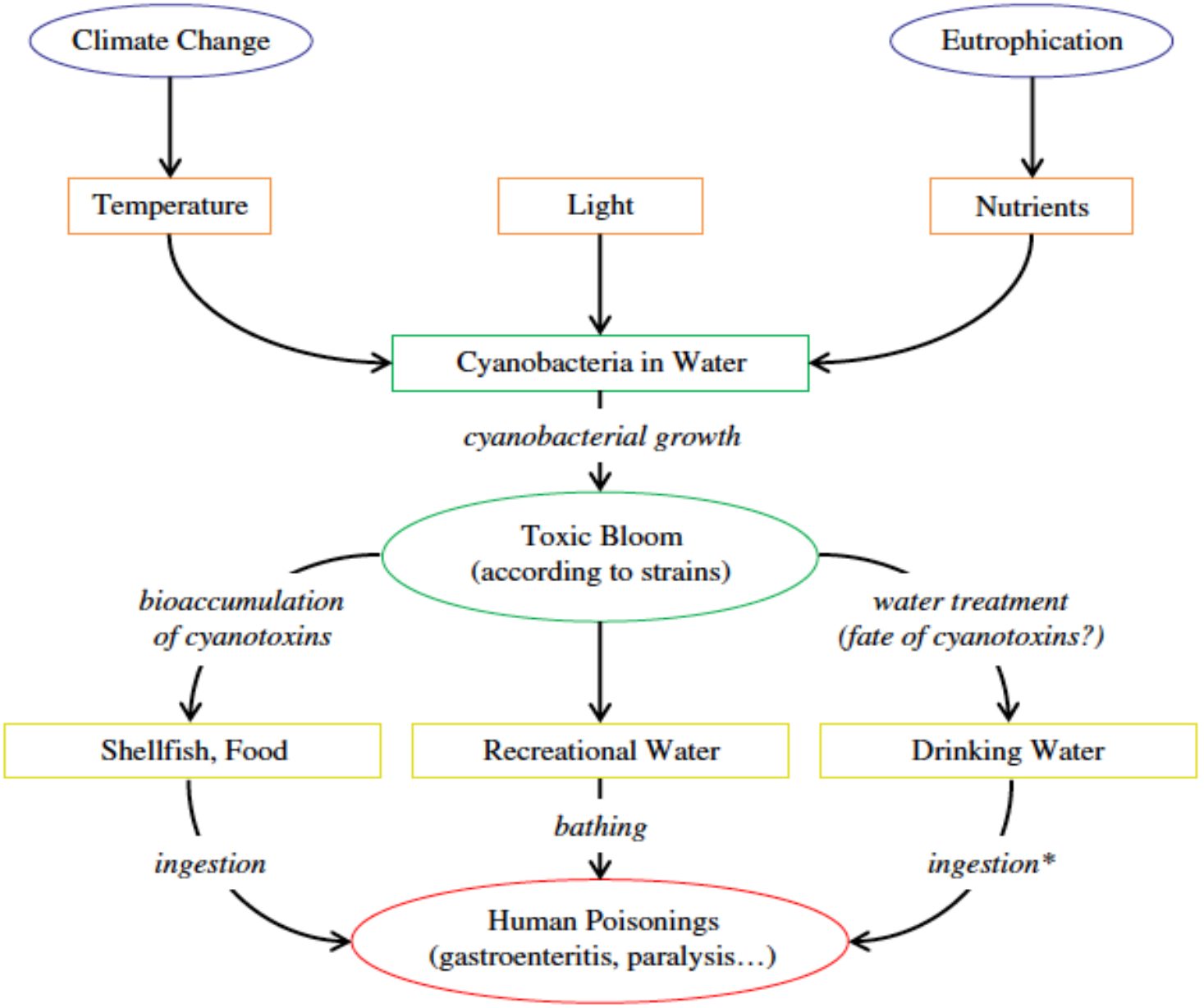


Cyanobacteria: photosynthetic prokaryotes. Cell diameter from 0,4µm to 40µm

Whiton & Potts, 2000

Increased eutrophication process on aquatic environments

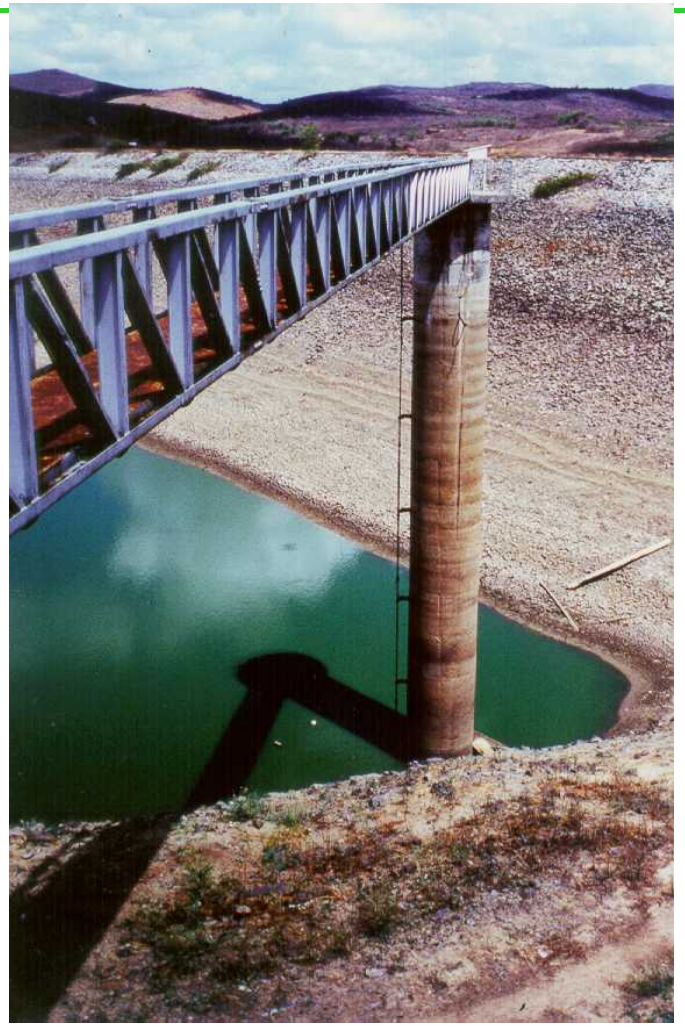




** 80% of human exposure to cyanotoxins (WHO, 1998)*

Extreme climatic events

