Presented By:
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The 2015 Draft Selenium Criteria – Review of the Document and Thoughts on Implementation

WESTCAS 2015 Fall Conference
Tucson, AZ
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GEI Consultants

Outline

- Background information on Se
- History of Se criteria
- Information on Se criteria updates
- Complications related to implementation of Se criteria

Selenium – Background

- **Selenium (Se)**
  - Essential micronutrient
  - Occurs in trace concentrations in nearly all environmental media
  - Anthropogenic activities can increase Se above background
  - Elevated Se also found in areas of Se-rich geology
    - Especially problematic in the Arid West
  - Margin between required/toxic concentrations is narrow

Selenium: Recent History of EPA Criteria

- **EPA's "current" Se criteria**
  - 20 µg/L acute, 5 µg/L chronic (**water column**)
  - Almost 30 yrs old (from the 1987 criteria document)
- **EPA has been in the process of revising the Se criteria for close to 20 years**
  - Following significant debate in Colorado in 1995, EPA held an expert workshop in 1998
  - Released drafts in 2002 and 2004
    - Move to tissue-based criterion; however, never finalized

Selenium:
The 2004 EPA Draft Criteria

- **Move from water to fish-tissue**
  - 7.91 mg/kg dw **whole-body fish**
    - Based on juvenile bluegill survival under winter stress
    - Recognized the importance of dietary Se uptake and bioaccumulation in aquatic biota
      - But, is it relevant to cold water streams/species, areas without ‘winter stress’?
    - EPA put out an unprecedented “call for data”
      - Need more studies on winter-stress
      - Need more information on effects on native populations
    - EPA re-did the original winter-stress bluegill study
    - Many parties provided more data
    - Nothing happened for the next 10 yrs
      - Except the phrase “we expect a new criteria document to come out soon”

Current Selenium Criteria

- **Some states use EPA's current acute criteria:**
  - Acute: 1/[f1/CMC1)+(f2/CMC2)],

    where f1 and f2 are the fraction of total Se comprised as selenite (Se^{+4}) and selenate (Se^{+6}), respectively, and CMC1 and CMC2 (acute values) are 185.9 and 12.82 µg/L, respectively
    - Based on acute toxicity data and calculations from 1987 criteria
- **Some states use EPA's old acute criteria:**
  - Acute: 20 µg/L
    - Not based on laboratory-derived toxicity data (see chronic)
- **Most states use EPA's "current" chronic criteria:**
  - Chronic: 5 µg/L
    - Not based on laboratory-derived toxicity data
    - Derived from field-observed no-effect level from Belews Lake, NC
      - Partially taking into account dietary pathway and unique toxic mechanism

FW Aquatic Life Selenium Criteria for WESTCAS states

State	Acute (µg/L)	Chronic (µg/L)
Arizona	33 (TR) – ephemeral streams only	2 (TR)
California (CTR)	Selenite/selenate equation	5 (TR)
Colorado	18.4 (D)	4.6 (D)
Nevada	20 (TR)	5 (TR)
New Mexico	20 (TR)	5 (TR)
Texas	20 (TR)	5 (TR)

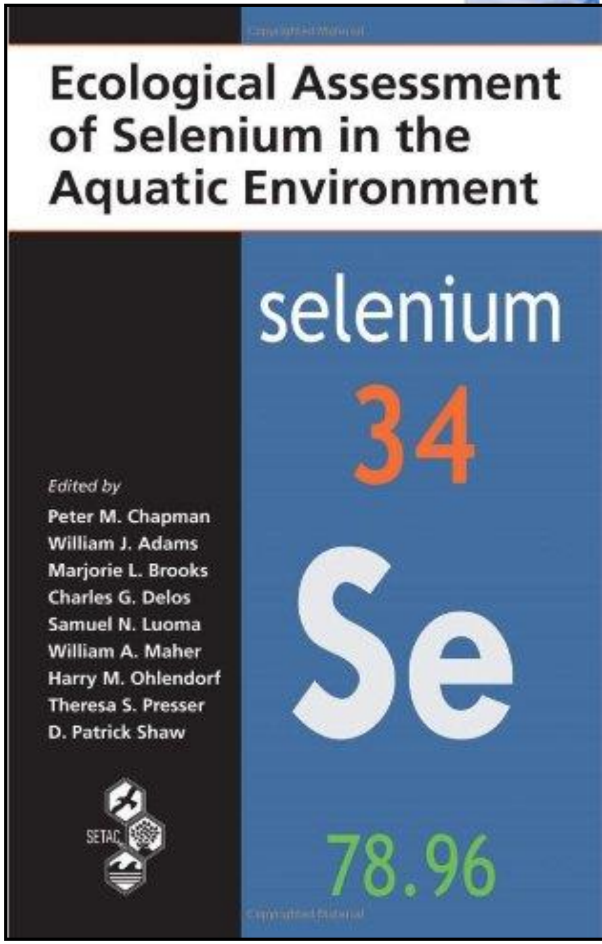
Selenium:
After the 2004 Updates

- **After the public comments came in**
  - EPA's "call for data"
    - Resulted in EPA/GLEC re-doing the Lemly winter stress study
    - Accepted lots of new studies
      - More maternal transfer studies
      - Also field studies
- **In 2009, an expert Pellston workshop was held**
  - Goal to discuss and address questions related to ecological assessment of Se

