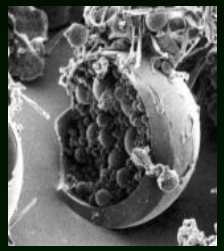
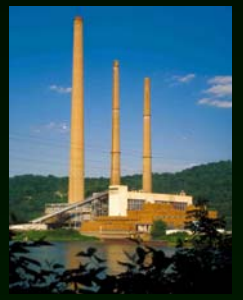
The Bioaccumulation of Selenium Derived from Coal Ash: An Overview



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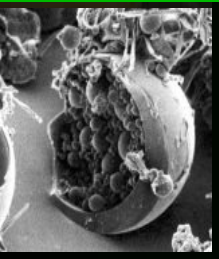
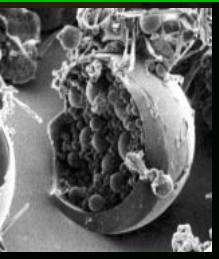




Overview

- Sources of Se from coal-fired power plants
- Chemistry, fate, and exposure factors
- Aquatic toxicology and bioaccumulation
- Fish tissue WQC: challenges and opportunities



Coal Combustion Product Production (1996)

Total CCP's produced = 92.5 metric t x 10^6

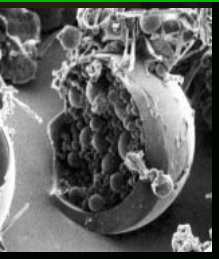
Distribution →

- Fly ash: 54 million mt
- Bottom ash: 15 million mt
- Boiler slag: 2 million mt
- FGD material: 22 million mt

Increasing rapidly

Total use of CCP's = 23 million mt (25% of total)

Most important uses: cement / concrete additive, structural fill, waste stabilization / solidification (fly ash)

