Rationale for not adopting the Biotic Ligand Model for Copper

The USEPA's updated criterion for protection of aquatic life from dissolved copper is based on the use of the Biotic Ligand Model (BLM) (USEPA 2007). There are numerous input parameters to the BLM, including DOC, pH, temperature, potassium, alkalinity, magnesium, sodium, calcium, sulfate, chloride, humic acid and sulfide. There were insufficient or no data available for humic acid and sulfide in the dataset used in this analysis, so proxy values of 10% and 0.0001 mg/L were used, at the recommendation of the USEPA (Luis Cruz, USEPA, personal communication, 10-9-18).

ANALYSIS AND DISCUSSION

The results of this analysis, using data for 112 samples from waterbodies in the Carson River Basin as input to the model, show that concentrations of DOC describe (or predict) 41% of the variability in the calculated criteria value; whereas chloride describes only 9% of that variability (**Table 1, Figures 1a-b**). Hardness, which was the basis of the previous criterion for copper (and which is Nevada's current criterion), describes about 20% of the variability in the criterion if used in the BLM (**Table 1, Figures 2a-b**). Data from other basins and waterbodies may not yield exactly the same results, in terms of the coefficient of determination (R^2); however, the analysis presented here for the Carson River Basin data offers an idea about how the BLM may improve the predictability of copper bioavailability in Nevada's surface waters.

Table 1. Coefficients of Determination (R^2) for Input Parameters (plus Hardness) to the BLM.

Independent Variables (x-axis) (Input Parameters)	Range of Concentrations for Input Parameters	Range of Concentrations for Input Parameters as defined in the BLM*	Coefficient of Determination, R^2 (Assumes Linear Relationship)
DOC	1.3 to 12.0 mg/L	0.05 to 30 mg/L	0.41
pH	6.7 to 9.0 SU	4.9 to 9.2 SU	0.34
Temperature	0.1 to 29.9 °C	10 to 25.0 °C	0.31
Potassium	0.7 to 6.0 mg/L	0.06 to 19.2 mg/L	0.29
Alkalinity	21.6 to 166 mg/L	1.9 to 360 mg/L	0.25
Magnesium	1.4 to 14.0 mg/L	0.024 to 51.9 mg/L	0.22
Sodium	2.5 to 88.0 mg/L	0.16 to 237 mg/L	0.20
Calcium	5.0 to 68.0 mg/L	0.2 to 120 mg/L	0.19
Sulfate	0.1 to 190 mg/L	0.096 to 278.4 mg/L	0.12
Chloride	1.2 to 65.1 mg/L	0.32 to 279.7 mg/L	0.09
Hardness	18.3 to 219.2 mg/L	1 to 150 mg/L	0.20

N=112 Samples, Carson River Basin

R^2 describes (or predicts) the percentage of variation seen in the dependent variable

* As near as I can glean from the document; need to investigate further.

Problematic Issues with the BLM

The model was established for a range of input parameters (see third column from left in Table 1) that generally, but not entirely, encompass the ranges of values found in the tested data set (second column from left in Table 1). However, evaluating the range of data found in the entire database indicated that about 30% of temperature data lie outside the model range, as do about 30% of sulfate data, 25% of magnesium data, 20% of sodium data, and 15% of calcium and chloride data (**Figures 3a-f**). How well the model works with out-of-range data is unknown. Additionally, data for certain input parameters have only just begun to be collected. Data for DOC and potassium have only been collected since 2014. Other data inputs, including humic acid and sulfide, are not routinely collected. In all cases, proxy data (i.e., fabricated values) must be used as input for missing data. The BLM will not run if input values are missing.

BWQP's new software for performing waterbody assessments, the water-quality and assessment reporting tool (WART), cannot handle the BLM at this time. It is possible that a separate module could be created to run the model outside of WART and automatically incorporate the results, but that is not a capability at present.

Additional Factors to Consider

As of this writing, review of state standards shows that only four (?) states (Delaware, Oregon, Kansas, and Idaho) have adopted the 2007 criterion for copper, using the BLM. It appears all other states have retained a hardness-based formula for calculating criteria values for copper; however, a number of these states allow use of the BLM for calculating site-specific criteria values. Many states also allow use of a water effects ratio (WER) for use in calculating site-specific criteria values.

