



Water Quality Standards Academy

**Biotic Ligand Model
and Copper Criteria**

March 2016

Office of Science and Technology
Office of Water
US Environmental Protection Agency

EPA Publication # 820Q16001



- Metals are naturally occurring and ubiquitous
 - But not always bioavailable
- Metals have complex chemistry
 - Toxicity can vary widely from place to place due to local conditions (e.g., pH, ionic composition, presence of natural organic matter, etc).
 - Can also vary widely in time at any given site (e.g., diurnal, seasonal).

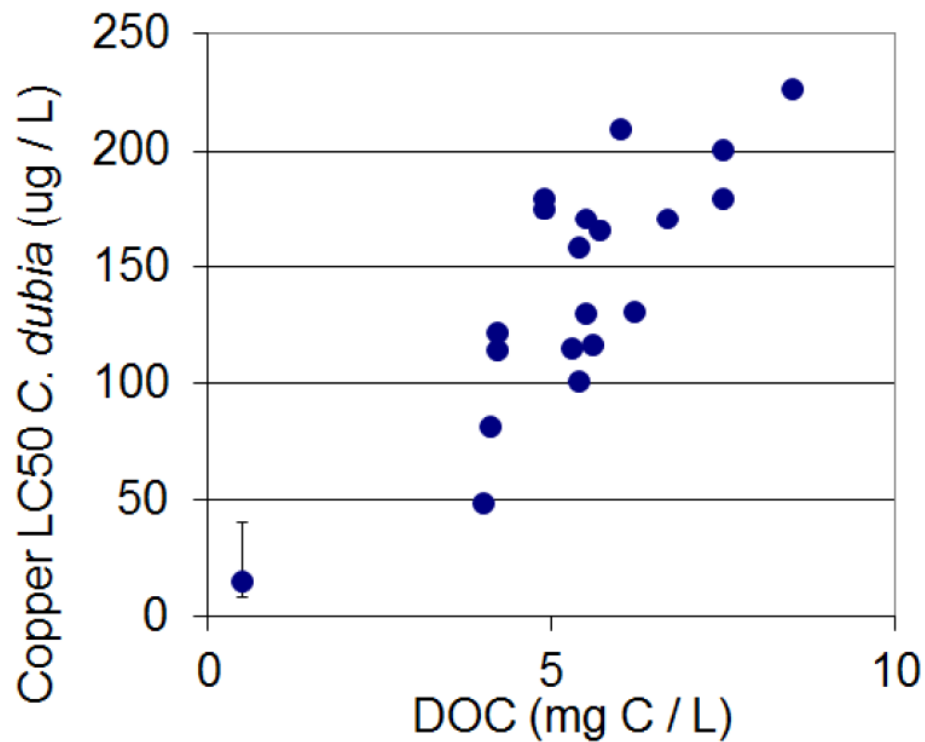
Metal Toxicity and Criteria



- EPA has addressed water chemistry and metals bioavailability by adjusting criteria to hardness.
- The hardness equations for metals are based on water where hardness typically covaries with pH and alkalinity.
 - This covariation is assumed in the equations.
- However, the hardness approach does not directly consider other water chemistry parameters (e.g., pH and DOC).
- Therefore, hardness-based WQC do not reflect all the effects of water chemistry on metals bioavailability.
- When more refined site-specific limits were needed they have been derived using “Water Effects Ratio” procedure.

