Fate and Effects of Microcystin in Nearshore and Upland Environments

Andrew McQueen, PhD
Research Biologist
US Army Engineer Research and Development Center (ERDC)

Karen Keil, PhD - USACE, Buffalo District
Mike Habberfield, PhD – USACE, Buffalo District
Burton Suedel, PhD – USACE, ERDC

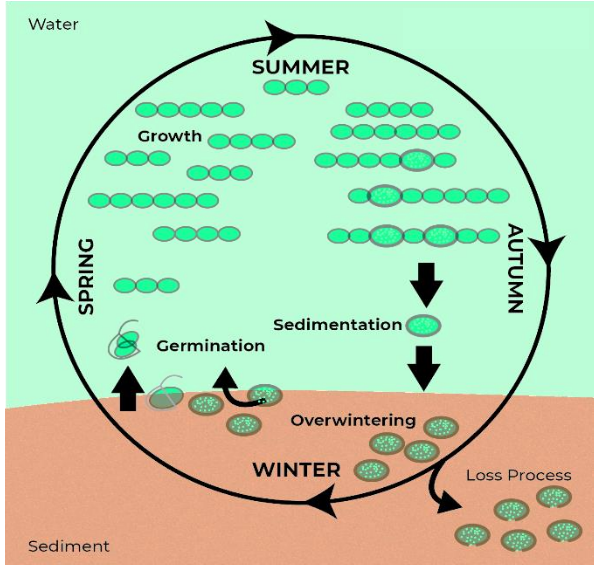
GLDT Informational Webinar
15 September 2020

ERDC
Engineer Research and Development Center
US Army Corps of Engineers®
U.S.ARMY

Innovative solutions for a safer, better world

Introduction

- Harmful algal blooms (HABs) are a reoccurring issue in the Great Lakes
- Algal toxin (Microcystin) concerns
  - e.g., 2014 Toledo drinking water crisis
  - Microcystin > 1 µg/L WHO guideline
  - 400,000 people had no drinking water for 3 days
- Cyanobacteria can remain viable in the sediment and contribute to subsequent bloom events
- Lack of understanding of risks of HABs and toxins in bottom **sediments**



Modified from Hense and Beckman (2006)

Beneficial Use of Dredged Sediment

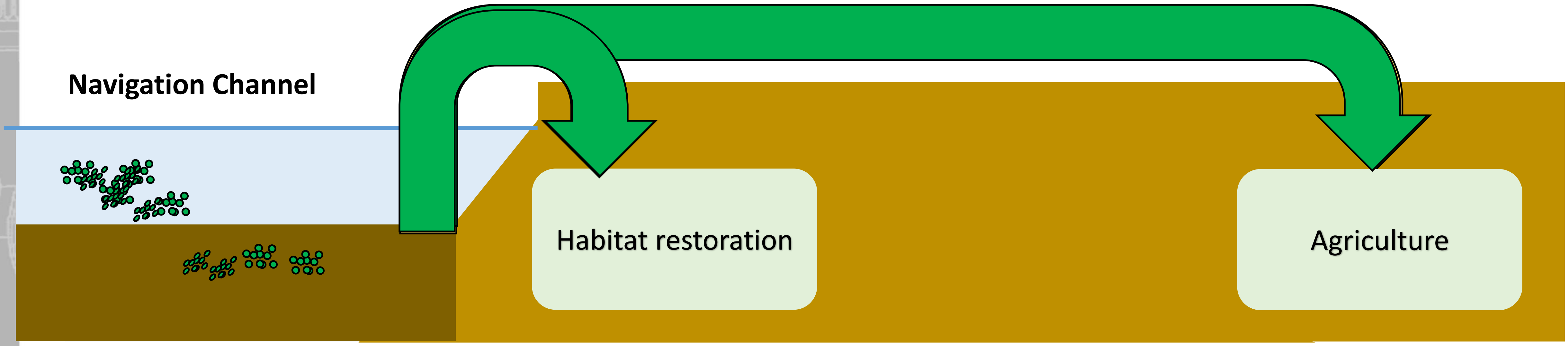
Beneficial uses

- habitat creation, agriculture, nearshore placement

If sediment is impacted by HAB toxins…

- where does it go and what are the risks?

