

# **Appendix C: Bioavailability Model Comparisons**

**for the**

## **Metals Cooperative Research and Development Agreement (CRADA) Phase I Report:**

### **Development of an Overarching Bioavailability Modeling Approach to Support US EPA's Aquatic Life Water Quality Criteria for Metals (EPA-822-R-22-001)**

**March 2022**

Table 1: Bioavailability Model Comparisons, Table 2: Supporting Information, and References were developed by the CRADA Partners.

Appendix C, Table 1: Bioavailability Model Comparison Table

Metal	Model Name	Version/ Identification	Type	Freshwater/ Saltwater	User-Interface	Output	Source	References	Primary toxicity modifying factors	Taxa model is applicable to	Chemistry Inputs needed
Aluminum	BLM	3.18.2.42	Full BLM	Freshwater	Free Software <sup>2</sup>	HCS	<a href="http://www.windwardenv.com/biotic-ligand-model/">www.windwardenv.com/biotic-ligand-model/</a>	[1]	pH, DOC, Hardness, Temperature	algae, invertebrates, fish	Temperature, pH, DOC, Al, Ca, Mg, Na, K, SO <sub>4</sub> , Cl
	MLR	N/A	MLR	Freshwater	Equation	HCS	Windward Environmental LLC	[2]	pH, DOC, Hardness	algae, invertebrates, fish	pH, DOC, Hardness
Cobalt	BLM	3.15.2.41	Full BLM	Freshwater	In Development	HCS	Windward Environmental LLC	In Development	Hardness, pH, DOC	algae, invertebrates, fish	Temperature, pH, Co, DOC, Humic acid %, Ca, Mg, Na, K, SO <sub>4</sub> , Cl, Alkalinity, S
	MLR	N/A	MLR	Freshwater	In Development	Bioavailable [Cobalt]	In Development / Windward Environmental LLC	In Development	Hardness, pH, DOC	algae, invertebrates, fish	pH, DOC, Hardness (Ca, Mg)
	BioMet	v5.0	Simplified BLM Lookup Tool	Freshwater	Free Software <sup>2</sup>	HCS, Bioavailable [Cobalt], RCR	In Development	In Development	Hardness, pH, DOC	algae, invertebrates, fish	pH, DOC, Ca, Co
Copper	USEPA BLM	USEPA 2007	Full BLM	Freshwater	Free Software <sup>2</sup>	CMC, CCC	<a href="http://www.epa.gov/wqc/aquatic-life-criteria-copper">www.epa.gov/wqc/aquatic-life-criteria-copper</a>	[3], supported by [4-12]	pH, alkalinity, hardness, DOC	invertebrates, fish	Temperature, pH, Cu, DOC, Humic acid %, Ca, Mg, Na, K, SO <sub>4</sub> , Cl, alkalinity, S
	ECCC BLM	v1.10	Full BLM	Freshwater	Free Software <sup>2</sup>	HCS	<a href="https://www.canada.ca/en/environment-climate-change/services/evaluating-existing-substances/federal-environmental-quality-guidelines-copper.html">https://www.canada.ca/en/environment-climate-change/services/evaluating-existing-substances/federal-environmental-quality-guidelines-copper.html</a>	[13, 14]	pH, alkalinity, hardness, DOC	algae, plants, invertebrates, fish	Required: Temperature, pH, Cu, DOC, hardness; Optional: Humic acid %, Ca, Mg, Na, K, SO <sub>4</sub> , Cl, alkalinity, S
	BC BLM	v1.11	Full BLM	Freshwater	Free Software <sup>2</sup>	WQG	<a href="https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/copper/bc_blm_setup.exe">https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/copper/bc_blm_setup.exe</a>	[15-17]	pH, alkalinity, hardness, DOC	algae, plants, invertebrates, fish, amphibians	Required: Temperature, pH, Cu, DOC, hardness; Optional: Humic acid %, Ca, Mg, Na, K, SO <sub>4</sub> , Cl, alkalinity, S
	Windward BLM	v3.41.2.45	Full BLM	Freshwater	Free Software <sup>2</sup>	L(E)C50, CMC, CCC	<a href="http://www.windwardenv.com/biotic-ligand-model/">www.windwardenv.com/biotic-ligand-model/</a>	[18], supported by [4-10]	pH, alkalinity, hardness, DOC	invertebrates, fish	Required: Temperature, pH, Cu, DOC, hardness; Optional: Humic acid %, Ca, Mg, Na, K, SO <sub>4</sub> , Cl, alkalinity, S
	BLM/gBAM	Modified HydroQual BLM software	Mixed regression + speciation model	Freshwater	Free Software <sup>2</sup>	L(E)C50, EC10	[21]	[19-21]	pH, alkalinity, hardness, DOC	invertebrates, fish	Temperature, pH, Cu, DOC, Humic acid %, Ca, Mg, Na, K, SO <sub>4</sub> , Cl, alkalinity, S