46 Scientists, Managers, Policy Makers; 4 continents; 5 countries

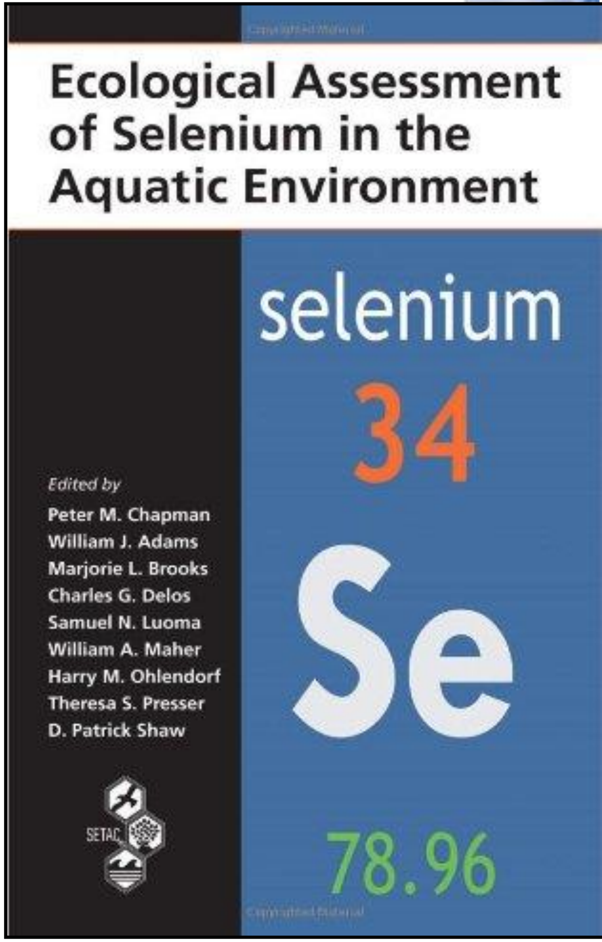
Selenium: After the 2004 Updates

- **Results of Se experts workshop, which focused on**
  - Discussing Se fate and effects in aquatic (freshwater, estuarine, marine) ecosystems
  - Determining the state-of-the-art
  - Provision of guidance for assessing and managing the environmental effects of Se
  - Documenting major sources of uncertainty requiring further research
- **Compilation of efforts by 46 scientists, managers, policy makers**
  - From 5 countries on 4 continents
- **Book published in 2010**
- **Excellent review of all things Se**
  - But no recommendations for final criterion



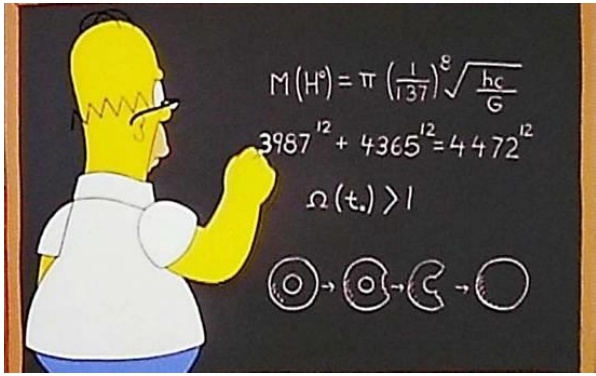
Selenium:
After the 2004 Updates

- **Appendix B Commentary**: Persistence of Some Fish Populations in High-Selenium Environments *by S. Canton*
  - Even with all the science, maternal transfer studies, draft criteria documents, modeling, etc., we still find fish in high Se environments where the science tells us they shouldn't be
    - Especially in the Arid West
  - Possible explanations?
    - Co-occurring elevated sulfate?
      - Reduces Se bioaccumulation and toxicity
    - Habitat limits presence of sensitive spp?
    - Population/community ecology
    - Species' natural history
    - Acclimation or tolerance?
    - Form of Se(selenate, selenite)
  - Clearly, Se criteria will be difficult to implement!
    - *More on that later…*



How are criteria *supposed* to be derived?

- **EPA's "1985 Guidelines" (Stephan et al. 1985)**
  - **First, gather all known toxicity data**
    - Keep what is 'acceptable' (more rules)
  - **Create toxicity database**
    - Rank data ("1" for lowest to "N" for highest)
      - Must meet 8-family rule
  - **Use 4 most sensitive genera**
    - Do some math



  - **None of the prior drafts did this!**

Meanwhile, over in Kentucky…

- **Given the delay at the national level, KY decided to update their standard in 2012-13**
  - Initial proposal – simply delete current acute 20 µg/L standard
    - Premise – no scientific reason for the number, no change in chronic
  - After comments (mostly from EPA Region 4), revised proposal to include both updated acute and chronic standards
- **Determined an updated Se standard is scientifically defensible**
  - New acute water-column toxicity and tissue-based chronic toxicity data made available since release of the current criterion (EPA 1987) and the last draft criterion (EPA 2004)

Acute Se Proposed in KY

- **Based on combination of**

1. **Equation based on forms of selenium (EPA 2012)**
   - Equation from "1995 updates" and the 1996 Great Lakes Initiative:

   CMC = 1/[f1/CMC1) + f2/CMC2)],

   Where f1 and f2 are fractions of total Se as selenite and selenate, respectively

2. **Plus, updated acute criteria from EPA 2004**

   CMC1 = 258 µg/L

   CMC2 = $\mathbf{e^{(0.5812[\ln(\text{sulfate})] + 3.357)}}$

   - If sulfate = 100 mg/L, CMC2 = 417 µg/L

The Toxicity Database

- **Fish tissue-based chronic criterion appropriate**
- **Data Sources**
  - Prior EPA Se criteria documents
  - Other reviews (DeForest, Adams, Ohlendorf)
- **Most studies present either whole-body *or* egg/ovary**
  - Used translators to develop complete whole-body and egg/ovary databases
    - Existing translators
      - FHM from GEI 2008, BG and Trout from NAMC-SWG White Paper
    - Updated "all species" translator
      - Added to database used in NAMC-SWG White Paper

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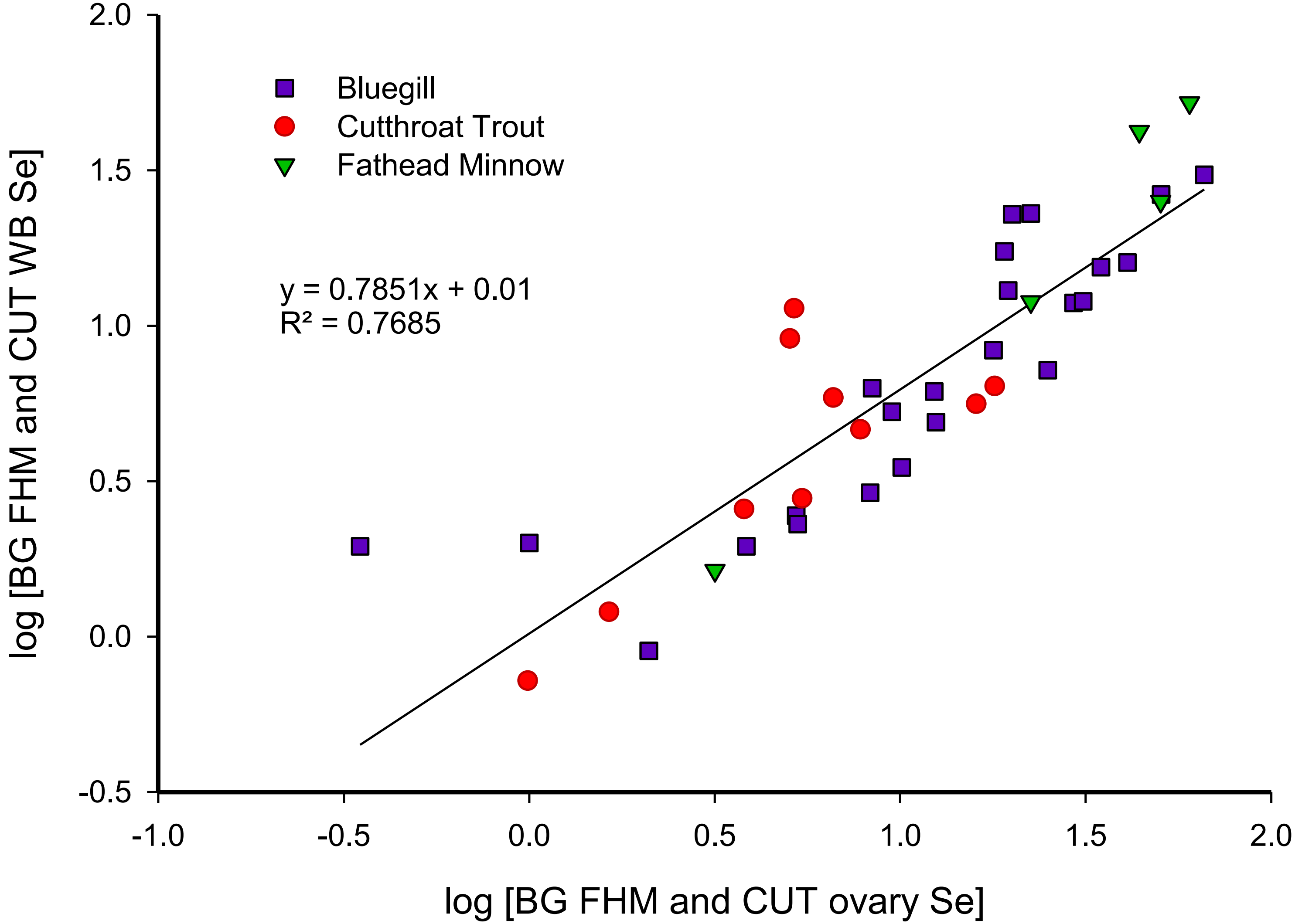


Modified "All-Species" regression using log-transformed egg/ovary and whole-body tissue selenium concentrations measured in bluegill, fathead minnow, and cutthroat trout.