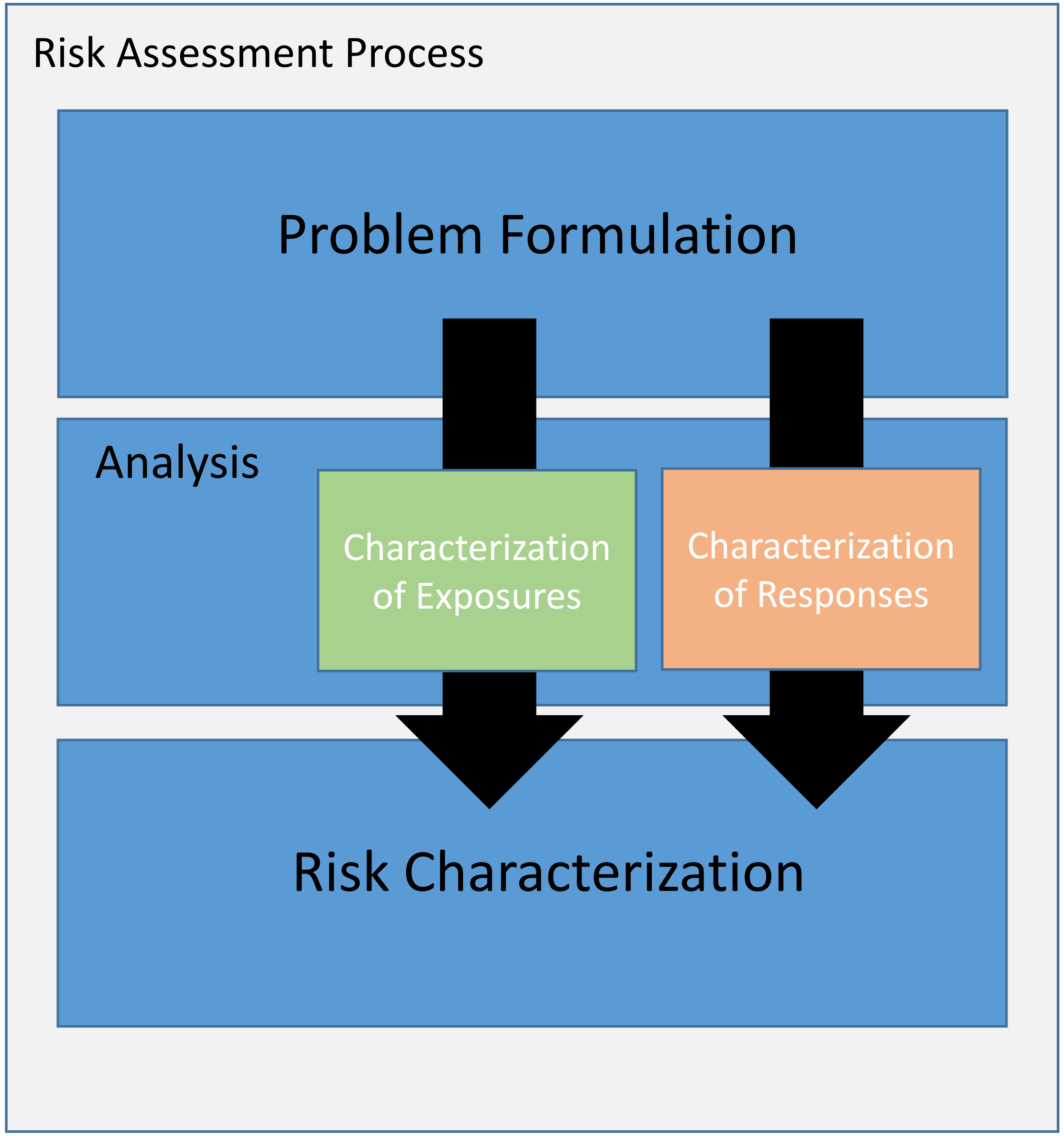
"We would suggest that the Army Corps of Engineers please consider Microcystins toxins that are produced by cyanobacteria that is commonly found in sediment and waters of the State. This is an important subject to factor in and we think it is worth addressing specifically for beneficial reuse of sediments." Ohio EPA