	BioMet	v5.0	Simplified BLM Lookup Tool	Freshwater	Free Software <sup>2</sup>	HCS, Bioavailable [Copper], RCR	<a href="http://www.bio-met.net">www.bio-met.net</a>	[22]; supported by [19-21, 23-28]	pH, DOC, Ca	algae, invertebrates, fish	pH, DOC, Ca, Cu
	M-BAT	v30.0	Simplified BLM Lookup Tool	Freshwater	Free Software <sup>2</sup>	PNEC, Bioavailable [Copper], RCR	<a href="http://www.wfduk.org/resources/rivers-lakes-metal-bioavailability-assessment-tool-m-bat">www.wfduk.org/resources/rivers-lakes-metal-bioavailability-assessment-tool-m-bat</a>	[29]; supported by [30-32]	pH, DOC, Ca	algae, invertebrates, fish	pH, DOC, Ca, Cu
	PNEC-Pro	v6.0	[M]LR	Freshwater	Free Software <sup>2</sup>	PNEC, Bioavailable [Copper], RCR	<a href="http://www.pnec-pro.com">http://www.pnec-pro.com</a>	[33]	DOC	algae, invertebrates, fish	Required: DOC; Optional: pH, Mg, Ca, Na, Cu
	WHAM-F <sub>tox</sub>	N/A	Toxicity model linked to speciation	Freshwater	WHAM 7 software + toxicity equation	EC50	[34]	[34]	Not specified	plants	Temperature, pH, Cu, DOM (fulvic and humic acids), Ca, Mg, Na, K, SO <sub>4</sub> , Cl, alkalinity, metals
	MLR	N/A	MLR	Freshwater	Equation	L(E)C50	[35]	[35]; additional examples [25, 27, 36, 37]	Hardness, pH, DOC	invertebrates, fish	pH, hardness, DOC
	Windward Marine BLM	v3.41.2.45	Full BLM	Saltwater	Free Software <sup>2</sup>	L(E)C50	<a href="http://www.windwardenv.com/biotic-ligand-model/">www.windwardenv.com/biotic-ligand-model/</a>	[18]; supported by [4-10, 12, 38-40]	pH, salinity, DOC	invertebrates, fish	Required: Temperature, pH, Cu, DOC, salinity; Optional: Ca, Mg, Na, K, SO <sub>4</sub> , Cl, PO <sub>4</sub> , DIC
Marine MLR	N/A	[M]LR	Saltwater	Equation	EC50	[38]	[38, 40]; additional examples: [41, 42]	DOC	invertebrate ( <i>Mytilus</i> sp.)	DOC	
Lead	BLM	Unified/North America	Full BLM	Freshwater	Free Software <sup>2</sup>	EC <sub>x</sub> ; FAV; FCV; acute and chronic HCS	<a href="http://www.windwardenv.com/biotic-ligand-model/">http://www.windwardenv.com/biotic-ligand-model/</a>	[43]; supported by [44-63]	Hardness, pH, DOC	invertebrates, fish	Temperature, pH, Pb, DOC, Humic acid %, Ca, Mg, Na, K, SO <sub>4</sub> , Cl, Alkalinity, S
	BLM/gBAM	EU Risk Assessment	Full BLM	Freshwater	Free Software <sup>2</sup>	Normalized SSD; HCS	<a href="https://www.ila-lead.org/responsibility/lead-blm-tool">https://www.ila-lead.org/responsibility/lead-blm-tool</a>	[64]; supported by [44-63, 65, 66]	Hardness, pH, DOC	algae, invertebrates, fish	Temperature, pH, Pb, DOC, Ca, Mg, Na, K, SO <sub>4</sub> , Cl, CO <sub>3</sub>
	Lead EQS Screening Tool	v1.0 (EU Risk Assessment)	DOC Equation	Freshwater	Free Software <sup>2</sup>	PNEC; bioavailable [Pb], RCR	<a href="https://www.wca-environment.com/index.php/models-and-downloads/Pb-EQS-Screening-Tool">https://www.wca-environment.com/index.php/models-and-downloads/Pb-EQS-Screening-Tool</a>	[32], [67]	DOC	algae, invertebrates, fish	DOC, Pb
	BioMet	v5.0	Simplified BLM Lookup Tool	Freshwater	Free Software <sup>2</sup>	HCS, Bioavailable [Pb], RCR	<a href="http://www.bio-met.net">www.bio-met.net</a>	In Development / WCA	pH, DOC, Ca	algae, invertebrates, fish	pH, DOC, Ca, Pb
	PNEC Pro	v6.0	[M]LR	Freshwater	Free Software <sup>2</sup>	PNEC	<a href="http://www.pnec-pro.com">http://www.pnec-pro.com</a>	[68]	DOC	algae, invertebrates, fish	Required: DOC; Optional: pH, Mg, Ca, Na, Pb
	MLR	Canadian WQG	MLR	Freshwater	N/A	long-term WQG	<a href="https://www.canada.ca/en/environment-climate-change/services/evaluating-existing-substances/federal-environmental-quality-guidelines-lead.html">https://www.canada.ca/en/environment-climate-change/services/evaluating-existing-substances/federal-environmental-quality-guidelines-lead.html</a>	[69]	Hardness, pH, DOC	algae, invertebrates, fish	pH, DOC, Hardness
MLR	N/A	MLR	Freshwater	N/A	EC <sub>x</sub> ; HCS	Unpublished Report	[70]	Hardness, pH, DOC	algae, invertebrates, fish	pH, DOC, Hardness	

