Using Higher Tier Data and Models in a Weight-of-Evidence Assessment to Determine a Water Quality Benchmark for Atrazine

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Introduction

- In 2003, United States Environmental Protection Agency (USEPA) registered atrazine
- However, condition of registration required an extensive water monitoring program in intensive corn and sorghum production areas
- To evaluate monitoring data, Level of Concern (LOC) for aquatic plant communities required
- LOC is the concentration in water below which unacceptable adverse effects to aquatic plant communities would not occur
- LOC derivation has been a difficult and contentious exercise
  - Several attempts with different methods since 2003
  - Scientific Advisory Panels in 2007, 2009 and 2012 did not endorse the LOCs proposed to date by USEPA
- Objectives of this study:
  - Review methods used by USEPA and others
  - Determine strengths and weaknesses of each method and score them based on relevance, quality and reliability
  - Conduct formal weight-of-evidence assessment to determine most appropriate LOC

Available Information

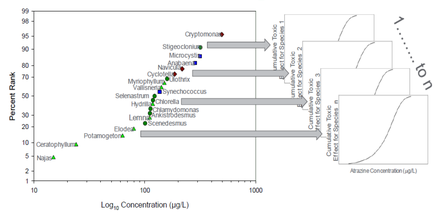
- Atrazine has considerable micro- and mesocosm (i.e., cosm) data for aquatic plant communities
  - 116 data points (i.e., treatments) for cosms in Giddings (2012), 5 studies published since that review
  - However, many cosm data points of poor quality
  - Cosm data points previously scored by USEPA and Giddings (2012), either for presence/absence of effect or magnitude of effect (Brock scores)
  - Some disagreement regarding scoring and whether studies should have been considered acceptable
  - New mesocosm study from Baylor Experimental Aquatic Research (BEAR) Facility recently published

Methods

- Cosm studies rigorously evaluated against a data quality rubric and acceptable studies were, if necessary, re-scored for presence/absence or magnitude of effect (see Supplemental Information in Moore et al., 2017)
- Large number of single species studies also available
  - At least 21 genera of algae and aquatic macrophytes tested
  - EC50s for specific growth rate determined by USEPA (2012)
- Four LOC methods evaluated in our study
  - Plant Assemblage Toxicity Index (PATI)
  - Comprehensive Aquatic System Model (CASM)
  - Brock et al. (2000) scoring of cosm results
  - USEPA Water Quality Criteria method using results of single species tests

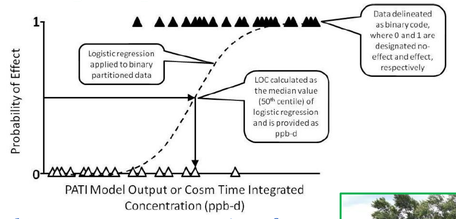
PATI Method

Step 1: Assemble Concentration-Response Curves



Step 2: Calculate Average Effect Across All Species

Step 3: Estimate PATI Model Output (60 d) for Cosm Treatments and Regress Against Treatment Outcomes



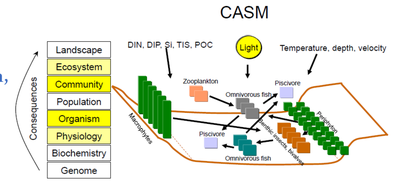
Weight-of-evidence

- PATI can be back-converted to an average concentration of specified duration, e,g., 60 days
- Advantages:
  - Directly relevant to protection goal
  - Can be used to evaluate time-varying concentrations in the environment
  - Endorsed by USEPA, more tepid response from Scientific Advisory Panels
  - Specific growth rate metric can be used to combine test results across studies of differing duration
- Disadvantages
  - Does not consider magnitude of effect or recovery in calibration step with cosm results
  - Does not consider timing of application
  - Does not consider specific habitats
  - *Very sensitive to scoring of cosm treatment results (effect vs no effect)*

Attribute	Weighting Factor	USEPA (2012) Dataset		Giddings (2012) Dataset		Comments
		Score (/5)	Weighted Score	Score (/5)	Weighted Score	
Relationship between assessment and measurement endpoints						
• Biological linkage between measurement and assessment endpoints	0.33	4	1.33	4	1.33	Inputs are at the population level, but method does not consider species interactions. Calibrated using community-level cosm studies.
• Linking exposure to response	0.33	3	1	3	1	Makes binary predictions regarding community-level effects.
• Utility of measure for judging environmental harm	0.33	2	0.67	3	1	SAP (2012) expressed concerns about method and dataset. Giddings (2012) provided improved dataset.
• Data quality and quantity	1	2	2	3	3	Results were strongly influenced by cosm data inputs and method performed better with improved cosm dataset.
Design and execution						
• Habitat specificity	0.33	1	0.33	1	0.33	Local and environmental conditions not considered.
• Sensitivity	0.33	2	0.67	4	1.33	Changes to uncertain inputs or assumptions influence the CE-LOC by 5- to 10-fold when using the USEPA (2012) dataset, and 2- to 3-fold using the Giddings (2012) dataset.
• Quantitativeness	0.33	3	1	3	1	PATI results are quantitative, but must be calibrated to cosm studies.
TOTAL SCORE (MAXIMUM = 15)	7 as implemented by USEPA (2012a), 9 if improved Giddings (2012) dataset used					

CASM Method

- Bioenergetics-based food web model designed to mimic 2nd and 3rd order Midwestern streams
- Include 20 periphyton species, 6 macrophyte species and bacteria, zooplankton, invertebrates, and fish consumers
- Uses single species results to parameterize effects to each taxon
- Uses cosm data to evaluate model performance