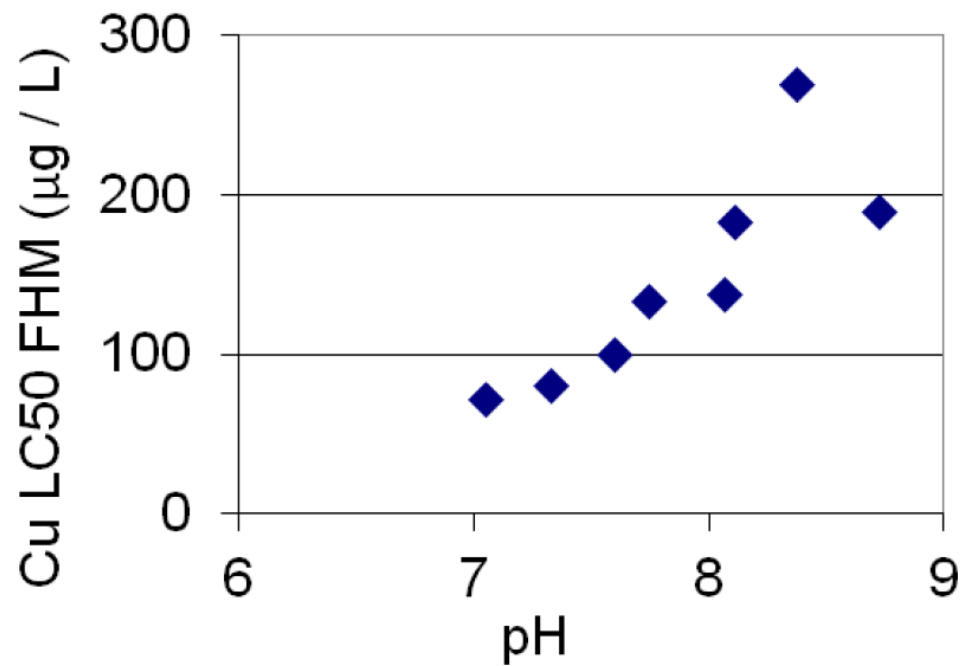


Traditional metals criteria do not account for **natural organic matter effects**



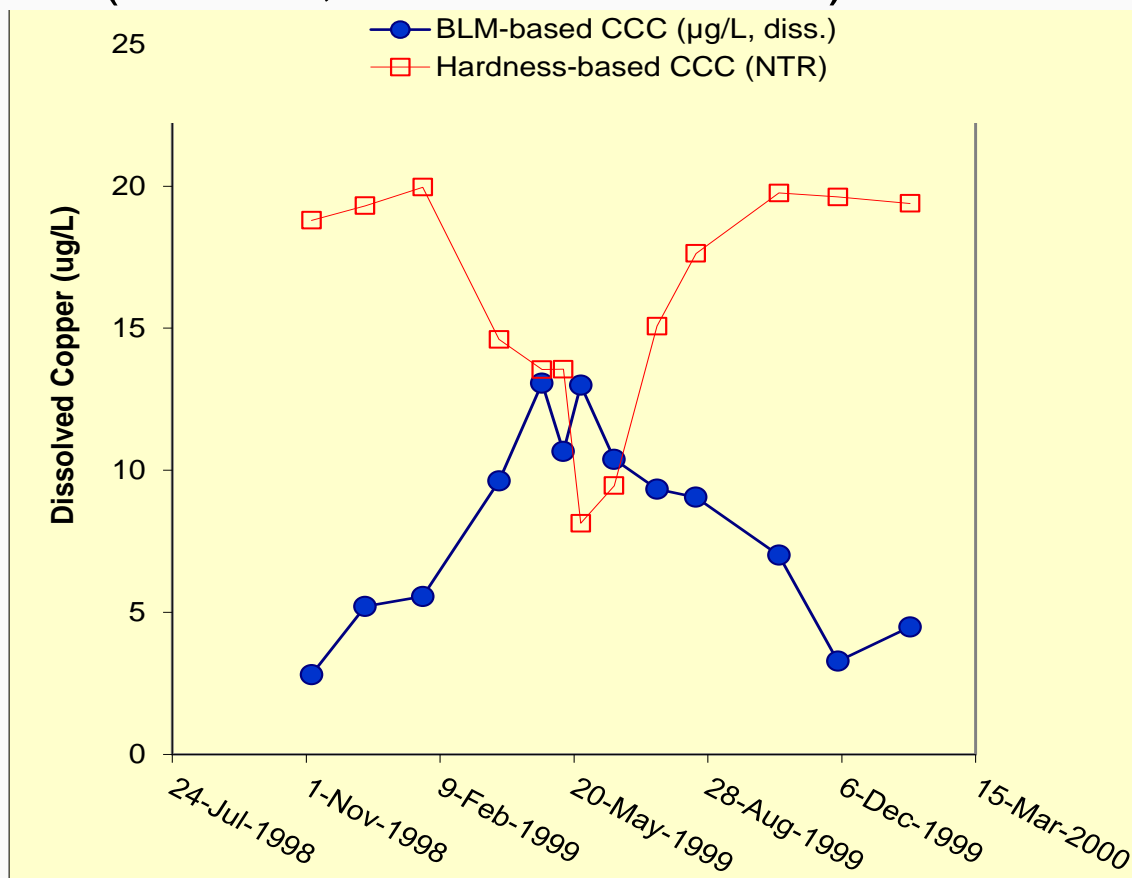


Traditional metals criteria do not account for **pH effects**





Because they do not account for pH or natural organic matter effects, traditional metals criteria can be overly stringent or underprotective (or both, at different times).