“El Niño” events promoting severe drought seasons

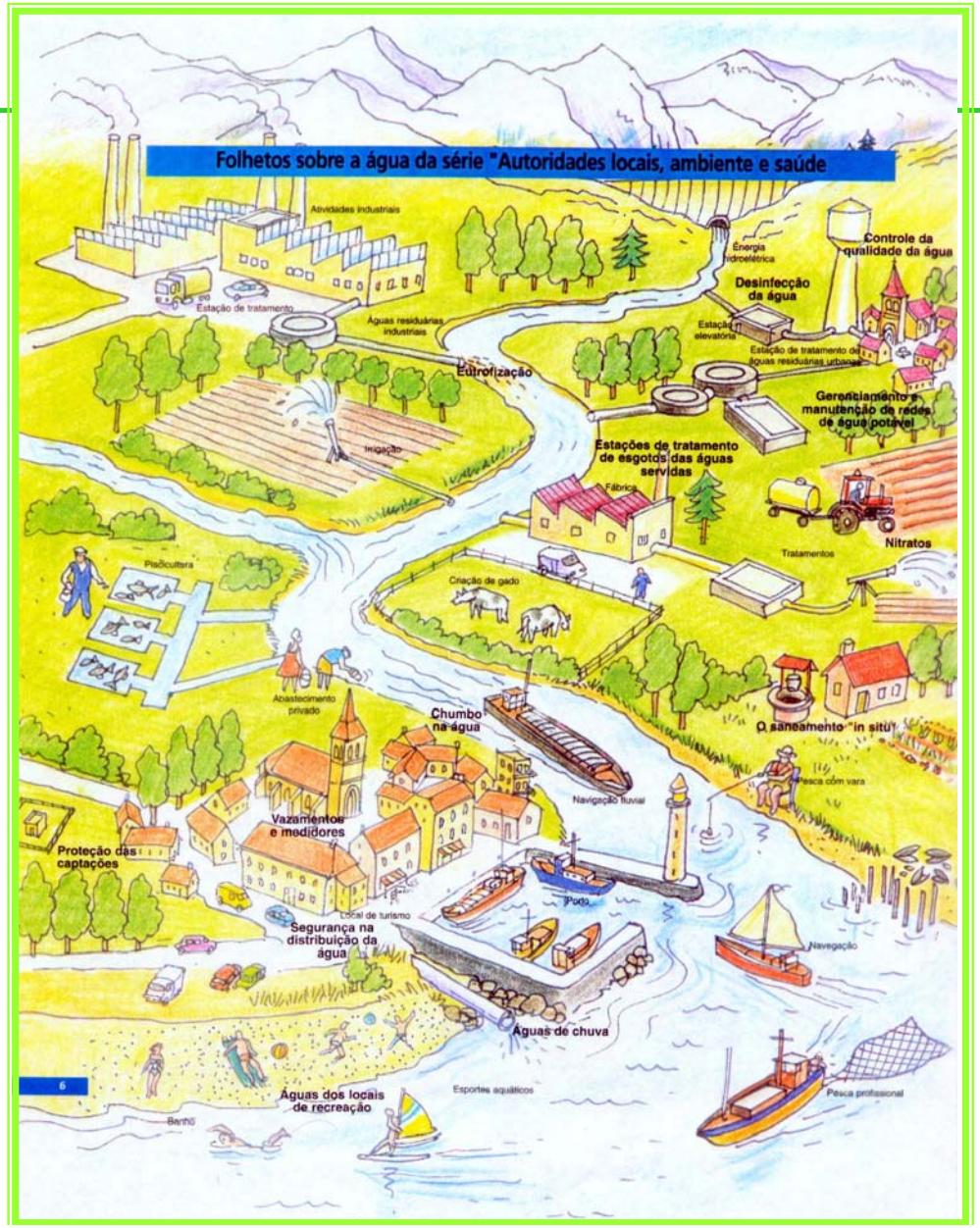


Tabocas Reservoir – Brazil, PE : 1997-1998-1999

MULTIPLE USES OF WATER RESOURCES

- **drinking water**
- **irrigation**
- **industrial**
- **navigation**
- **recreation**
- **aquaculture**

Eutrophication



Cyanobacterial Blooms in drinking water supplies

Events in:

Argentina

Brazil

Chile

Honduras

Mexico

Uruguay

Venezuela

Cyanobacterial Blooms in Coastal Lagoons

O Globo 08/2000

Events in reservoirs for multiples uses

PORCE II reservoir

ANTIOQUIA – COLOMBIA

Microcystis bloom in coastal zone

O Globo 11/11/04

Reports about occurrence of cyanobacterial blooms

Reports observing blooms in Europe for at least 1,000 years

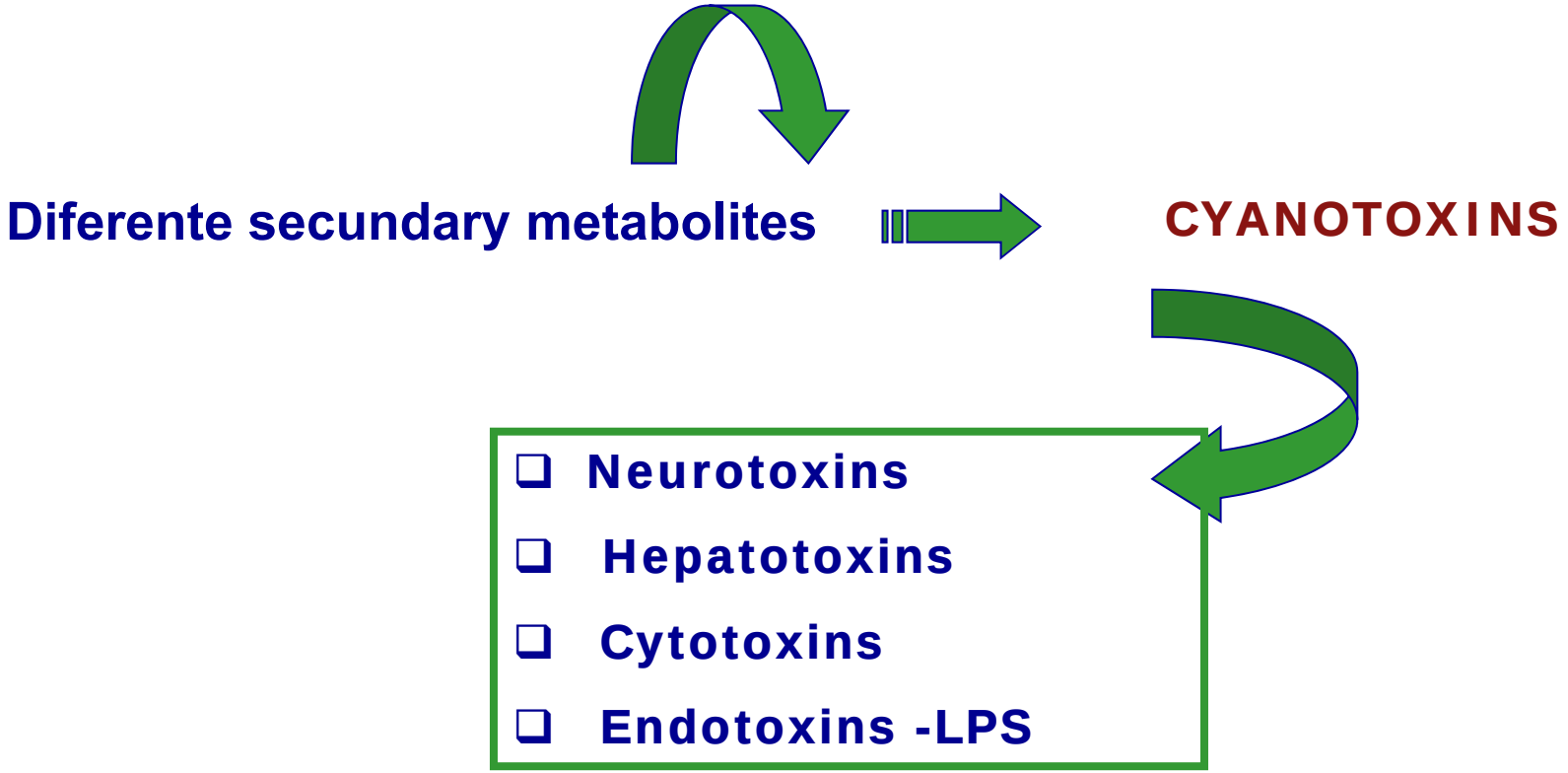
Geraldus Cambresis (1188) described Lake Llangorse (Wales) as: *"the lake has many miraculous properties ....it sometimes turns bright green, and in other days it has been known to become scarlet, not all over, but as if blood were flowing along certain currents and eddies".....*

There are also reports that indicate traditional knowledge of the toxicity of blooms among native peoples of North America, Africa and Australia. (Codd et al., 2005)

First technical reports about animal deaths by ingestion of cyanobacteria

Place	Cyanobacteria	Animal death	Reference
Jutland – Denmark – 4 lakes	No identifyed	Cattle and fish	Hald (1883)
Australia – Lake Alexandria	*Nodularia spumigena*	Sheep, cattle, horses, pigs and dogs	Francis (1878)
Pomerania (Polonia) – Lake Barlewice	*Microcystis aeruginosa, Anabaena flos-aquae, "limnochlide flos-aquae"(Aphanizo menon flos-aquae*)	Foals, ducks, chickens, pigs and fish	Benecke (1884)