KY's Chronic Database

- **Evaluated species expected to be found in KY**
  - Whole-body and egg-ovary toxicity data for relevant fish species (including naturalized and/or surrogate species) used to calculate GMCVs

1. Bluegill*
2. Brook trout*
3. Northern pike*
4. Largemouth bass*
5. Brown trout
6. Rainbow trout
7. White sucker
8. White sturgeon
9. Western mosquitofish
10. Fathead minnow

**Four most Se-sensitive species in database*

KY's Chronic Criterion

- Ranked by sensitivity and calculated standard using EPA 1985 Guidelines

Whole-body

Rank	Genus	GMCV	ln GMCV	(ln GMCV)^2	P = R/(N+1)	$\sqrt{P}$
4	*Micropterus*	10.96	2.3943	5.7324	0.3636	0.6030
3	*Esox*	10.92	2.3906	5.7149	0.2727	0.5222
2	*Salvelinus*	10.34	2.3360	5.4570	0.1818	0.4264
1	*Lepomis*	8.92	2.1883	4.7886	0.0909	0.3015
		SUM	9.3092	21.6929	0.9090	1.8531

Calculations: Chronic Whole-body Criterion

$$S^2 = \frac{\Sigma\,(\ln GMCV)^2 - (\Sigma \ln GMCV)^2/4}{\Sigma P - (\Sigma\,\sqrt{P})^2/4} = \frac{21.6930 - (9.3092)^2/4}{0.9091 - (1.85317)^2/4} = 0.5519 \qquad S = 0.7429$$

$L = [\Sigma \ln GMCV - S(\Sigma\sqrt{P})]/4 = [9.3092 – 0.7429\ (1.85317)]/4 = 1.9831$

$A = S\ (\sqrt{0.05}) + L = (0.7429)(0.2236) + 1.9831 = 2.1492$

Final Chronic Value = FCV = e^A = 8.5783 ≈ **8.6 µg/g dry weight whole-body**

KY's Chronic Criterion

Egg/ovary

Rank	Genus	GMCV	Ln GMCV	$(\ln \text{GMCV})^2$	P = R/(N+1)	$\sqrt{P}$
4	*Micropterus*	22	3.0910	9.5543	0.3636	0.6030
3	*Lepomis*	22	3.0910	9.5543	0.2727	0.5222
2	*Esox*	20.4	3.0155	9.0932	0.1818	0.4264
1	*Salvelinus*	20	2.9957	8.9744	0.0909	0.3015
		Sum	12.1934	37.1769	0.9191	1.8531

Calculations: Chronic Egg/Ovary Criterion

$$S^2 = \frac{\Sigma(\ln GMCV)^2 - (\Sigma \ln GMCV)^2/4}{\Sigma P - (\Sigma\sqrt{P})^2/4} = \frac{37.1769 - (12.1934)^2/4}{0.9091 - (1.85317)^2/4} = 0.1482 \qquad S = 0.3850$$

$$L = [\Sigma \ln GMCV - S(\Sigma\sqrt{P})]/4 = [12.1934 - 0.3850\,(1.85317)]/4 = 2.8700$$

$$A = S\,(\sqrt{0.05}) + L = (0.3850)(0.2236) + 2.8700 = 2.9561$$

Final Chronic Value = FCV = e^A = 19.2220 ≈ **19.2 µg/g dry weight egg/ovary**

KY’s Selenium Standards

- **Adopted by KY in 2013**
- **EPA approved chronic standard Nov 2013**
  - Disapproved acute water column-based standard as “not protective”
  - Ironic, as it’s EPA’s current Se acute criterion!
- **Of course, NGO’s sued EPA for approving**
  - Nonetheless, KY using in permits and updated their “general permit” for coal mining to include the fish tissue-based standard
    - General permit update also approved by EPA
- **KY standard turned out to be a precursor of things to come!**

EPA's 2015 Draft Selenium Criterion

- Like KY, more in line with the 1985 guidelines
- Critical evaluation of 16 reproductive studies
- Results in fish tissue thresholds for 12 species in 10 genera

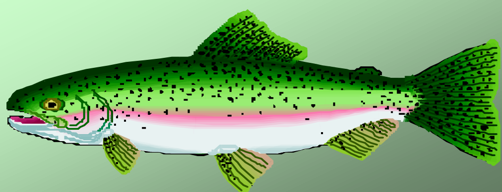
1. White Sturgeon
2. Bluegill
3. Brown Trout
4. Largemouth Bass
5. Rainbow/Cutthroat Trout
6. Fathead Minnow
7. Desert Pupfish
8. Northern Pike
9. Dolly Varden
10. Mosquitofish (live bearer)

- Also included chronic invertebrate data for rotifer, oligochaete, mayfly
  - In an attempt to meet the "8-family rule"

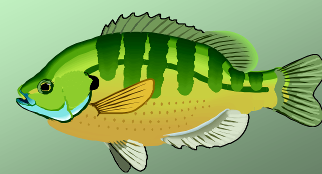
What is the “8 Family Rule” you ask?