BLM Basics



- The biotic ligand model (BLM) is a predictive tool that can account for variations in metal toxicity using local water chemistry information.
- The BLM reflects the latest science on metals toxicity to aquatic organisms.
- The BLM for copper in freshwater uses ten input parameters; pH, DOC, Ca, Mg, Na, SO₄, K, Cl, alkalinity, temperature.

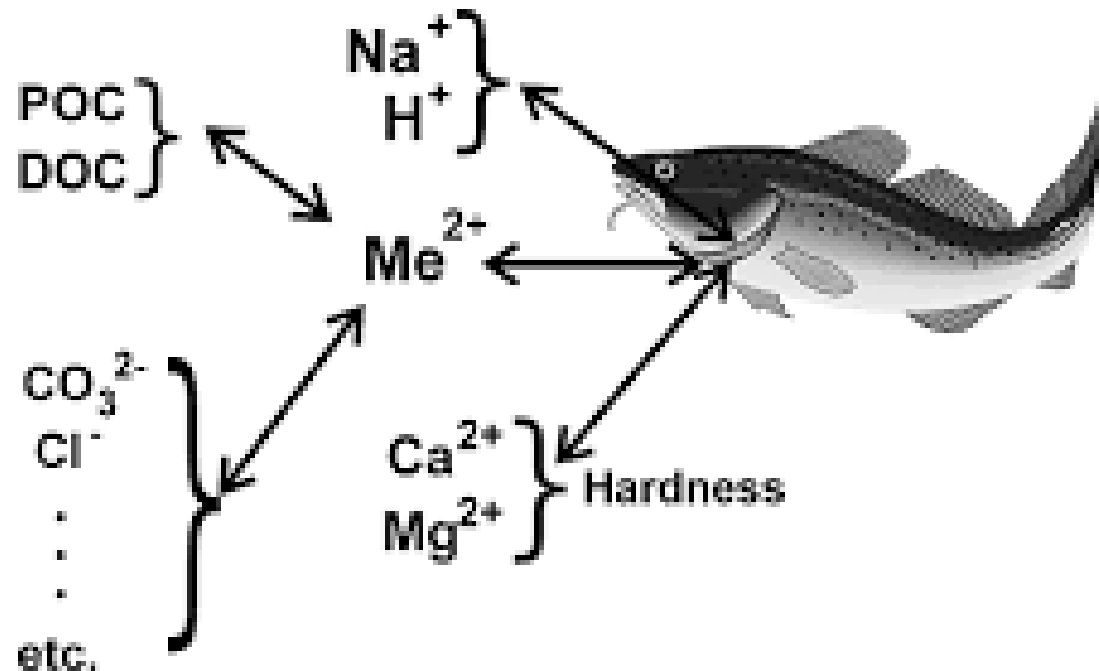
BLM Conceptual Framework



SCHEMATIC OF BIOTIC LIGAND MODEL

FORMATION OF
METAL COMPLEXES

COMPETITIVE BINDING
AT GILL



EPA's History with the BLM



- The BLM is based on conceptual modeling and experimental work that began in the early 1980's, with development continuing to the present day.
- In 1999, the BLM approach was presented to EPA's Science Advisory Board (SAB).
 - The SAB found that the BLM can “significantly improve predictions of the acute toxicity of certain metals across an expanded range of water chemistry parameters compared to the WER [Water-Effect Ratio]”.

EPA's History with the BLM



- EPA refined the BLM and incorporated it into the 2003 Draft Update of Ambient Water Quality Criteria for Copper.
- The current BLM-based freshwater aquatic life criterion is EPA's Aquatic Life Ambient Freshwater Criteria – Copper 2007 Revision (EPA-822-R-07-001).
- EPA is also investigating BLMs for aluminum, zinc, lead.