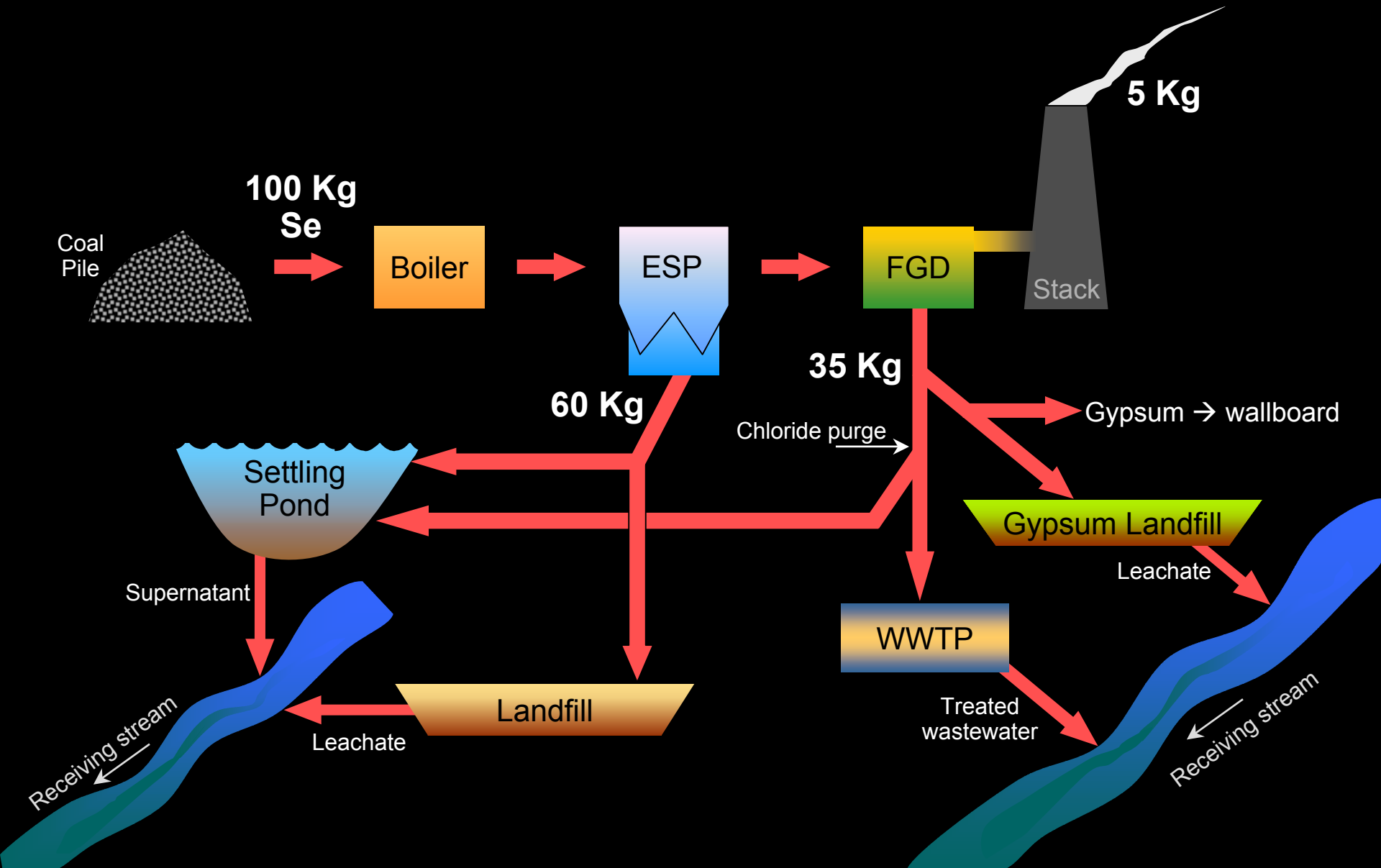





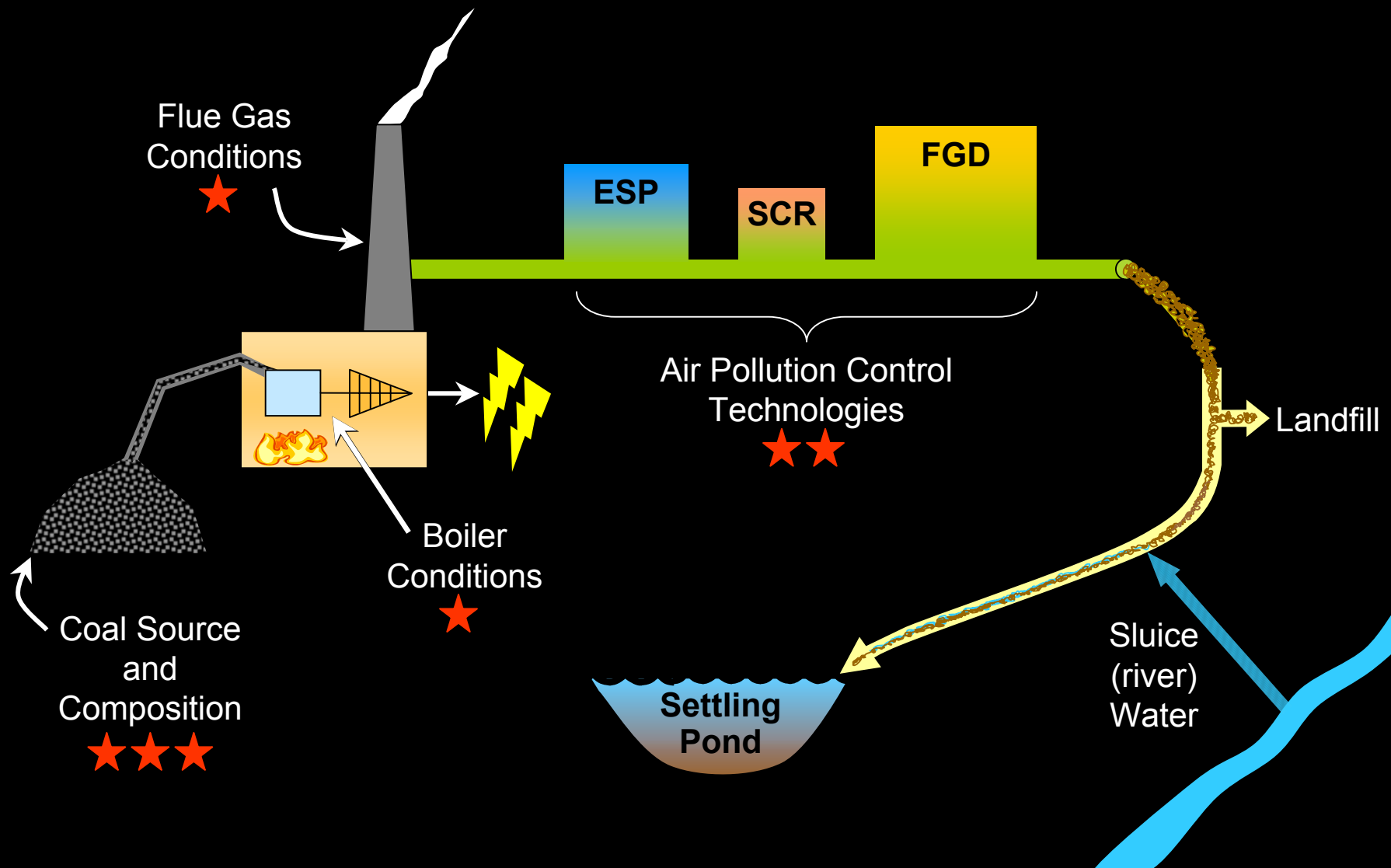
Selenium: Chemical Properties

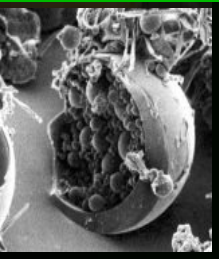
- Chemically and biologically, Se mimics sulfur.
- Inorganic and organic forms show high affinity to sulfydral groups (proteins); organic Se molecules are many, but analytical separation is problematic.
- Se antagonizes the bioaccumulation and toxicity of Hg. Most likely mechanism is formation of Hg-Se complexes; prevents direct attachment of Hg to proteins.