Minimum Dataset For Freshwater Criteria Derivation
Studies are carefully screened for data quality

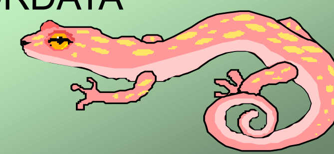
SALMONID



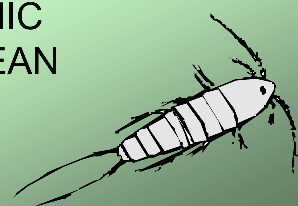
SECOND
FISH
FAMILY



Another member of the Phylum
CHORDATA

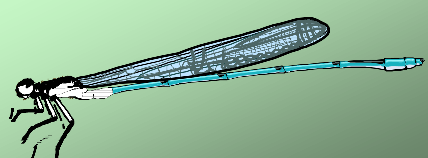


PLANKTONIC
CRUSTACEAN

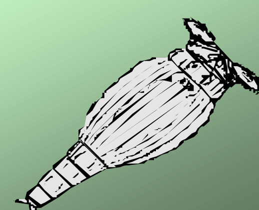


BENTHIC
CRUSTACEAN

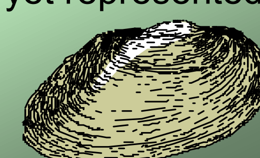
AQUATIC INSECT



ROTIFERA,
ANNELIDA,
MOLLUSCA



OTHER INSECT OR MOLLUSCA
or Organism not yet represented



Eight Family Requirement

Minimum Data Requirement	Fulfilled?	Number
Salmonidae	Yes	3
Second Fish Family	Yes	2
Chordata (fish, amphibian, etc)	Yes	5
Planktonic Crustacean	Waived*	1
Benthic Crustacean	Waived*	1
Insect	Yes	1
Rotifera, Annelida, or Mollusca	Yes	1
Other Insect or Phylum not represented	Yes	1
Total “N”		**15**

*waived due to known insensitivity of invertebrates, but still “counts” as part of the 8-family rule!

2015 EPA Draft Criteria

Media Type	Fish Tissue		Water Column[3]	
Criterion Element	**Egg/Ovary[1]**	**Fish Whole-Body or Muscle[2]**	**Monthly Average Exposure**	**Intermittent Exposure**
Magnitude[5]	15.8 mg/kg	8.0 mg/kg whole-body or 11.3 mg/kg muscle (skinless, boneless filet)	1.2 µg/L in lentic systems 3.1 µg/L in lotic systems	Equation….
Duration	Instantaneous measurement[4]	Instantaneous measurement[4]	30 days	Number of days per month with an elevated concentration
Frequency	Never to be exceeded	Never to be exceeded	Not more than once in three years on average	Not more than once in three years on average

[1] Overrides any whole-body, muscle, or water column elements when fish egg/ovary concentrations are measured.

[2] Overrides any water column element when both fish tissue and water concentrations are measured.

[3] Water column values are based on dissolved total selenium in water.

[4] Instantaneous measurement. Fish tissue data provide point measurements that reflect integrative accumulation of selenium over time and space in the fish at a given site. Selenium concentrations in fish tissue are expected to change only gradually over time in response to environmental fluctuations.

Se Criteria Review

- **Positives**
  - Preference for tissue-based criteria
    - Better reflects mode of toxicity for Se toxicity
      - Dietary exposure, bioaccumulation in biota, and passage to egg tissue
    - Se can cause deformities and other developmental issues, affecting survival of larvae
  - Use of EC_{10}s
    - More conservative, consistent with other recent approaches
  - Timing of tissue data collection
    - Samples collected at same site within 1 year can serve as matched pairs
  - Reliance on maternal transfer rather than juvenile survival data

Se Criteria Review

- **Things we think need more work**
  - Data usage and calculations…
  - Nationwide lentic and lotic water column-based criteria not appropriate
  - What about sites without fish?
  - What about sites with naturally high Se?

Se Criteria Review

- **Data usage and calculations**
  - White Sturgeon
    - Data are questionable based on partial response

      - EPA fit 4 different curves to data with same goodness of fit
    - Take geomean of all curves and update White Sturgeon GMCV to 17.8 mg/kg (from 16.27 mg/kg)
  - Bluegill

    - Hermanutz et al. (1996) study – EPA combined Studies I and II – too many differences, should be excluded
    - Exclusion of Hermanutz study updates Bluegill GMCV to 22.57 mg/kg (from 17.95 mg/kg)
  - Brown Trout

    - Formation Environmental (2011) study – EPA used “worst case” scenario approach to derive brown trout EC_{10}, but we think their “optimistic” scenario is more realistic
    - Use of *realistic* scenario updates Brown Trout GMCV to 21.16 mg/kg (from 18.09 mg/kg)

Se Criteria Review

- **Most studies results as either whole-body *or* egg/ovary – rarely both**
  - But we still need data for all tissue types, so…
  - EPA used translators to develop complete egg/ovary, whole-body and muscle databases
    - Developed based on median of matched whole-body and egg/ovary data
    - In the past EPA has recommended regression based conversion factors
  - GEI developed regression based translators when regression had R^2 value > 0.70

GEI Recalculations

Rank	GMCV (mg Se/kg dw EO)	Species	SMCV (mg Se/kg dw EO)
9	56.22	Dolly Varden, *Salvelinus malma*	56.22
8	<34	Northern Pike, *Esox lucius*	<34
7	27	Desert Pupfish, *Cyprinodon macularius*	27
6	<23.85	Fathead Minnow, *Pimephales promelas*	<23.85
5	22.71	Cutthroat Trout, *Oncorhynchus clarki*	24.45
		Rainbow Trout, *Oncorhynchus mykiss*	21.1
4	22.57*	Bluegill Sunfish, *Lepomis macrochirus*	22.57*
3	21.16*	Brown Trout, *Salmo trutta*	21.16*
2	20.35	Largemouth Bass, *Micropterus salmoides*	20.35
1	17.8*	White Sturgeon, *Acipenser transmontanus*	17.8*