SUMMARY AND RECOMMENDATIONS

The model probably does predict copper bioavailability (hence, toxicity) more accurately than simply using a hardness-based calculation. The data suggest that DOC is the variable (input parameter) most closely predictive of copper bioavailability. In comparing criteria values calculated using both the hardness-based equation (current standard) and the BLM, the BLM generally produces criteria values that are higher than those produced by the hardness-based equation (see **Figures 2a-b**). This could benefit dischargers by increasing the allowed limits of copper in their discharges; hence, the possible benefit to adopting the BLM as an allowable secondary method for deriving site-specific criteria values. Because it appears that the hardness-based criteria values are more conservative than the BLM criteria values in the majority of cases, the need to adopt the BLM as the primary criterion is not compelling.

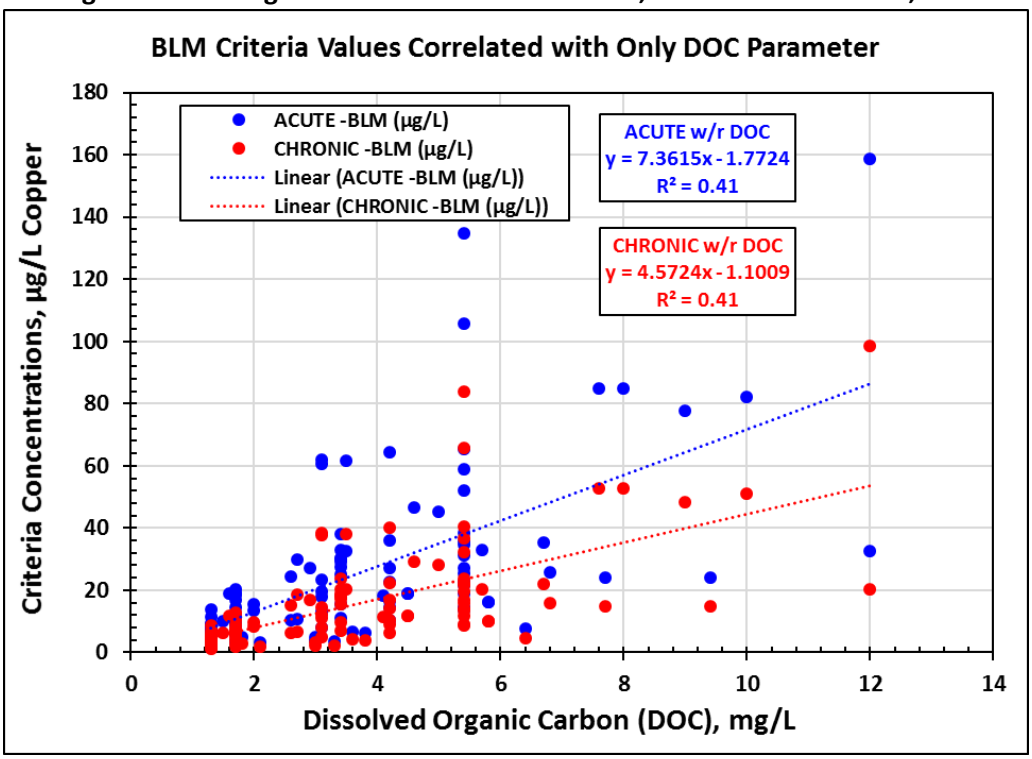
At this time, BWQP could consider adopting the BLM as an alternative or secondary method for deriving site-specific criteria values, but its adoption as the primary tool for assessments is not a priority.