Attribute	Weighting Factor	Score (/5)	Weighted Score	Comments
Relationship between assessment and measurement endpoints				
• Biological linkage between measurement and assessment endpoints	0.333	4	1.33	Inputs are at the population level, but model output is at the community level.
• Linking exposure to response	0.333	5	1.67	Models atrazine chemographs to make quantitative predictions at the community level.
• Utility of measure for judging environmental harm	0.333	3	1	Complexity of model limits its use for derivation of a screening LOC.
Data quality and quantity	1	3	3	Inputs from laboratory studies or methods followed standard practices, but uncertain cosm inputs can influence results.
Design and execution				
• Habitat specificity	0.333	5	1.67	Method accounts for environmental conditions and is representative of 2nd to 3rd order Midwestern streams.
• Sensitivity	0.333	4	1.33	Changes to uncertain inputs or assumptions influence LOC by a factor of 2.5.
• Quantitativeness	0.333	3	1	Results are quantitative, but must be calibrated to cosm studies.
TOTAL SCORE (MAXIMUM = 15)			11	

Weight-of-evidence

- Has high habitat specificity and directly relates to protection goal
- Proposed 60-day LOC of 19.6 µg/L (Nair et al., 2015)
- 60-day LOC is robust to changes in input parameters
- Scientific Advisory Panel generally supportive of method
- Advantages
  - Well-accepted model with outputs directly relevant to protection goal
  - For atrazine, modeled effects correlated with measured effects in cosms
  - Evaluates effects and recovery, and includes indirect effects
- Disadvantages
  - Difficult to do, requires many inputs
  - Too site-specific?

Brock et al. (2000) Scoring of Cosm Results

- For each test concentration from an acceptable cosm study, derive a score:
  1. No effect
  2. Slight effect
  3. Significant effect followed by return to control levels within 56 days
  4. Significant effect without return to control levels during an observation period of less than 56 days
  5. Significant effect without return to control levels for more than 56 days
- Regress scores vs test concentration (need to account for exposure duration in the analysis)
- USEPA considers scores of 1 and 2 to be of no concern
- Determine average concentration leading to a score of 2 (=community –level LOC)

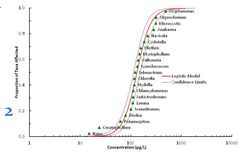
Attribute	Weighting Factor	Score (/5)	Weighted Score	Comments
Relationship between assessment and measurement endpoints				
• Biological linkage between measurement and assessment endpoints	0.33	5	1.67	Inputs and outputs are at the community level of organization.
• Linking exposure to response	0.33	3	1	Method results in a semi-quantitative relationship between concentration and effect.
• Utility of measure for judging environmental harm	0.33	2	0.67	Method widely accepted, but most studies were of low quality or not relevant.
Data quality and quantity	1	1	1	Very few relevant and acceptable data points near the LOC estimated by other methods.
Design and execution				
• Habitat specificity	0.33	1	0.33	Does not consider local or regional environmental conditions.
• Sensitivity	0.33	1	0.33	Sensitivity analyses have not been performed.
• Quantitativeness	0.33	3	1	Mesocosm study results are expressed semi-quantitatively, but are an indication of biological significance.
TOTAL SCORE (MAXIMUM = 15)	6			

Weight-of-evidence

- We re-evaluated contentious and new cosm studies
- Most were unacceptable, particularly close to proposed LOC values
- High uncertainty with this approach
- Proposed LOC of 25 µg/L

Water Quality Criteria Method

- Derived species sensitivity distribution using most up-to-date database of single species toxicity results
- Derived LOC by dividing HC5 by 2
- Proposed LOC = 26 µg/L



Attribute	Weighting Factor	Score (/5)	Weighted Score	Comments
Relationship between assessment and measurement endpoints				
• Biological linkage between measurement and assessment endpoints	0.33	1	0.33	Inputs are at the species level of organization. No inferences can be made at the community level.
• Linking exposure to response	0.33	1	0.33	Method does not account for exposure data.
• Utility of measure for judging environmental harm	0.33	3	1	Method is well accepted and standardized for species-level effects, but has limited certainty for judging community-level effects.
Data quality and quantity	1	5	5	Methods and toxicity test protocols are highly standardized.
Design and execution				
• Habitat specificity	0.33	1	0.33	Method does not consider environmental conditions.
• Sensitivity	0.33	5	1.67	Changes to uncertain assumptions influence the LOC by less than 2-fold.
• Quantitativeness	0.33	3	1	Method does not consider environmental factors, species interactions, functional redundancy, or community-level processes.
TOTAL SCORE (MAXIMUM = 15)			9.67	

Conclusions

- Using scoring rubric, CASM method had highest reliability, Brock et al. (2002) method had lowest reliability
- Range of LOCs from 4 methods was narrow (19.6 to 26 µg/L)
- Weighted LOC = 23.6 µg/L
- Independent and well-designed lotic cosm study by King et al. (2016) demonstrated that our weighted LOC for atrazine is protective of aquatic plant communities

Method	LOC (µg/L)	Weight-of-Evidence Score (/15)	Notes
PATI (Giddings Dataset)	25	9	Based on our analysis, the Giddings (2012) dataset was clearly superior to the dataset used by USEPA (2012a). Therefore, the 60-day CE-LOC derived by Giddings (2012) used here.
CASM	19.6	11	60-day LOC from screening analysis by Nair et al. (2015).
Cosm Dataset Directly	25	6	Derived from cosm studies considered relevant and acceptable or supplemental in our analysis.
Water Quality Criterion	26	9.67	Derived using the database in USEPA (2012a).
Weighted Atrazine LOC			**23.6 µg/L**

Acknowledgements

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