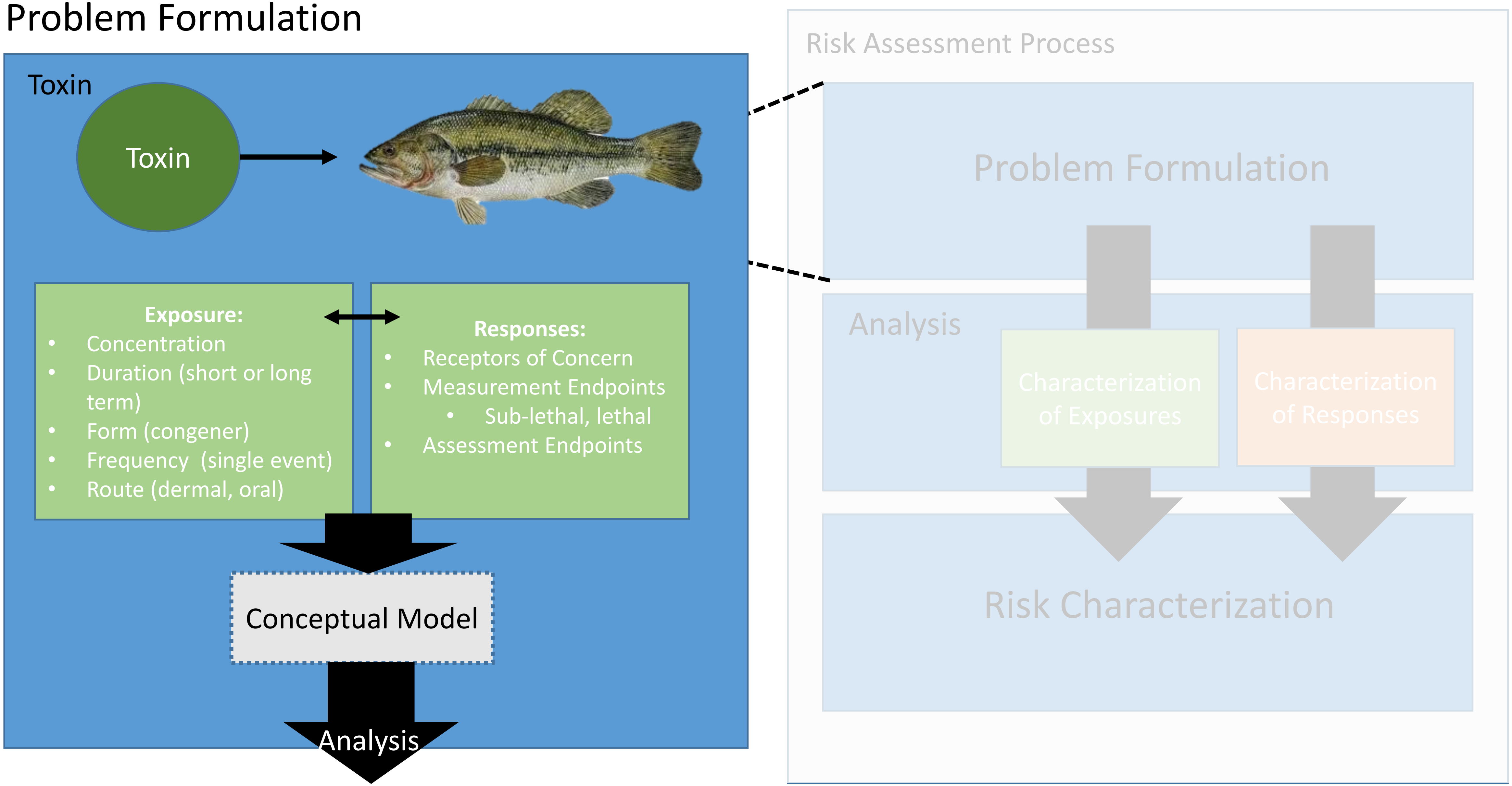
Outline

1) Importance of fate and transport processes for understanding exposure and risk