Sources of Se from Coal-Fired Power Plants



Fly Ash – Factors Affecting Chemical Composition





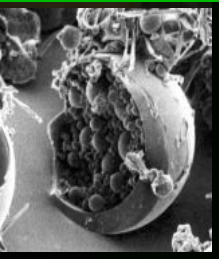
Power Plant vs Mining Waste Streams

- Ash Ponds are:
  - More heterogeneous due to variations in fuel type and pollution control technologies.
  - Lower in most trace metals, but mass loads may be same or higher.
  - Influenced by complex, often dystrophic, biological productivity and food webs.
  - Alkaline when western coal is burned.
  - Being made more complex by introduction of ammonia and high salts (FGD inlets).

Se Speciation in Coal Ash Ponds

*Plant**	*Coal*	*Coal Se (ppm)*	*% S*	*% Se^{+4}, Ash Pond Outlet (median)*
Amos (WV)	Appalachian – M	2.0	0.81	67
Big Sandy (KY)	East KY	-	0.98	66
Gavin (OH)	Pittsburgh #8	1.5	3.8	76
Muskingum River (OH)	Appalachian – N	2.0	2.9	64
Tanners Creek (IN)	Appalachian – M PRB	3.7	0.63	87

**** All Plants have ESP and SCR's. Gavin has wet FGD.***

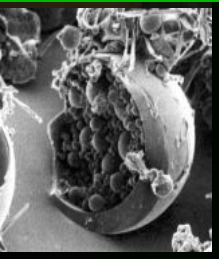





Coal Ash: When is Risk of Se Impact High?

Cationic metals: low pH, low hardness, low DOM, low biological productivity, unaffected by food chain structure (most do not biomagnify).

Selenium: high pH, high alkalinity, low sulfate, high DOM, high biological productivity, 3 or more consumer levels, long hydraulic retention time.