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Metal	Model Name	Version/ Identification	Type	Freshwater/ Saltwater	User-Interface	Output	Source	References	Primary toxicity modifying factors	Taxa model is applicable to	Chemistry Inputs needed
Nickel	BLM	EU Risk Assessment	Full BLM	Freshwater	Excel + WHAM based software	HCS	Nys et al. 2016 [71], WHAM VI	[71-74]	Hardness, pH, DOC	algae, invertebrates, fish	Temperature, pH, Ni, DOC, Humic acid %, Ca, Mg, Na, K, SO4, Cl, Alkalinity, S
	BioMet	v5.0	Simplified BLM Lookup Tool	Freshwater	Free Software <sup>2</sup>	HCS, Bioavailable [Nickel], RCR	<a href="http://www.bio-met.net">www.bio-met.net</a>	In Development / WCA	pH, DOC, Ca	algae, invertebrates, fish	pH, DOC, Ca, Ni
	M-BAT	20150206	Simplified BLM Lookup Tool	Freshwater	Free Software <sup>2</sup>	PNEC, Bioavailable [Nickel], RCR	<a href="http://www.wfdok.org/">http://www.wfdok.org/</a>	[32]	pH, DOC, Ca	algae, invertebrates, fish	pH, DOC, Ca, Ni
	BLM	Best Overall Pooled	Full BLM	Freshwater	Free Software <sup>2</sup>	ECx, HCS, FAV	<a href="http://www.windwardenv.com/biotic-ligand-model">www.windwardenv.com/biotic-ligand-model</a>	[88]	Hardness, pH, DOC	algae, invertebrates, fish	Temperature, pH, Ni, DOC, Humic acid %, Ca, Mg, Na, K, SO4, Cl, Alkalinity, S
	BLM	North American <i>C. dubia</i> Model	Full BLM	Freshwater	Free Software <sup>2</sup>	ECx	<a href="http://www.windwardenv.com/biotic-ligand-model">www.windwardenv.com/biotic-ligand-model</a>	[88]	Hardness, pH, DOC, Alkalinity	invertebrates (may be limited to <i>C. dubia</i> )	Temperature, pH, Ni, DOC, Humic acid %, Ca, Mg, Na, K, SO4, Cl, Alkalinity, S
	PNEC Pro	v6.0	[M]LR	Freshwater	Free Software <sup>2</sup>	PNEC, RCR	<a href="http://www.pnec-pro.com">http://www.pnec-pro.com</a>	[68]	Hardness, pH, DOC	algae, invertebrates, fish	Required: DOC; Optional: pH, Mg, Ca, Na, Ni
	MLR	N/A	MLR	Freshwater	Equation	ECx	Equation in Croteau et al. (2021). Accepted	[89]	Hardness, DOC	algae, invertebrates, fish	Hardness (Ca/Mg), DOC, pH, Ni
	BLM	Marine	Full BLM	Saltwater	Free Software <sup>2</sup>	ECx	<a href="http://www.windwardenv.com/biotic-ligand-model">www.windwardenv.com/biotic-ligand-model</a>	[90]	DOC	invertebrates	Temperature, pH, Ni, DOC, Humic acid %, Ca, Mg, Na, K, SO4, Cl, Alkalinity, S
Zinc	BLM	Unified/North America	Full BLM	Freshwater	Free Software <sup>2</sup>	ECx; FAV; FCV	<a href="http://www.windwardenv.com/biotic-ligand-model/">www.windwardenv.com/biotic-ligand-model/</a>	[75]; supported by [4, 76-80]	Hardness, pH, DOC	invertebrates, fish	Temperature, pH, Zn, DOC, Humic acid %, Ca, Mg, Na, K, SO4, Cl, Alkalinity, S
	BLM/gBAM	EU Risk Assessment	Full BLM	Freshwater	Free Software <sup>2</sup>	ECx; HCS after post-processing <sup>1</sup>	<a href="http://www.windwardenv.com/biotic-ligand-model/">www.windwardenv.com/biotic-ligand-model/</a>	[81]; supported by [80, 82]	Hardness, pH, DOC	algae, invertebrates, fish	Temperature, pH, Zn, DOC, Humic acid %, Ca, Mg, Na, K, SO4, Cl, Alkalinity, S