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2	20.35	Largemouth Bass, *Micropterus salmoides*	20.35
1	17.8*	White Sturgeon, *Acipenser transmontanus*	17.8*

GEI Recalculations

Rank	Genus	GMCV	ln GMCV	(ln GMCV)^2	P = R/(N+1)	$\sqrt{P}$
1	Acipenser	17.80	2.8792	8.2898	0.0526	0.2294
2	Micropterus	20.35	3.0131	9.0787	0.1053	0.3244
3	Salmo	21.16	3.0521	9.3154	0.1579	0.3974
4	Lepomis	22.57	3.1166	9.7133	0.2105	0.4588
		Sum	12.0610	36.3972	0.5263	1.4101

Calculations:
Chronic Egg/Ovary Criterion

$$S^2 = \frac{\sum(\ln GMCV)^2 - (\sum \ln GMCV)^2/4}{\sum P - (\sum\sqrt{P})^2/4} = \frac{36.3972 - (12.0610)^2/4}{0.5263 - (1.4101)^2/4} = 1.0306 \quad S = 1.0152$$

$L = [\sum \ln GMCV - S(\sum\sqrt{P})]/4 = [12.0610 - 1.0152(1.4101]/4 = 2.6574$

$A = S(\sqrt{0.05}) + L = (1.0152)(0.2236) + 2.6574 = 2.8844$

Final Chronic Value = FCV = e^A = **17.9 mg/kg**

Compared to EPA Egg/Ovary criterion of 15.8 mg/kg

GEI Recalculations

- Convert egg/ovary values to whole-body and muscle using revised conversion factors
- Perform same ranking and calculations
- Results:
  - Whole-body criterion = 9.5 mg/kg (EPA 8.0 mg/kg)
  - Muscle criterion = 12.0 mg/kg (EPA 11.3 mg/kg)

Derivation of EPA Water Column Criteria – based on use of USGS Biodynamic Model

- **Presser and Luoma's biodynamic model**
  - Models Se uptake through the food chain to estimate a protective water column [Se]
    - Water, particulates/sediment, invertebrate tissue, fish tissue [Se]
  - Uses thresholds for whole-body fish or bird eggs

The model is a linear equation:

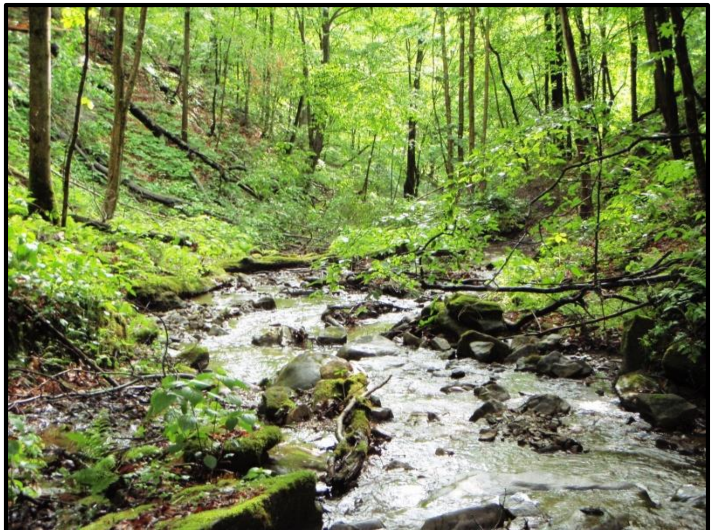
- C_{water} (µg/L) $= C_{predator} / (K_d \times TTF_{invertebrate} \times TTF_{predator}) \times 1000$

Where:

C_{water}	= Se in water, µg/L
$C_{predator}$	= Se in fish whole-body, µg/g dw (fish tissue threshold)
K_d	= Partitioning coefficient (water → particulates)
$TTF_{invertebrate}$	= Trophic transfer factor invertebrate (particulates → invertebrates)
TTF_{prey}	= Trophic transfer factor predator (invertebrates → fish)

Biodynamic Model

- **Presser and Luoma (2010) biodynamic model**
  - Uses site-specific data or "average" values reported elsewhere. That is, you can either
    - Calculate K_d and TTFs using Se data from your site of interest, ***or***
    - Use "expected" K_d and TTFs calculated from averages concentrations measured in similar streams



Biodynamic Model

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- Here's some examples of results and issues that arise when site-specific data are used (note – run with 2004 draft tissue criterion):

	Site Data					Calculated from Site Data			Model Result	
Example	Water [Se]	Sed [Se]	Invert [Se]	Fish [Se]	Fish Tissue Threshold	K_d	TTF_{inv}	TTF_{fish}	Protective C_{water} (µg/L)	Notes
A	5	0.75	2	8	7.9	150	2.67	4.00	**4.9**	
B	10	1.5	4	16	7.9	150	2.67	4.00	**4.9**	Double all
C	5	75	200	8	7.9	15000	2.67	0.04	**4.9**	100x sediment and invert
D	5	750	2000	8	7.9	150000	2.67	0.00	**4.9**	1000x sediment and invert
E	5	0.75	2	16	7.9	150	2.67	8.00	**2.5**	Double fish Se
F	10	0.75	2	8	7.9	75	2.67	4.00	**9.9**	Double water Se

- Basically, when averages of site-specific data are used, the only parameters that matter are water and fish Se
  - Sediment and invertebrate Se values "cancel out"
  - Results end up equal to those derived using the simpler bioaccumulation factor (BAF = Se in fish/Se in water)

Don’t fall asleep yet, there’s more……

- How did EPA derive water column criteria of 1.3 for lentic systems, and 3.1 for lotic systems?