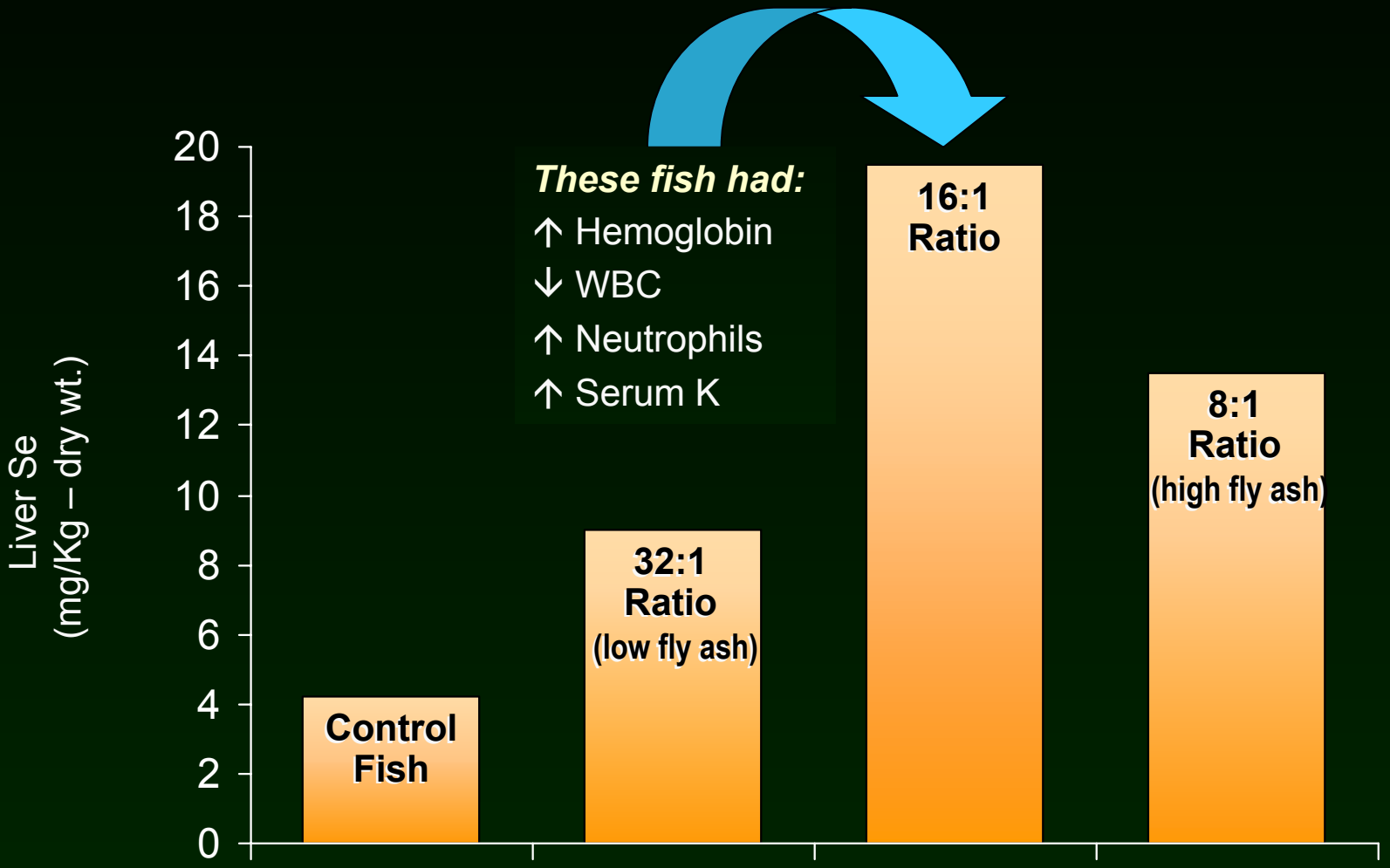





Bioaccumulation of Se from Fly Ash (AEP, 1999)

- Hatchery-reared bluegill exposed to lab water / fly ash ratios of 32:1, 16:1, and 8:1. Controls had no fly ash.
- 3-week static-renewal exposure with aeration and feeding.
- Fish removed and processed for tissue metals, hematology, and serum chemistry. Water sample analyzed.

Results – Se Accumulation in Liver Tissue



Se Distribution in a Fly Ash Pond Stream
1. Stingy Run, OH

Caddis fly Se:
19 mg/kg

Green sunfish
Liver Se: 10.4 mg/kg

Bluegill sunfish
Liver Se: 57 mg/kg
Ovary Se: 32 mg/kg
Teste Se: 37 mg/kg
Whole body Se: 17 mg/kg