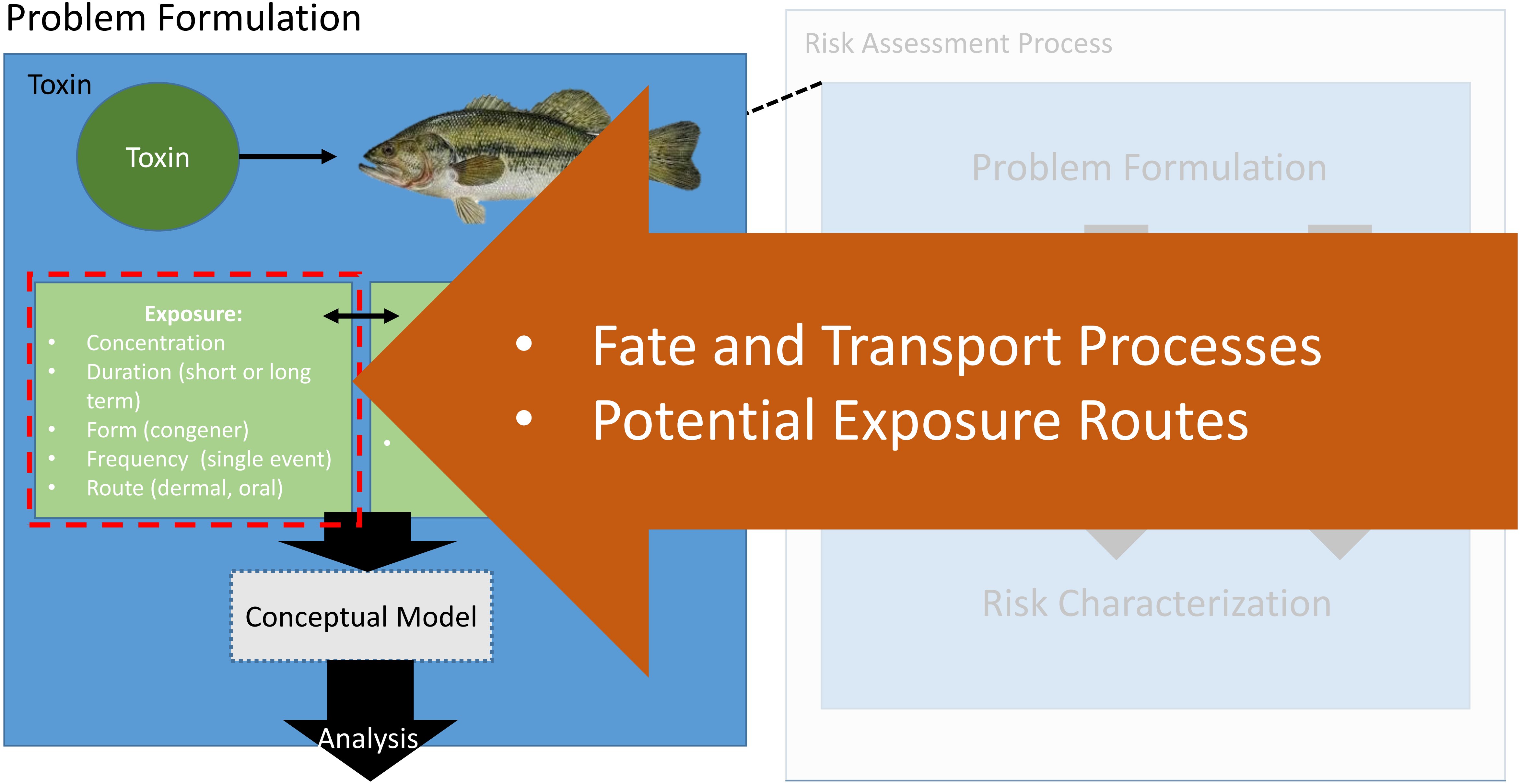
2) Determine algal toxin (microcystin) fate, transport, and exposure routes for upland or nearshore environments


Risk Assessment Process
Problem Formulation
Analysis
Characterization of Exposures
Characterization of Responses
Risk Characterization

Problem Formulation



Problem Formulation



Objectives

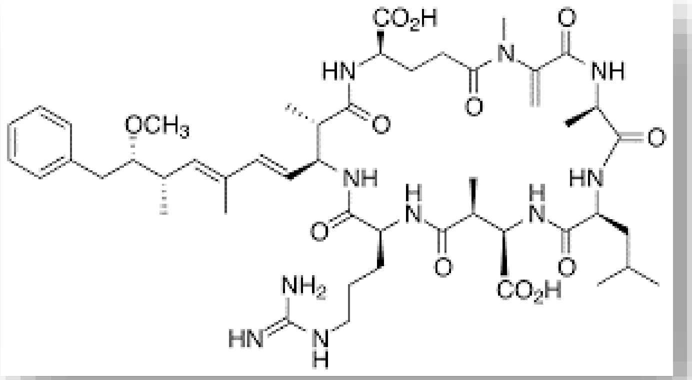
1. Identify the predominate fate and transport processes of MCs in sediments and soils

2. Identify potential exposure pathways for human and ecological receptors

Introduction: Microcystins (MCs)

- Secondary metabolites produced by numerous cyanobacteria
  - e.g., Microcystis, Anabaena, Planktothrix
- Endotoxins with adverse effects to **humans**, livestock, fish, aquatic invertebrates, and plants
- More than 100 congeners identified
- Microcystin-LR (MC-LR) is well-studied
- Fate and transport in sediments and soils?

Microcystin-LR



Approach

- Literature review on fate and transport of MCs
- Focus on sediments and soils
- Identify potential exposure pathways for human and ecological receptors