VARIOUS CYANOBACTERIA GENERA AND SPECIES



Cyanotoxins

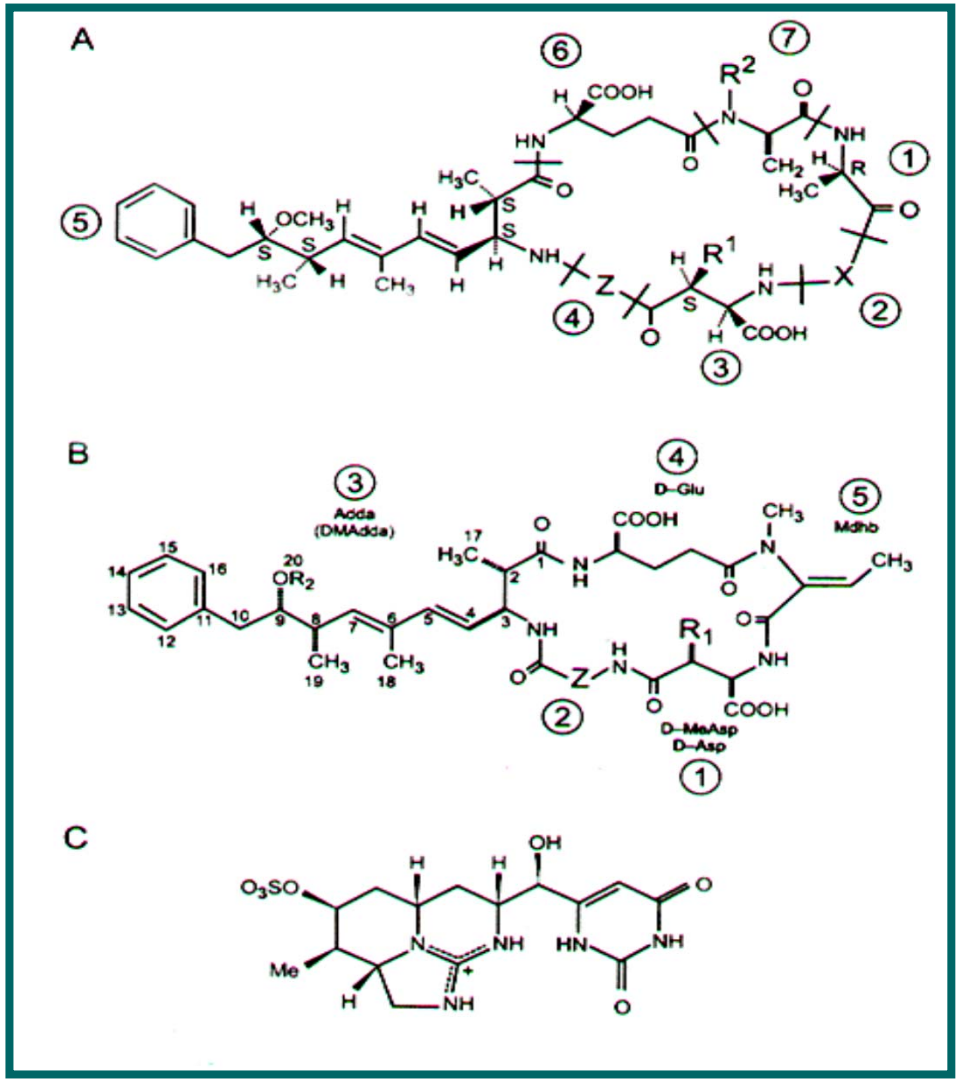
Neurotoxins

- Anatoxin-a
- Guanitoxin (ATX-A(s))
- Saxitoxins

Hepatotoxins

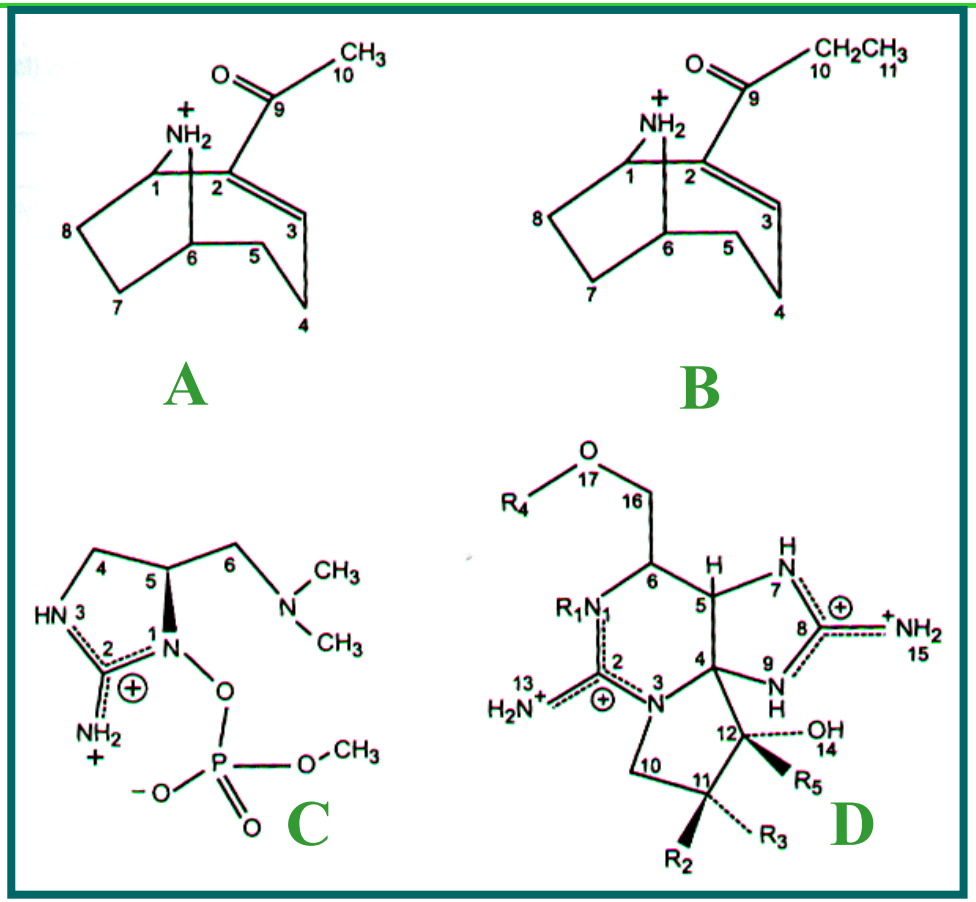
- Microcystins
- Nodularin
- Cylindrospermopsin

Chemical structure of Hepatotoxins



(A) Microcystin
(B) Nodularin
(C) Cylindrospermopsin

Chemical Structure of Neurotoxins



(A) anatoxin-a, (B) homoanatoxin-a, (C) guanitoxin; (D) saxitoxins (general structure)