Derivation of EPA Water Column Criteria

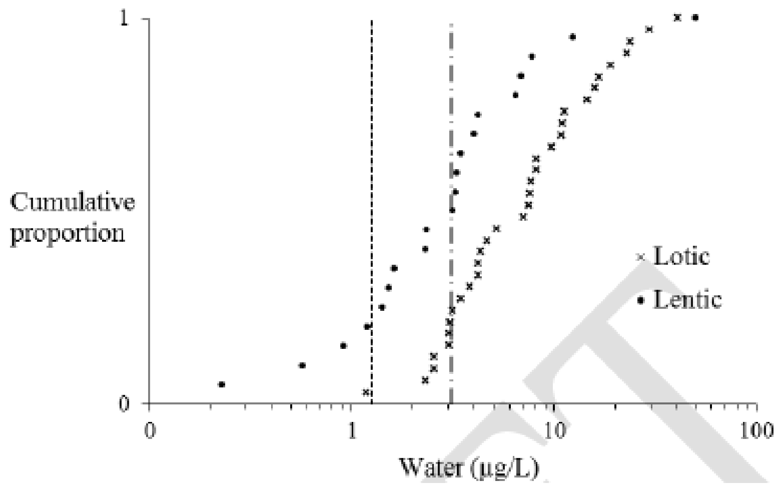
- EPA used site-specific data for 20 lentic and 33 lotic sites
  - Enrichment factors – partitioning of Se between dissolved and particulate state
  - Conversion factors – egg/ovary to whole body
  - Composite trophic transfer functions – degree of biomagnification across trophic levels
- Translated these values to a protective water column concentration

$$C_{water} = \frac{C_{egg/ovary}}{TTF \ x \ EF \ x \ CF}$$

- Generated a probability distribution of data
- Used the 20th percentile value as the water column criteria

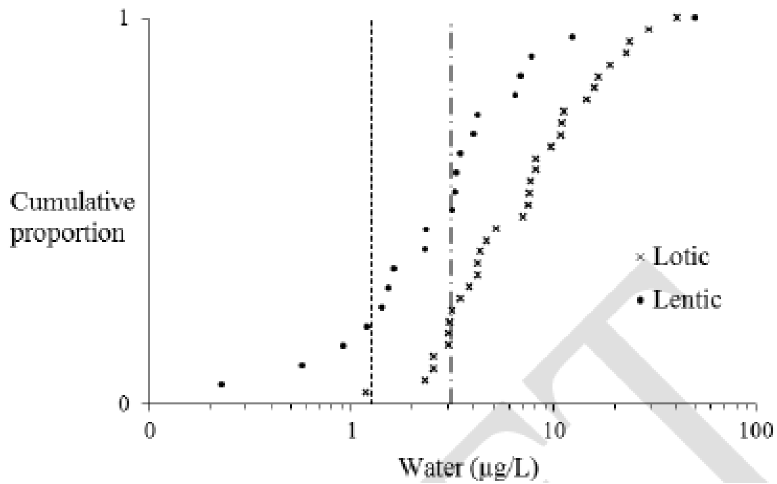
Lentic = 1.2 µg/L **Lotic = 3.1 µg/L**

Derivation of EPA Water Column Criteria

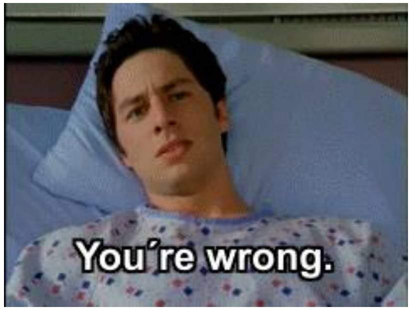


- Each and every point on this graph is protective of the egg/ovary criterion based on the site-specific parameters at that site
- 80% of the sites would be overprotected and 20% of the sites would be underprotected

Derivation of EPA Water Column Criteria



- Each and every point on this graph is protective of the egg/ovary criterion based on the site-specific parameters at that site
- 80% of the sites would be overprotected and 20% of the sites would be underprotected
- Results in a criterion that is wrong virtually 100% of the time!