MC Physical and Chemical Properties

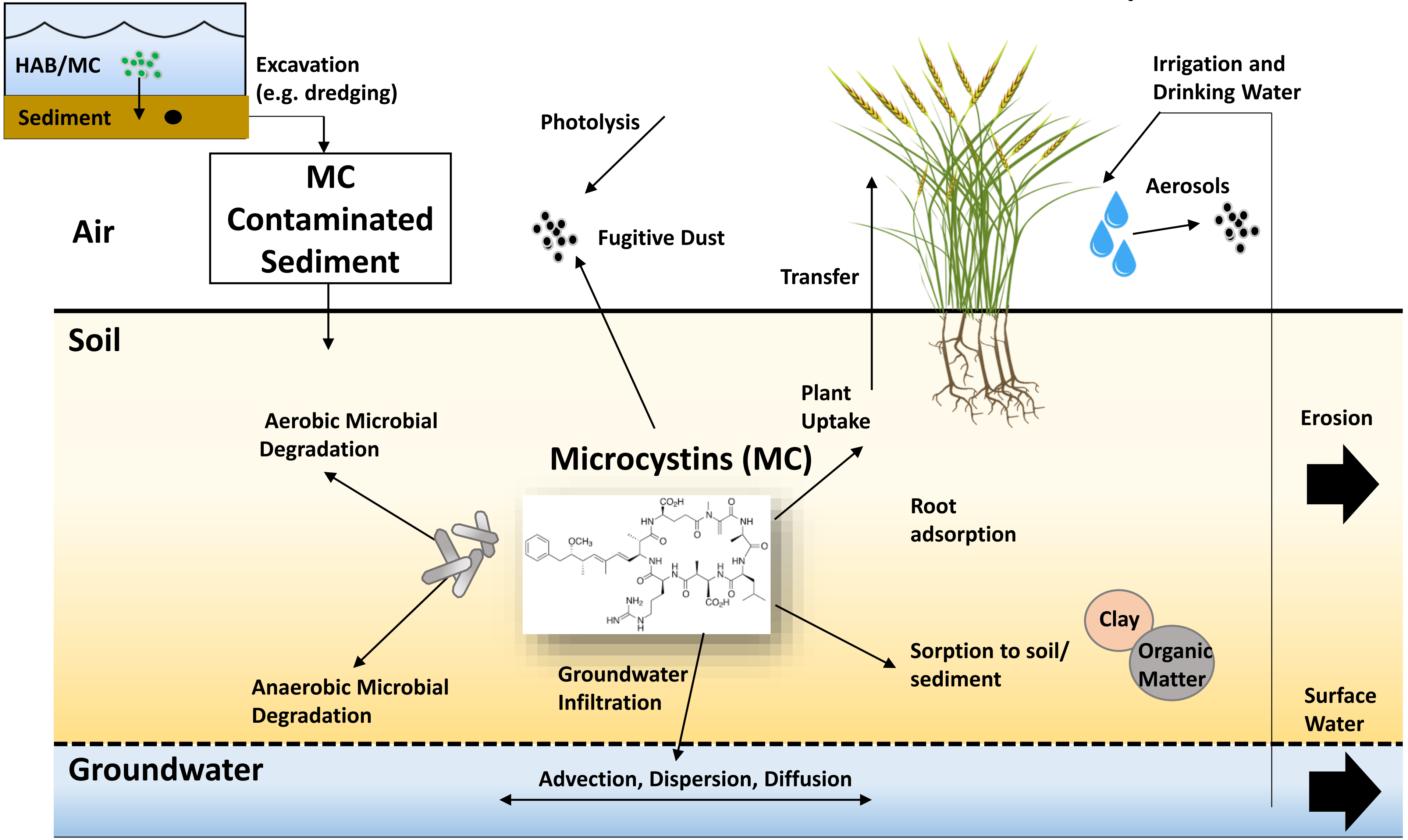
Parameter	Characteristic	Citation
Molecular weight	995.17 g/mol	Chemical Book 2018
Water Solubility	> 1 g/L	
Log KoW	-0.37 (neutral pH)	
Soil Kd		
Sediment A (4-8% OM)	5 ml/g (pH of 7.0)	
Sediment B (17-21% OM)	35 ml/g (pH of 7.0)	
Soil A (2.5% OC; 4% clay)	0.8 ml/g (pH of 6.7)	
Soil B (5% OC; 32% clay)	4.5 ml/g (pH of 6.7)	Miller et al. 2011

Take Home:

Likes Water

Soil affinity dependent on pH, organic matter, grain size

MC Transfer and Transformation Pathways



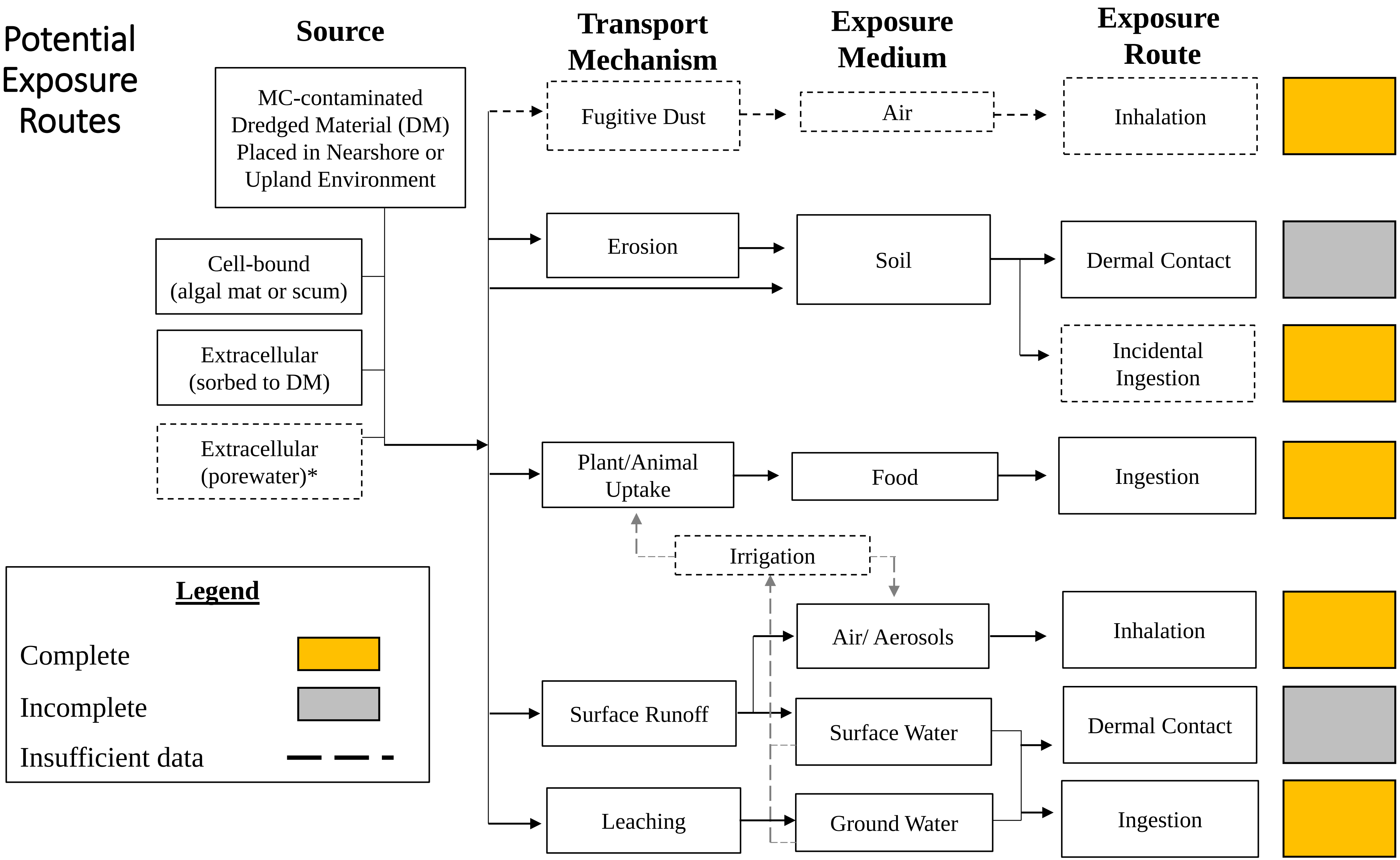
MC Transfer and Transformation – Where does it go?

Pathway	Comment	Citation
Microbial degradation (aerobic and anaerobic)	Half lives days to weeks (soil)	Miller and Fallowfield 2001; Chen et al. 2006
Soil hydraulic mobility	Mobility in soils; <20% sorbed to soils	Crobel et al. 2014; Corbel et al. 2016
Transfer to plants and animals (aqueous)	• Fruits, vegetables, grains • Fish • Invertebrates (bivalves, crustaceans)	Codd et al. 1999; Chen et al. 2012; Lee et al. 2017; Xi et al. 2007; Martins and Vasconcelos 2009, Kotak et al. 1996; Gutierrez-Praena et al. 2012
Aerosols	Water droplets Dust particles	Blanchard and Syzdek, 1972; Backer et al. 2010
Photolysis	Half lives minutes to hours	Tsuji et al. 1995; Kinley et al. 2018
Hydrolysis	Stable in water	USEPA 2015
Heat	Structurally resistant to heat 300° C	USEPA 2015

MCs Transfer and Transformation in Soils

- MCs are mobile in soils
  - Dependent on soil characteristics (pH, organic matter content, grain size)
- **Microbial degradation** is an important pathway
  - Dependent on conditions (nutrients, microbial density and diversity, temperature)
- Potential transfer of MCs to plants and animals
  - High degree of uncertainty related to upland environments
  - Irrigation or surface water may be an important component of MC transfer to biota