Latin America

Area: 19,197,000 km^2
Population: 642,216,682 (2018)

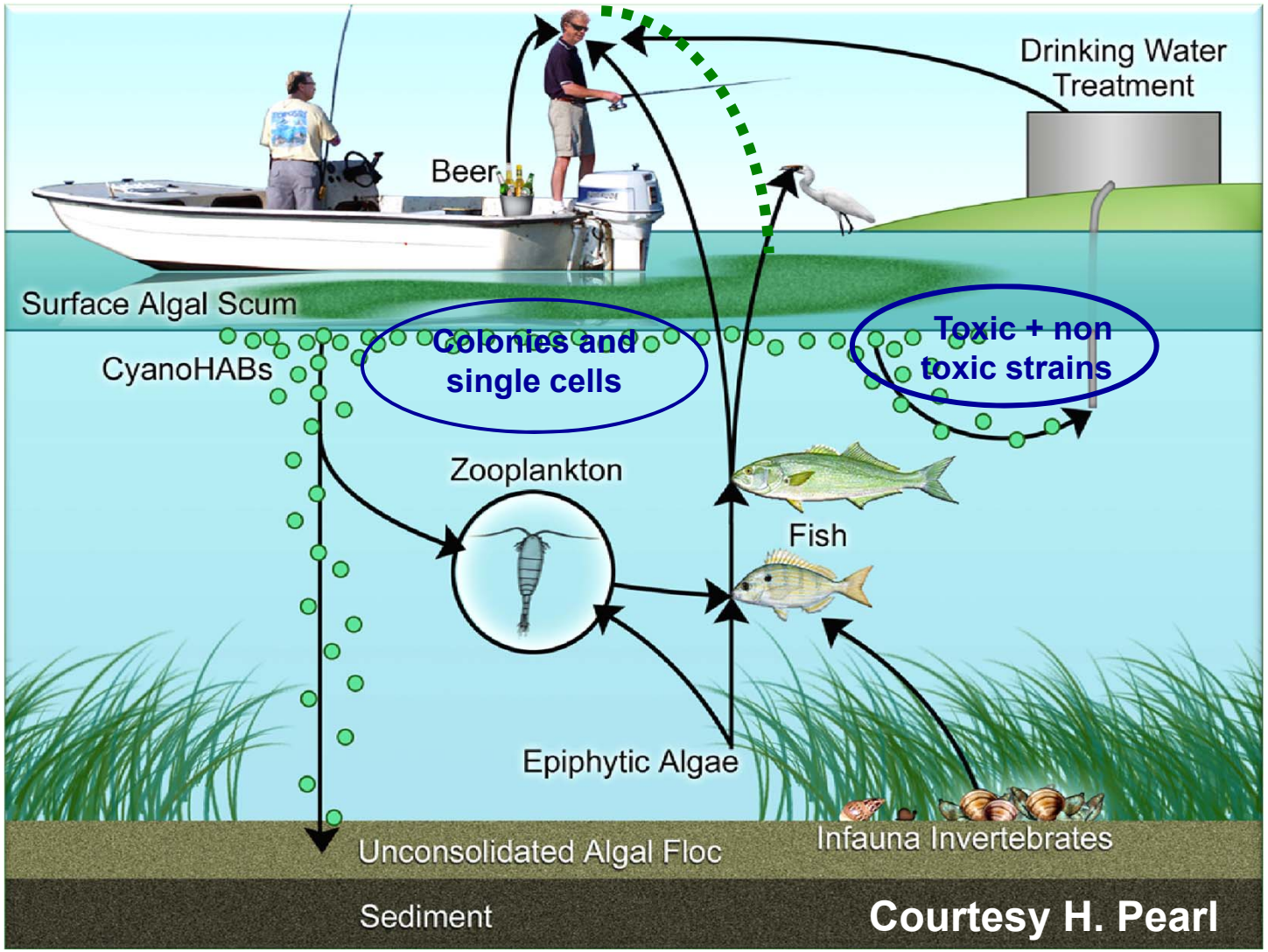
Countries: 20

13% of the Earth's land surface area

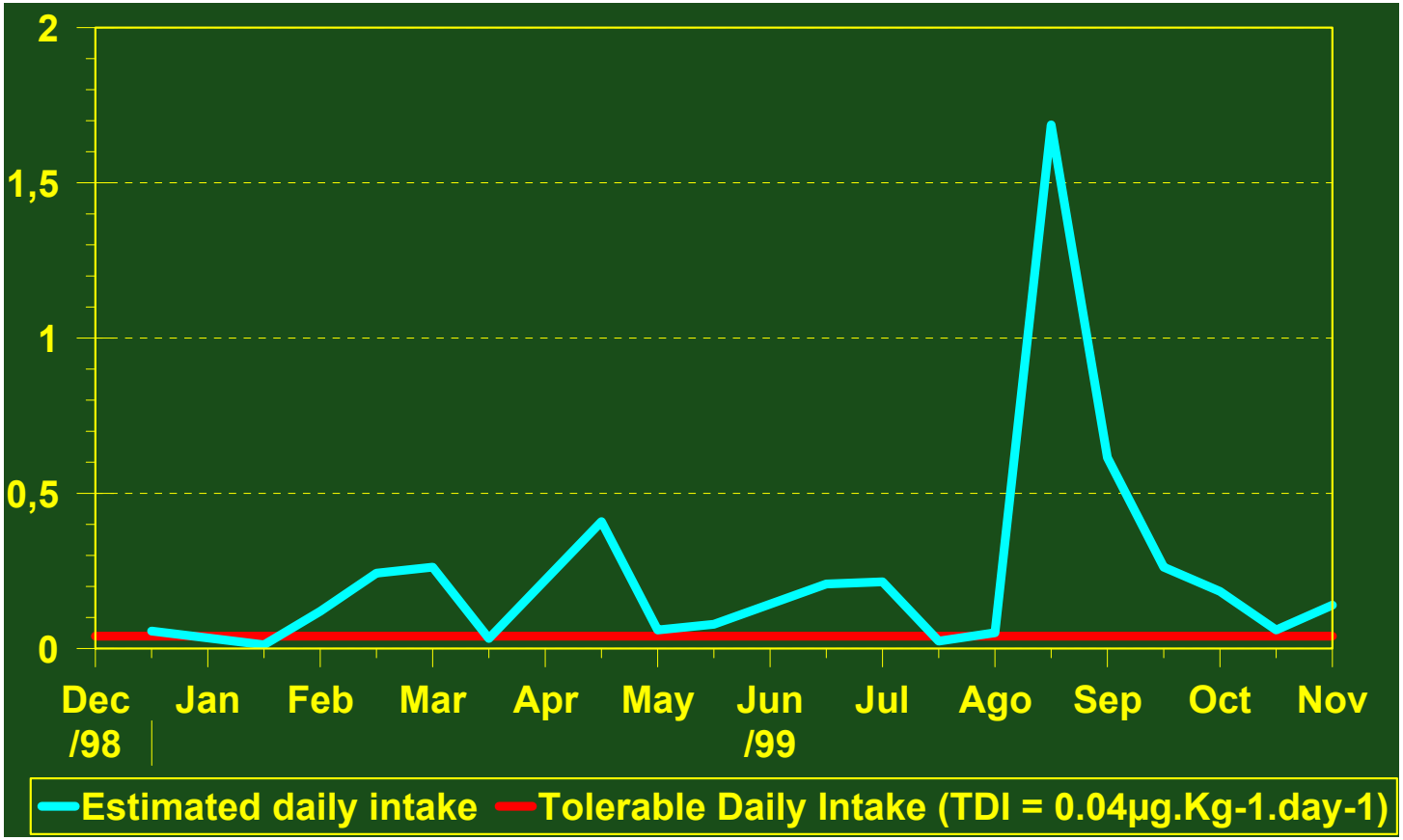
According to WHO (2017)

- only 22% of wastewater is safely managed.
- about 23 million people are living without clean, safe drinking water.