Derivation of EPA Water Column Criteria

- Data set is very limited
  - 20 lentic and 33 lotic sites – most data >20 years old
- GEI added additional site-specific data to the lotic dataset
  - 47 additional sites - recent
  - "Protective" values range from 1.2 to 81.0 µg/L
- Results in lotic value of 4.2 µg/L (EPA = 3.1)
- Similar exercise with CO only data
  - Resulted in lotic value of 5.8 µg/L
- Approach is strongly influenced by the amount of data used – one number does not fit all

Derivation of EPA Water Column Criteria

- Counterintuitive results using model
  - EFs are assumed to be constant
    - Actually vary inversely – higher EFs at low Se, lower EFs at high Se
    - Results in low Se water bodies driving the criterion elements as these EFs are high

Lotic example:

Deerlick Cr. translated water column = 1.19 µg/L
based on Se conc. 0.2 µg/L, EF 2.24 L/g

Luscar Cr. translated water column = 8.15 µg/L
based on Se conc. 10.7 µg/L, EF 0.33 L/g

Creeks are similar in location, size, both support Rainbow Trout – counterintuitive that water column concentrations that differ by 6x would both result in tissue conc. of 15.8 mg/kg

Alternative Chronic Water Column Criteria?

- Develop protective water concentrations that attain tissue-based criterion but are dependent on sulfate (Deforest et al. 2014)
- $$Water\ Se\ concentration = exp\left[\frac{ln(fish\ Se\ conc) - 4.320 + 0.5774\ (\ln(SO_4)}{0.4751}\right]$$
- Using GEI's egg/ovary value of 17.9

Sulfate Conc. (mg/L)	Water Column Se Conc. (µg/L)
50	5.7
100	13.1
150	21.5
200	30.5
250	40.0

Tissue-Based Selenium Criteria Implementation

- Implementation will not be easy!
- Guidance (including guidance for fish tissue sampling) is not included with the draft Se criteria document
  - Guidance document will be separate
    - No public comment period that we've heard

Tissue-Based Selenium Criteria Implementation

- What about sites with no fish?
  - EPA's default approach is to use water-column criteria
- In ephemeral or intermittent streams fish are not limited by water quality but by quantity
- Could use EPA's chronic invertebrate data to establish protective tissue concentration for invertebrates
  - Mayfly was most sensitive – GMCV of 24.2 mg/kg Se

- If downstream waters are in attainment with fish tissue criteria, no need to protect non-existent fish upstream

Tissue-Based Selenium Criteria Implementation

- Additional concerns for “fishless waters” and waters with “new or increased inputs of selenium until equilibrium is reached
  - Footnote states water column values have primacy
- May provide issues with antibacksliding /antidegradation for NPDES permit writers
  - Some states can address this, others do not have exceptions

Tissue-Based Selenium Criteria Implementation

- **What about sites with multiple fish species – many of which with unknown Se toxicity?**
  - Which species are sampled?
  - Are some more/less sensitive?
  - How are data combined - treated separately, averaged over all species/all sites?
  - Further complication of the criterion based on egg/ovary tissue
    - Requiring sampling specifically during key portions of each fish species’ reproductive cycle

Implementation Options

- **Offer options to translate between tissue concentrations and water column concentrations**
  - Calculate site-specific protective water column Se concentration, no national water number
    - Uses tissue-based criterion with site-specific bioaccumulation conditions
  - Equation 18 in criteria document

What about Acute Criteria?

- EPA does not include acute criteria – instead uses “intermittent exposure” element

$$WQC_{int} = \frac{WQC_{30\,day} - Cbk_{grnd}(1 - fint)}{f_{int}}$$

- Oversimplification - calculates a 30-day average
- Recommend use of biokinetic model
  - Discussed in Appendix K of the 2015 criteria document
  - More in depth in DeForest et al. 2015

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Biokinetic Food Chain Modeling of Waterborne Selenium Pulses into Aquatic Food Chains: Implications for Water Quality Criteria

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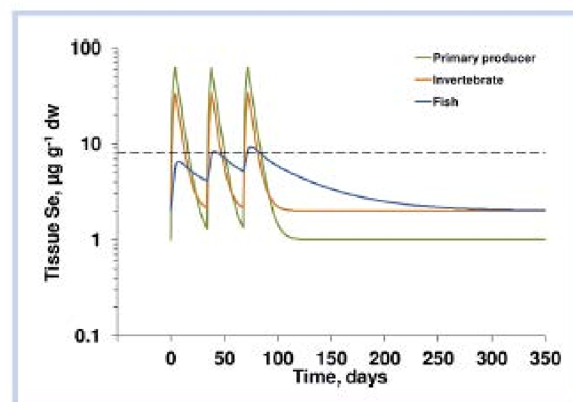
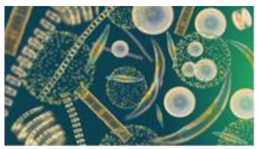


What about Acute Criteria?

- DeForest et al. biokinetic modeling



  - Periphyton and phytoplankton based food chains

  - Predicts whole-body fish concentrations
    - Background Se
    - Magnitude of Se pulse
    - Duration of Se pulse

  - Calculated pulses that would still be protective of EPA whole-body criteria
    - 1-day selenate – 144 µg/L; 1-day selenite – 57 µg/L
    - 4-day selenate – 35 µg/L; 4-day selenite – 16 µg/L

Summary

- After 20 years, we've come a long way and the result is a much better criterion based on dietary uptake mode of Se toxicity as measured in fish tissues
- Yet, in many ways, evaluation of appropriate approaches to implement Se criteria is still in flux
- Establishing a new criterion without thorough discussion of implementation fraught with danger!
  - Doesn't EPA remember the history of their other tissue-based criterion; methylmercury?!

Questions?

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