Bullhead minnow
Whole body Se: 45 mg/kg

FAP Crest

Dam

Effluent
Discharge

Se in Water:
17 µg/L

Se in Sediments:
20 mg/kg

Se Distribution in a Fly Ash Pond Stream
2. Little Scary Creek, WV

Caddis fly Se:
31 mg/kg

Hellgrammite
Se: 25 mg/kg

Bluegill sunfish:
Liver Se: 53 mg/kg
Ovary Se: 23 mg/kg
Teste Se: 25 mg/kg

FAP Crest

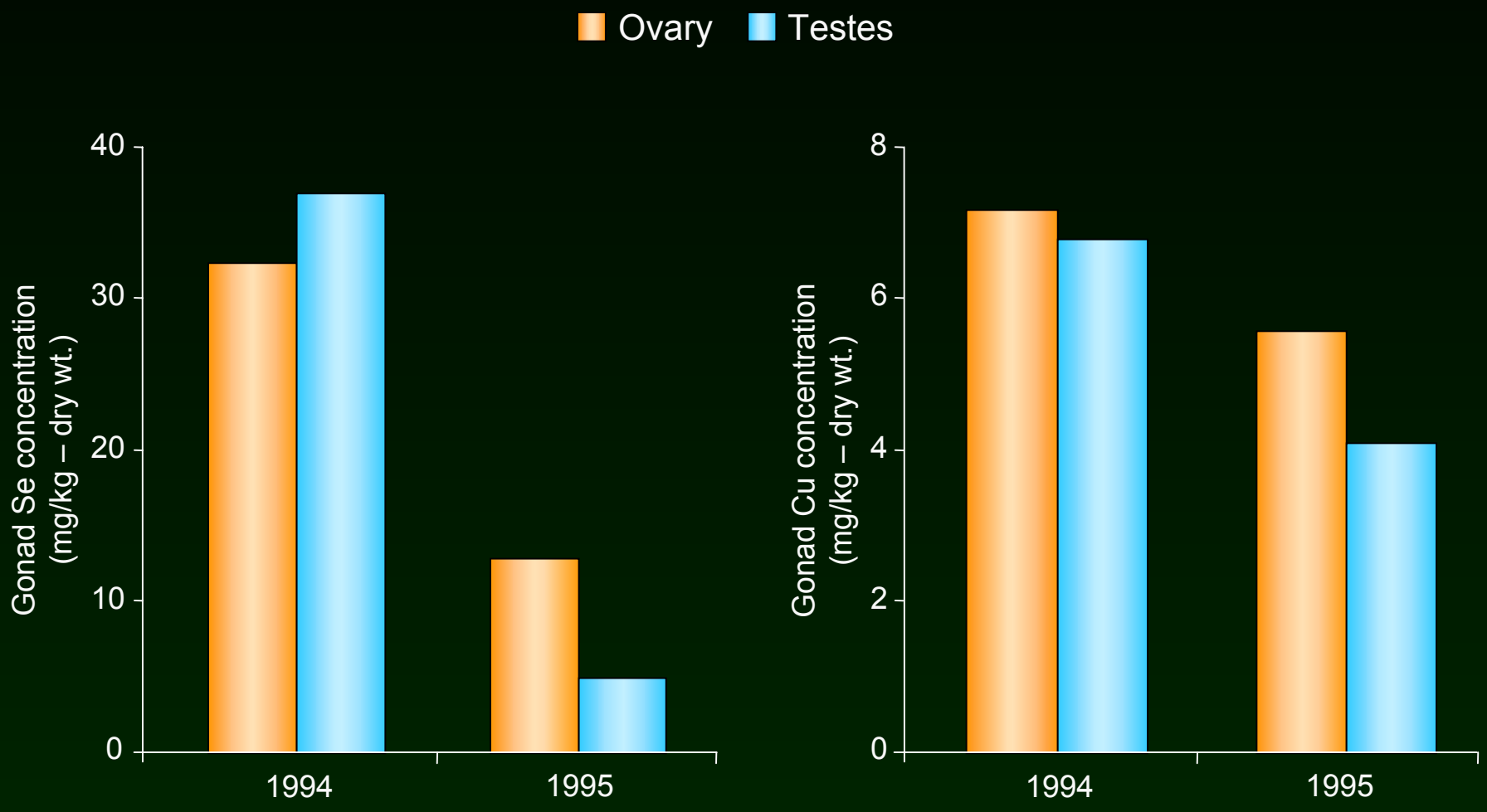
Dam

Effluent
Discharge

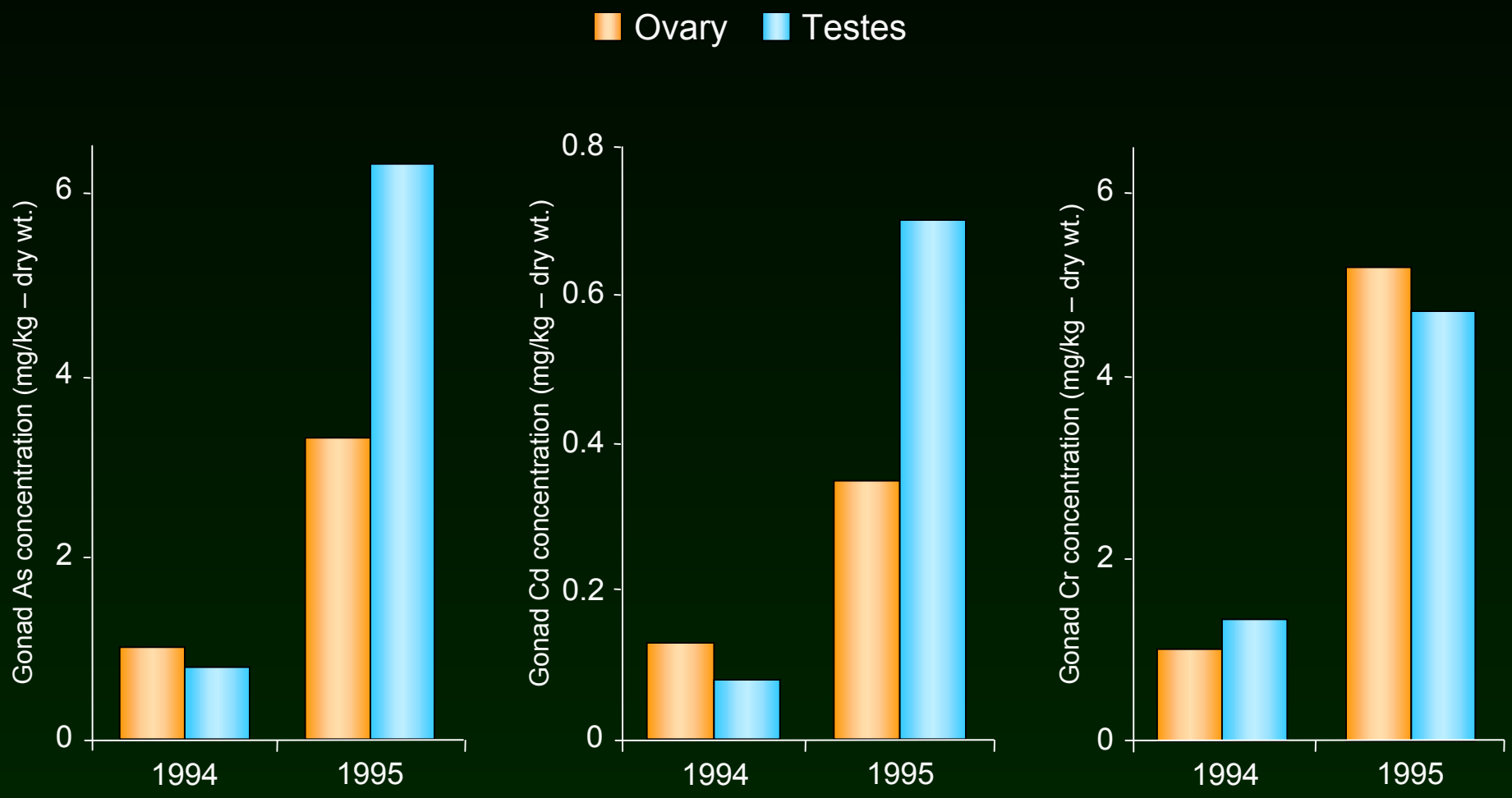
Se in Water:
34 µg/L
(100% Se^{+4})