Trophic cyanotoxin connections



Estimated daily intake of Microcystin by fish consumption



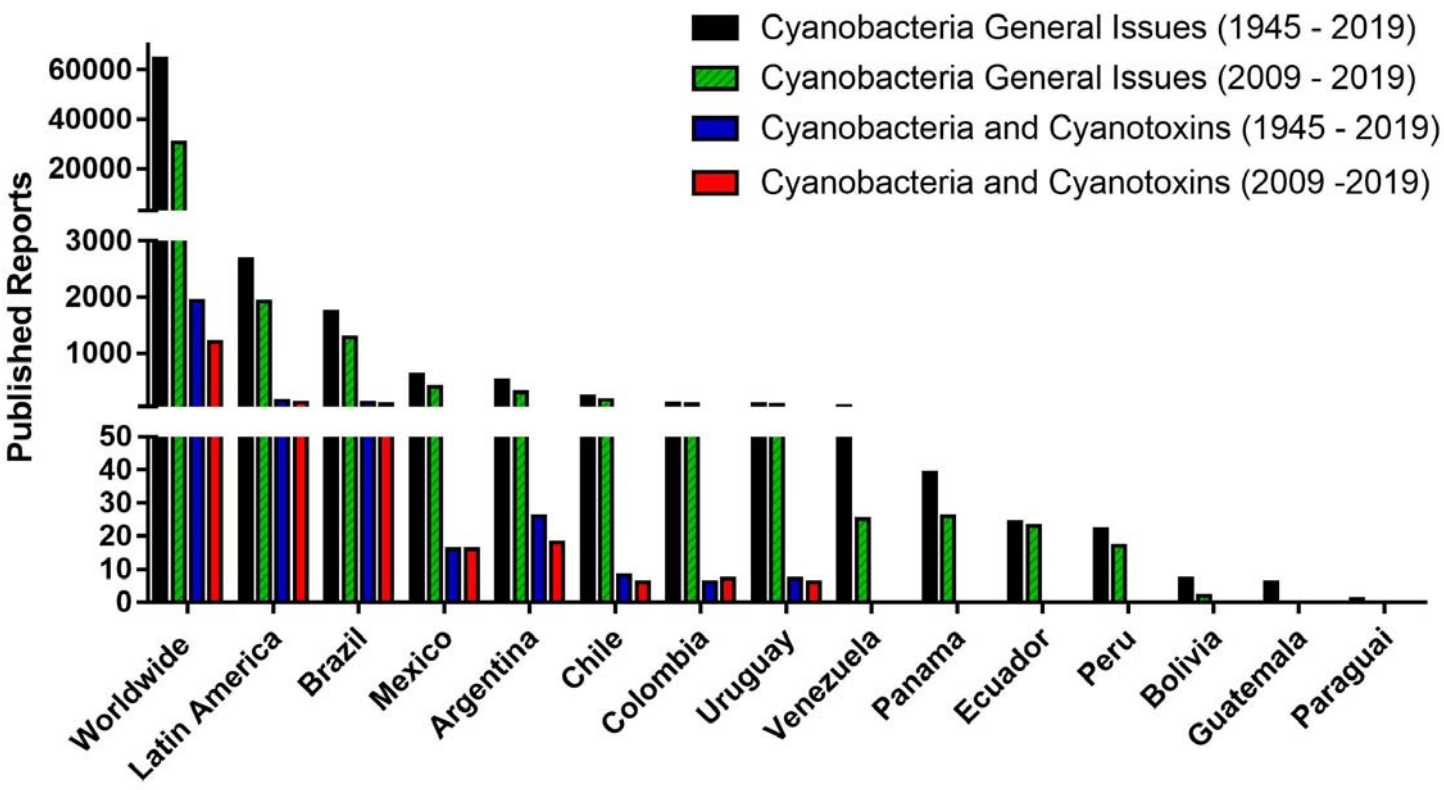
***Magalhães et al* (2001)**

Microcystin in aquatic organisms for human consumption**

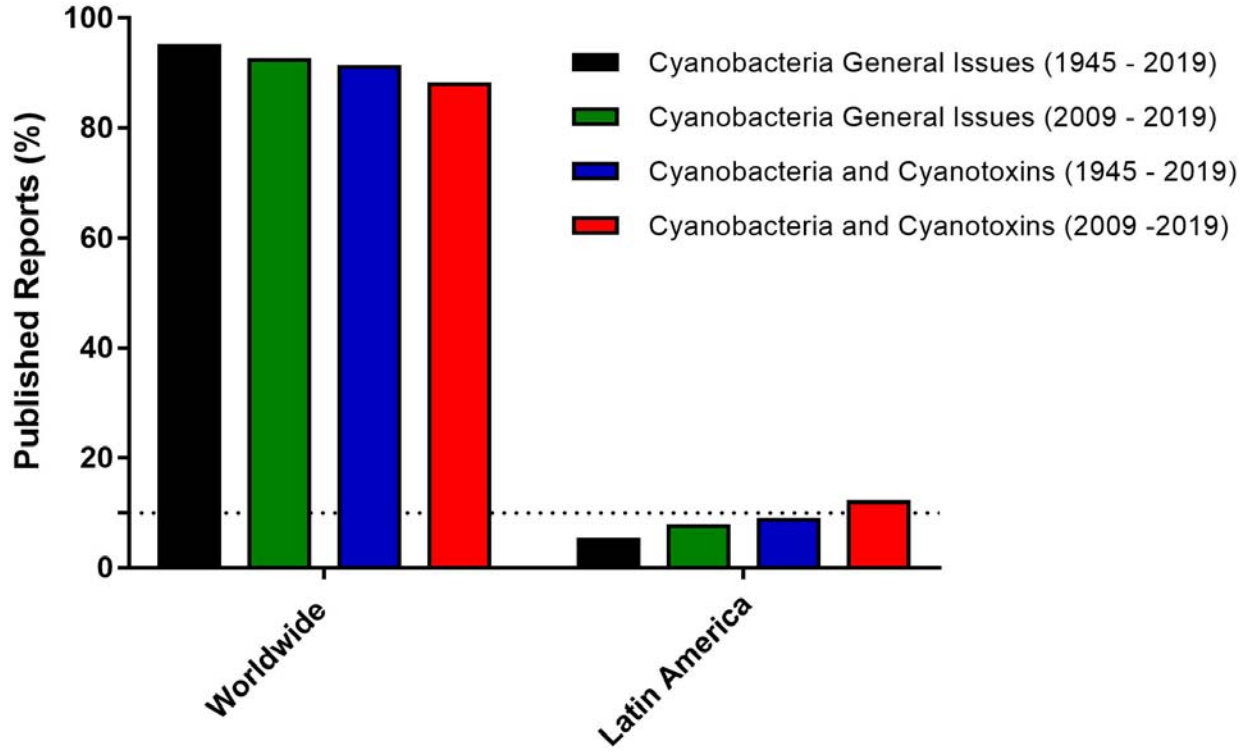
Organism	MC µg g^{-1}	TDI factor*	Reference
Pejerrey	0.05 - 0.34	2.7 - 18.2	Cazenave et al. 2005
Carp	0.038	2.0	Li et al. 2004
Tilapia	0.002 - 0.337	0.1 - 18.1	Magalhaes et al. 2001
Unidentified crab	0.103	5.5	Magalhaes et al. 2003
Red Swamp Crawfish	0.005 - 0.010	0.3 - 0.5	Chen & Xie, 2005a
Freshwater Shrimp	0.006 - 0.026	0.3 - 1.4	Chen & Xie, 2005a
Anodonta woodiania	0.009 - 0.026	0.5 - 1.4	Chen & Xie, 2005b
Hyriopsis cumingii	0.022 - 0.039	1.2 - 2.1	Chen & Xie, 2005b
Lamprotula leai	0.021 - 0.058	1.1 - 3.1	Chen & Xie, 2005b

*calculated for a 70 kg person using total TDI 0.04 µg kg-1 BW d-1 and a consumption of 150 g fresh weight