	M-BAT	v30.0 - 20150206	Simplified BLM Lookup Tool	Freshwater	Free Software <sup>2</sup>	PNEC	<a href="http://www.wfdok.org/resources/river-lakes-metal-bioavailability-assessment-tool-m-bat">www.wfdok.org/resources/river-lakes-metal-bioavailability-assessment-tool-m-bat</a>	[32]	pH, DOC, Ca	algae, invertebrates, fish	pH, DOC, Ca, Zn
	BioMet	v5.0	Simplified BLM Lookup Tool	Freshwater	Free Software <sup>2</sup>	HCS	<a href="http://www.bio-met.net">www.bio-met.net</a>	In Development / WCA	pH, DOC, Ca	algae, invertebrates, fish	pH, DOC, Ca, Zn
	PNEC Pro	v6.0	[M]LR	Freshwater	Free Software <sup>2</sup>	PNEC	<a href="http://www.pnec-pro.com">http://www.pnec-pro.com</a>	[68]	DOC	algae, invertebrates, fish	Required: DOC; Optional: pH, Mg, Ca, Na, Zn
	MLR	Canadian WQG	MLR	Freshwater	N/A	short-term WQG; long-term WQG	<a href="http://ceqg-rcaecme.ca/download/en/360">http://ceqg-rcaecme.ca/download/en/360</a>	[83]	Hardness, pH, DOC	algae, invertebrates, fish	pH, DOC, Hardness
	MLR	N/A	MLR	Freshwater	N/A	ECx; FAV; FCV	In Development	In Development	Hardness, pH, DOC	algae, invertebrates, fish	pH, DOC, Hardness
BLM	Marine	Full BLM	Saltwater	N/A	ECx; FAV; FCV	Preliminary/Pilot BLM [84]	[84]	pH, salinity, DOC	invertebrates, fish	Required: Temperature, pH, Zn, DOC, salinity; Optional: Ca, Mg, Na, K, SO4, Cl, PO4, DIC	

<sup>1</sup> Model can produce effect concentrations normalized to specified water chemistry conditions, but HCS must be derived from normalized SSDs after model application

<sup>2</sup> Registration may be required to download the software

Definitions:

- BC - British Columbia
- BLM - Biotic ligand model
- CCC - Criteria continuous concentration
- CMC - Criteria maximum concentration
- DIC - Dissolved inorganic carbon
- DOC - Dissolved organic carbon
- ECCC - Environment and Climate Change Canada
- EC10 - 10 percent effect concentration
- EC50 - 50 percent effect concentration
- ECx - 'x' percent effect concentration
- EU - European Union
- FAV - Final acute value
- FCV - Final chronic value
- gBAM - Generalized bioavailability model
- HCS - Hazardous concentration 5th percentile
- L[E]C50 - 50 percent lethal or effect concentration
- M-BAT - Metal bioavailability assessment tool
- MLR - Multiple linear regression
- [M]LR - Multiple linear regression and/or simple linear regression
- PNEC - Predicted no effect concentration
- RCR - Risk characterization ratio
- SSD - Species sensitivity distribution
- TRV - Toxicity reference value
- USEPA - United States Environmental Protection Agency
- WHAM - Windermere humic aqueous model
- WQG - Water quality guideline



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