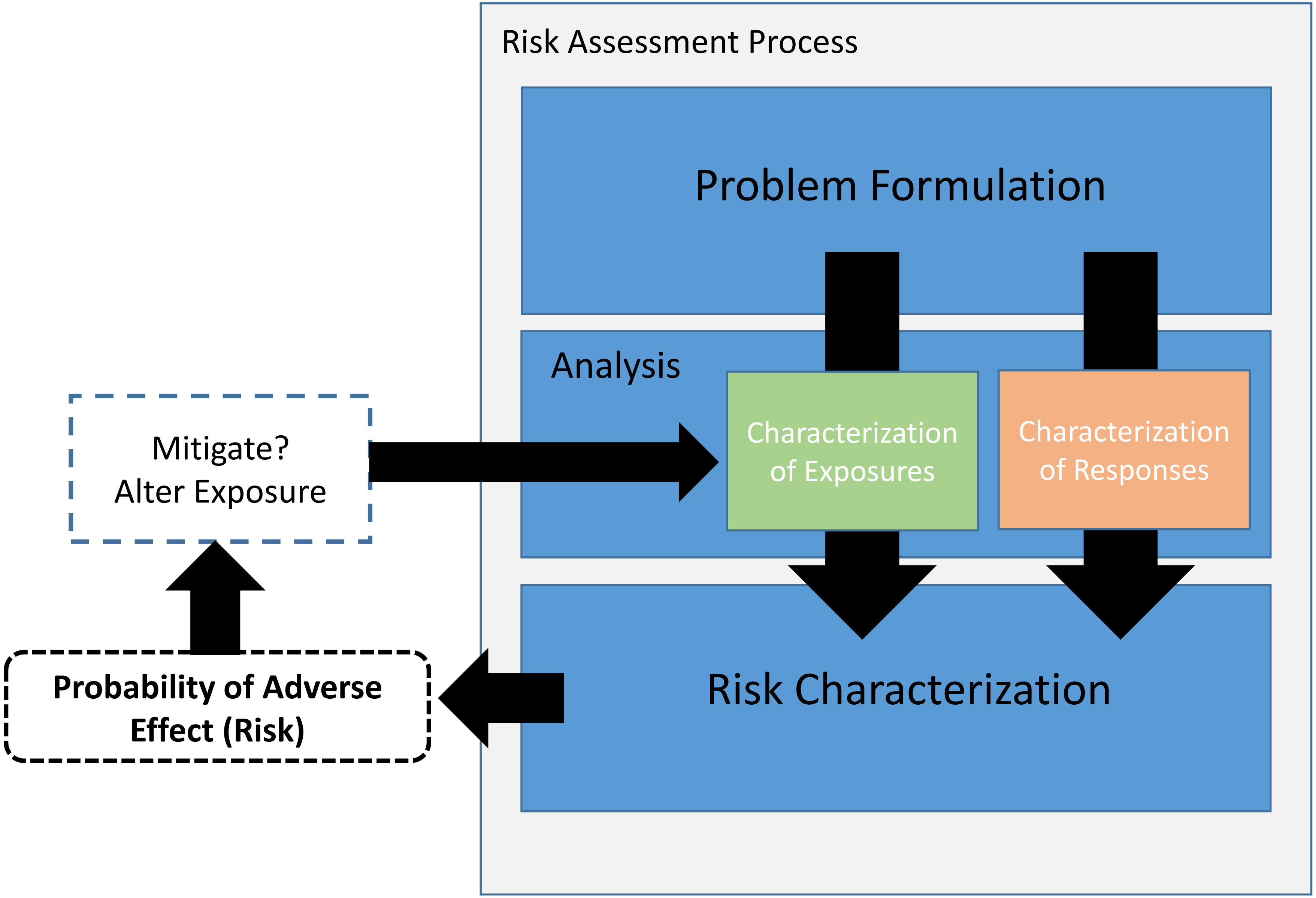
Potential Exposure Routes



*Porewater MCs are likely dependent on origin and placement method of DM (e.g. confined disposal facility versus newly dredged)

Data Gaps (Exposures)

- Standard laboratory methods for quantifying MC in a solid matrix
- Persistence, bioavailability, and degradation processes of MC in soil with varying characteristics (e.g., grain size and organic content)
- Influence of sorption of MCs to soil/sediment particles to bioavailability
- Aerosolization of microcystin from a solid matrix (e.g., beach sand or upland soil), subsequent transport, and resultant concentrations associated with inhalation risk to human receptors


Risk Assessment Process
Problem Formulation
Analysis
Characterization of Exposures
Characterization of Responses
Risk Characterization
Mitigate? Alter Exposure
Probability of Adverse Effect (Risk)

Summary

- MCs are mobile in upland soils
  - Dependent on soil characteristics (pH, organic matter content, grain size)
- Microbial degradation is an important degradation pathway
  - Dependent on conditions (nutrients, microbial density and diversity, temperature)
- Potential transfer of MCs to plants and animals
  - High degree of uncertainty related to the relevance in upland sites
- Potential exposure routes include ingestion via drinking water and ingestion (i.e., transfer of MCs to groundwater)
  - High degree of uncertainty of the rate and extent of transfer of MCs to groundwater

Resources

Technical Report
Fate and Effects of Microcystins in Nearshore and Upland Environments: A Literature Review
https://hdl.handle.net/11681/35274