**data compiled in Ibelings & Chorus, Environ. Poll. (2007)

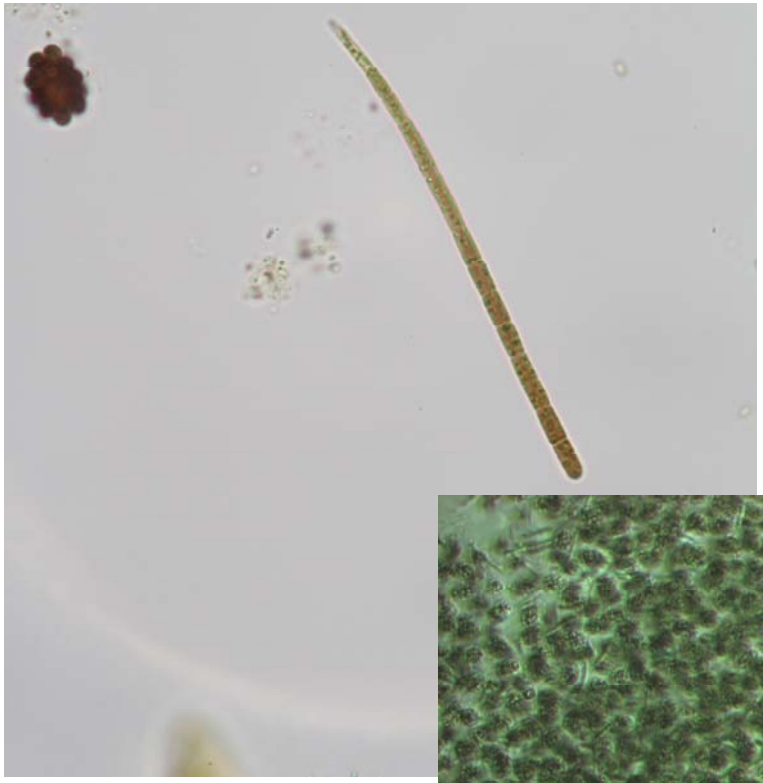


Overview of literature about cyanobacteria general issues, cyanobacteria bloom occurrence and cyanotoxins (Thomson Reuters Web of Science)



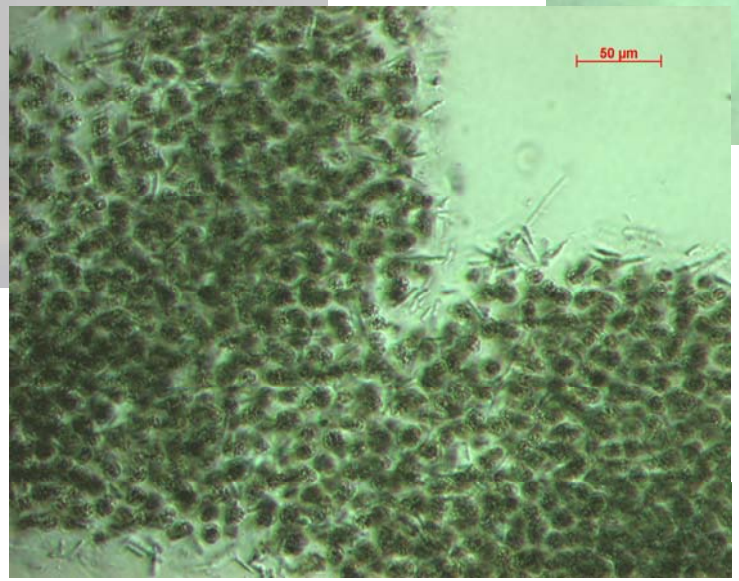
Percentage of worldwide and Latin America published reports about cyanobacteria general issues, cyanobacteria bloom occurrence and cyanotoxins (Thomson Reuters Web of Science).

Most common cyanobacteria genera



Raphidiopsis

Dolichospermum



Microcystis

Gaps in Latin America studies and Prospects for Countermeasures

Taxonomy and Systematics

- Identification of different morphotypes
- Identification of types of resting stages
- Different strategies among closely related species or different populations of the same species

Monitoring Program

- Historical records and local knowledge
- Design of monitoring programs using an early warning system by the improvement of observation systems

Gaps in Latin America studies and Prospects for Countermeasures

Ecology

- Critical features and mechanism underlying the population dynamics of cyanobacteria in the context of physical and chemical forcing
- Dynamics of toxin production under different environmental conditions
- Influence of specific anthropogenic activities on the frequency, intensity, and geographic distribution of particular cyanobacteria species (ecotypes)

Gaps in Latin America studies and Prospects for Countermeasures

Chemical and **(Eco)Toxicology**

- Improvement of the facilities and expertise for analytical techniques
- Development of alternative toxicity tests
- Standardization of analytical techniques

Summarizing data from Latin American countries

	Occurrence of blooms	Most common genera	Cyanotoxins	Report incidents
Argentina	1,2,3,4,5 1= rivers; 2= reservoirs; 3= lakes 4= coastal lagoons 5= estuaries	*Microcystis* *Dolichospermum (Anabaena)*	Microcystins Neurotoxins not identified	Bad taste and odor; Fish and birds death; Skin irritation; Digestive and respiratory disorders
Brazil	1,2,3,4,5	*Microcystis* *Dolichospermum* *Raphidiopsis*	Microcystins Saxitoxins Guanitoxin (ATX-A(s)) Cylindrospermopsin	Bad taste and odor; Fish and birds death; Human death; Digestive disorders
Chile	3	*Microcystis*	Microcystins	-
Colombia	2,4,5	*Microcystis* *Raphidiopsis*	-	Massive fish death
Uruguay	1,2,3,4,5	*Microcystis* *Dolichospermum* *Nodularia*	Microcystins	Digestive disorders;
Venezuela	2,3	*Microcystis* *Dolichospermum* *Raphidiopsis*	-	Bad taste and odor

	Methods for cyanotoxins analysis	Management actions	Educational Actions
Argentina	Mouse bioassay HPLC LC-MS ELISA	Phytoplankton monitoring program; Sewage treatment plants; Drinking water guidelines under revision	Raising poster distribution; Workshops; Training courses
Brazil	Mouse bioassay HPLC LC-MS ELISA	Phytoplankton monitoring program; Improvement of drinking water treatment	Folders and technical literature distribution; Training courses; Workshops
Chile	HPLC ELISA MALDI-TOF-MS	Phytoplankton monitoring program	-
Colombia	-	Phytoplankton monitoring program	Training course and workshop
Uruguay	ELISA	Phytoplankton monitoring program; Advise against recreational actives near blooms; Drinking water guidelines under revision	Training courses; Workshops
Venezuela	Mouse bioassay		Workshops