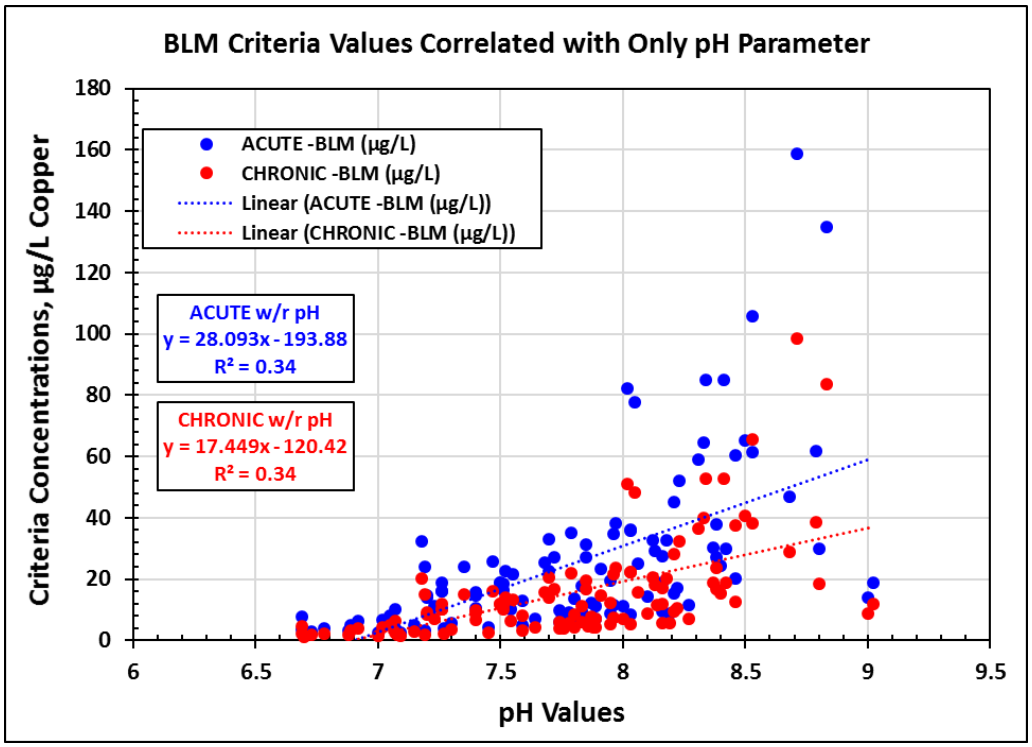
DOCUMENTS

USEPA. 1996. 1995 Updates: Water Quality Criteria Documents for the Protection of Aquatic Life in Ambient Water. Office of Water. EPA-820-B-96-001.

USEPA. 2007. Aquatic Life Ambient Freshwater Quality Criteria – Copper. 2007 Revision. EPA-822-R-07-001. February.

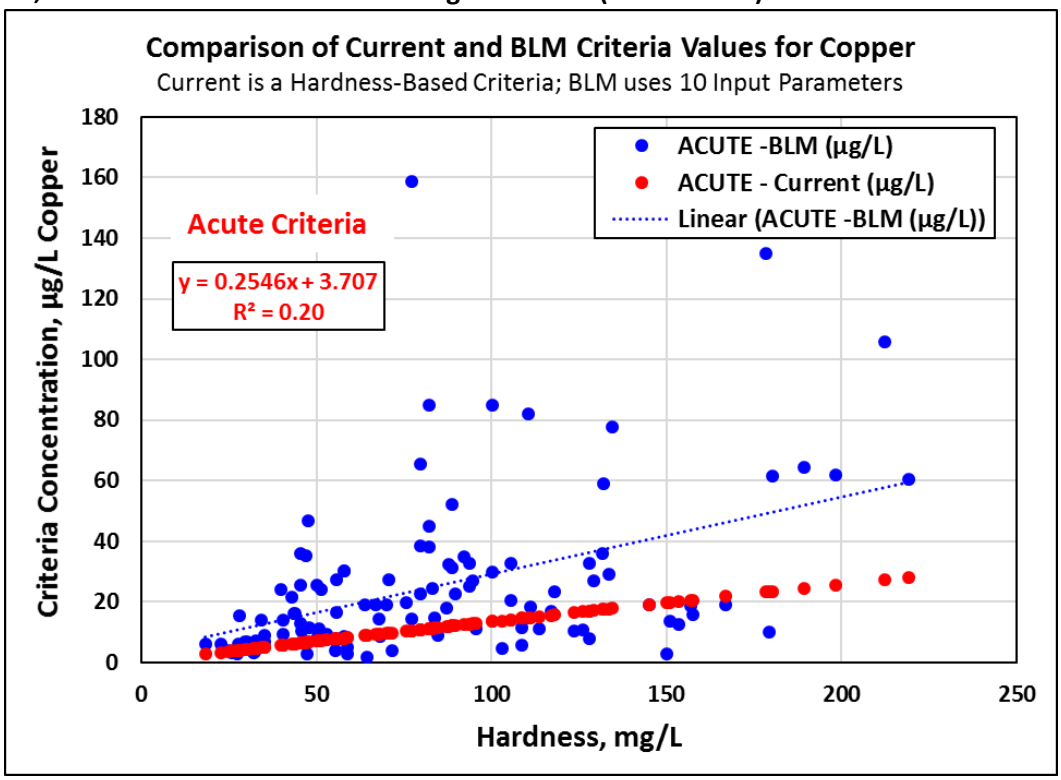
Figures 1a-b. Predictive relationship between individual input parameters (here, DOC and pH) and the corresponding copper criterion values generated using the BLM. Chloride not shown, but had an R^2 of 0.09; see Table 1.