Se in Sediments:
17 mg/kg

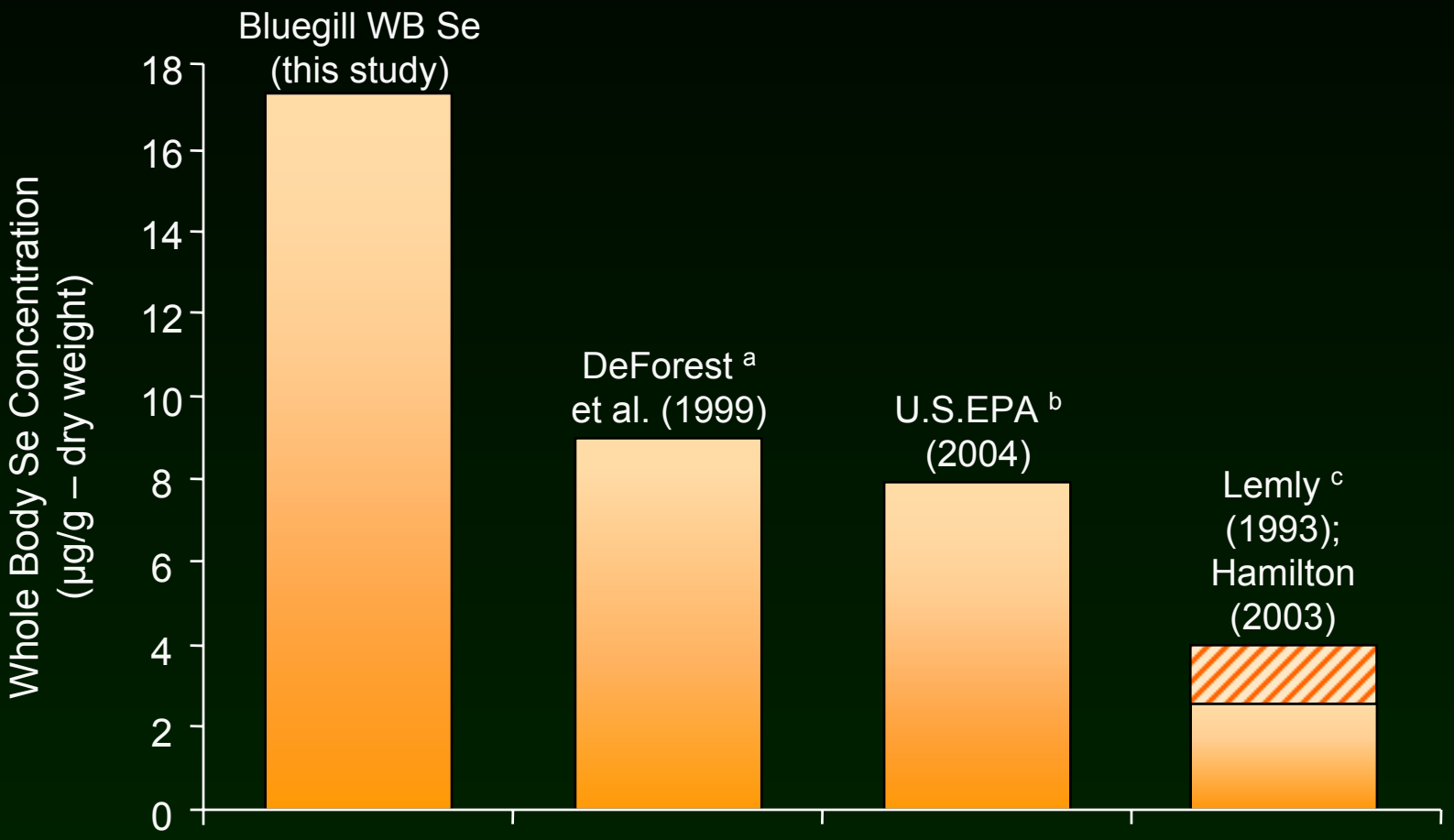
Temporal trends in concentrations of selenium and copper in bluegill gonad tissue for fish collected from Stingy Run during 1994 (fly ash sluiced to pond) and 1995 (sluicing ceased).