Implementation Paradigm Shift

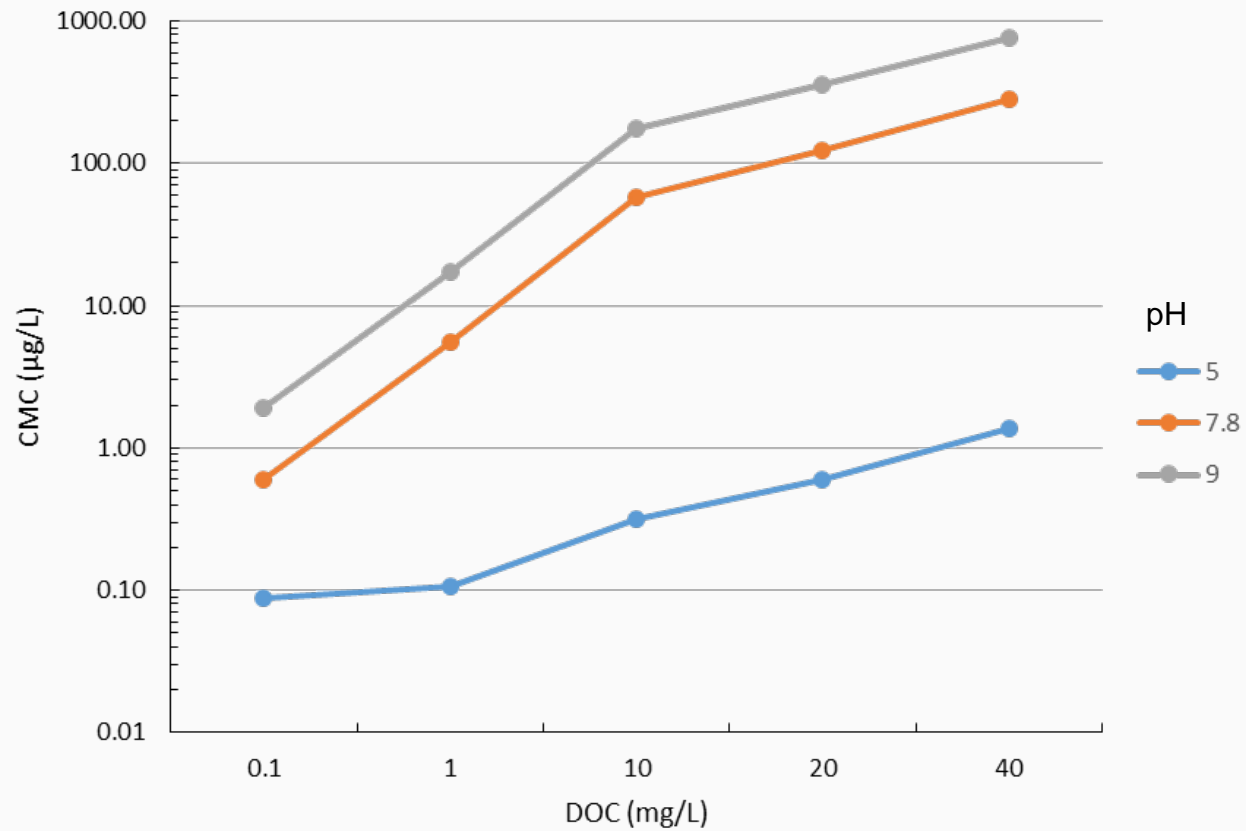


- The BLM requires more inputs than other criteria: pH, DOC, Ca, Mg, Na, SO₄, K, Cl, alkalinity, temperature.
- States have limited resources for monitoring water chemistry on a statewide basis.
- Some BLM parameters (i.e., major ions, DOC) are not routinely collected currently.
- DOC and pH greatly influence BLM outputs and should be collected on a routine basis.

Effect of pH and DOC



pH and DOC Effects on BLM-derived WQC



Challenges and Solutions



- Challenge 1: Completing a database for BLM use when a site has missing water chemistry parameters.
 - Solution: Estimate Missing Parameters
- Challenge 2: Time variable water chemistry affects BLM results.
 - Solution: The Fixed Monitoring Benchmark approach

Estimating Missing Parameters



- While it is preferable to collect data for the water quality parameters at the site, this may not always be practical or even possible.
- EPA recognizes that a practical method to estimate missing water quality parameters is needed.
- EPA has developed geochemical ions (GI) estimates of the BLM water quality input parameters, based on existing data drawn from large National surface water quality datasets.

Estimating Missing Parameters



- EPA provides 10th percentile estimates of geochemical ions based on stream order and level III ecoregions.
- EPA provides 10th percentile estimates for DOC by ecoregion based on an analysis of a compilation of national organic carbon databases.
- EPA recommends measurement of pH and temperature directly to use as an input in the BLM.



- EPA is completing work on two technical documents
 - Derivation of a fixed monitoring benchmark (FMB)
 - Estimation of missing BLM water quality parameters
- Both documents have been externally peer reviewed
- Updating copper criteria
 - Updating aquatic toxicity data
 - Chronic BLM criteria are being derived
- Developing saltwater copper criteria



- Metals toxicity is dependent on many factors that affect the bioavailability of the metal in the aquatic environment.
- Biotic ligand models account for complex interactions between metals in solution and competing ligands.
- EPA uses the BLM for copper criteria and is investigating BLMs for other metals.