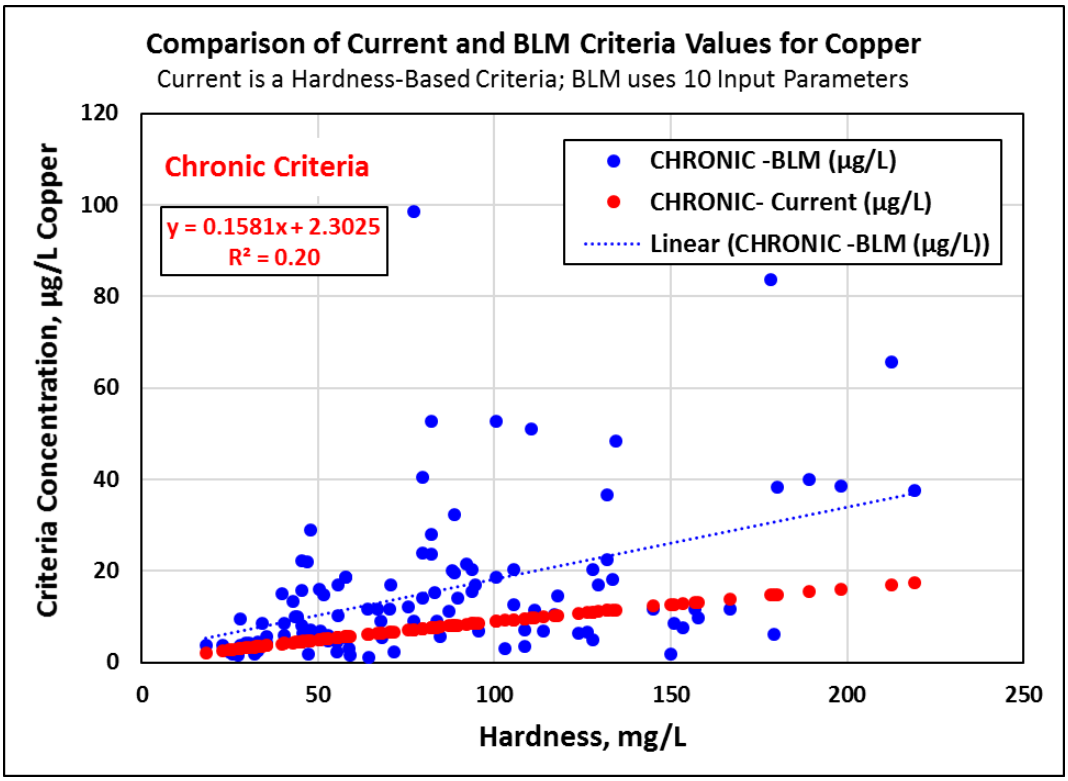




The **coefficient of determination, R^2,** is the square of the correlation (R) between the predicted scores in a data set versus the actual set of scores. An R-squared of 0.34, for example, means that 34% of the **criterion variability** is described or predicted by the input parameter (**independent variable)**, such as pH and DOC, shown above.

Figures 2a-b. Comparison of current hardness-based criteria values for copper and model-based criteria values for copper, where BLM refers to the Biotic Ligand Model (USEPA 2007).





Data described above are from Carson River Basin (NV08) for water years 2009 to 2016, N= 112 samples.

Figures 3a-f. Range of data values in BWQP data warehouse, shown as percentiles, compared against the upper and lower limits of the model input parameters. Red dashed lines indicate model minimum and maximum values.