Publication
Toxic benthic freshwater cyanobacterial proliferations review paper
https://doi.org/10.1111/fwb.13532

ERDC/TN DOTS-20-1
January 2020

Fate and Effects of Microcystin in Nearshore and Upland Environments: A Literature Review

by Andrew D. McQueen, Michael W. Habberfield, Karen G. Keil, and Burton C. Suedel

STUDY PURPOSE: Dredged material (DM) impacted by harmful algal blooms (HABs) potentially introduces algal toxins (e.g., microcystins (MCs)) to areas where material is being stored (e.g., confined disposal facilities (CDFs)) or beneficially used for nearshore and upland placement for land and habitat improvements. The objective of this study was to conduct a literature review of the current information related to the fate and transport of MCs in upland

Received: 25 January 2020 | Revised: 29 April 2020 | Accepted: 5 May 2020
DOI: 10.1111/fwb.13532

REVIEW

Freshwater Biology WILEY

Toxic benthic freshwater cyanobacterial proliferations: Challenges and solutions for enhancing knowledge and improving monitoring and mitigation

Susanna A. Wood[1] | Laura T. Kelly[1] | Keith Bouma-Gregson[2] | Jean-François Humbert[3] | Haywood Dail Laughinghouse IV[4] | James Lazorchak[5] | Tara G. McAllister[6] | Andrew McQueen[7] | Kaytee Pokrzywinski[7] | Jonathan Puddick[1] | Catherine Quiblier[8,9] | Laura A. Reitz[10] | Ken G. Ryan[11] | Yvonne Vadeboncoeur[12] | Arthur Zastepa[13] | Timothy W. Davis[10]

[1]Cawthron Institute, Nelson, New Zealand
[2]Office of Information Management and Analysis, California State Water Resources Control Board, Sacramento, CA, U.S.A.
[3]Institute of Ecologye and Environmental Sciences, INRAE/Sorbonne University, Paris, France
[4]Agronomy Department , Fort Lauderdale Research and Education Center, University of Florida, Davie, FL, U.S.A.
[5]Office of Research and Development, Center for Monitoring and Modeling, U.S. Environmental Protection Agency, Cincinnati, OH, U.S.A.
[6]Te Pūnaha Matatini Centre of Research Excellence for Complex Systems, University of Auckland, Auckland, New Zealand
[7]Environmental Laboratory, US Army Corps of Engineers, Engineer Research & Development Center, Vicksburg, MS, U.S.A.
[8]National Museum of Natural History, UMR MCAM, Communication Molecules and Adaptation of Micro-organisms, Paris, France
[9]Paris University, Paris, France
[10]Department of Biological Sciences, Bowling Green State University, Bowling Green, OH, U.S.A.
[11]School of Biological Sciences, Victoria University of Wellington, Wellington, New Zealand
[12]Department of Biological Sciences, Wright State University, Dayton, OH, U.S.A.
[13]Environment and Climate Change Canada, Canada Centre for Inland Waters, Burlington, ON, Canada

Correspondence
Susanna A. Wood, Cawthron Institute, 98 Halifax Street East, Nelson 7010, New Zealand.
Email: susie.wood@cawthron.org.nz

Funding information
USDA National Institute of Food and Agriculture, Grant/Award Number: Hatch project # FLA-FTL-005697; Great Lakes Restoration Initiative; Faculty of Science, Victoria University of Wellington, Grant/Award Number: VUW Grant 80837; Royal Society of New Zealand, Grant/Award Number: CAW1601 and CSG-CAW1701; National Institute of Water and Atmospheric Research Ltd: Under the causes and effects of water quality degradation: Eutrophication risk assessment programme

Abstract

1. This review summarises knowledge on the ecology, toxin production, and impacts of toxic freshwater benthic cyanobacterial proliferations. It documents monitoring, management, and sampling strategies, and explores mitigation options.
2. Toxic proliferations of freshwater benthic cyanobacteria (taxa that grow attached to substrates) occur in streams, rivers, lakes, and thermal and meltwater ponds, and have been reported in 19 countries. Anatoxin- and microcystin-containing mats are most commonly reported (eight and 10 countries, respectively).
3. Studies exploring factors that promote toxic benthic cyanobacterial proliferations are limited to a few species and habitats. There is a hierarchy of importance in environmental and biological factors that regulate proliferations with variables such as flow (rivers), fine sediment deposition, nutrients, associated microbes, and grazing identified as key drivers. Regulating factors differ among colonisation, expansion, and dispersal phases.

Freshwater Biology. 2020;00:1–19. wileyonlinelibrary.com/journal/fwb | 1

THANK YOU!

QUESTIONS?

Contact Information

Andrew McQueen, PhD
Research Biologist
USACE ERDC

Andrew.d.mcqueen@usace.army.mil

ENGINEER RESEARCH & DEVELOPMENT CENTER