Temporal trends in concentrations of arsenic, cadmium, and chromium in bluegill gonad tissue for fish collected from Stingy Run during 1994 (fly ash sluiced to pond) and 1995 (sluicing ceased).

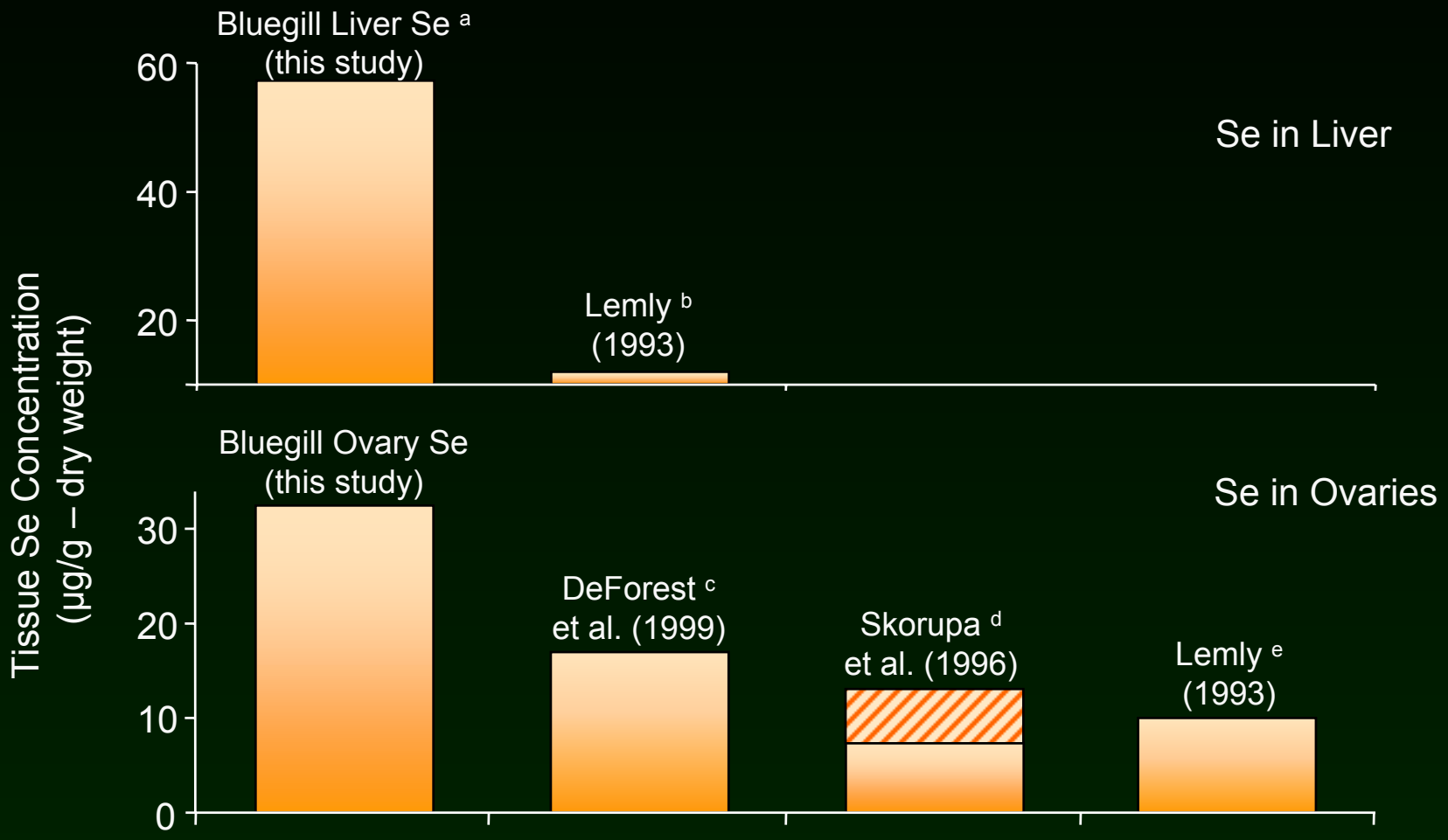


Recommended Safe Whole Body Threshold



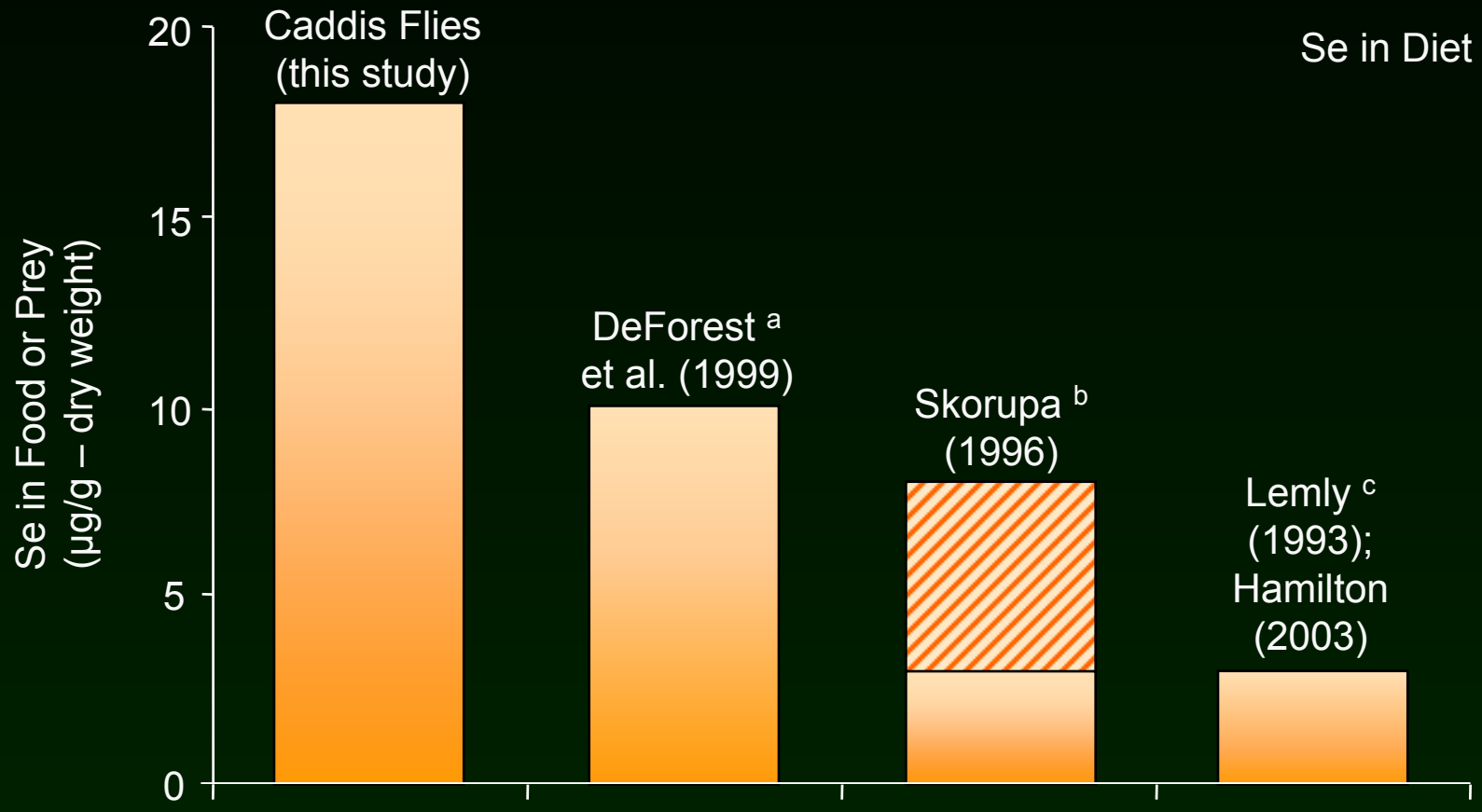
[a] Calculated EC_{10} for larval mortality (warmwater fish)
[b] Calculated EC_{20} for bluegill sunfish (most sensitive species) based on increased sensitivity of juvenile fish during long-term cold temperature exposure
[c] Chronic exposure threshold for both warmwater and coldwater fish

Recommended Safe Tissue Threshold



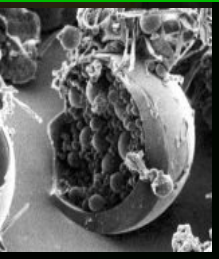
[a] Reported in Lohner et al. (2001)
[b] Based on effect level for rainbow trout
[c] Calculated EC_{10} for warmwater fish species
[d] Estimated IC_{10} of reproductive impairment for sensitive fish species
[e] Based on lowest effect level for bluegill sunfish

Recommended Safe Dietary Sources of Se



[a] Calculated EC_{10} for warmwater fish species
[b] Based on exposure of larval fish to Se-enriched diets (salmonids and sunfish)
[c] Based on most sensitive response for fish and wildlife species

Bluegill Sunfish in Stingy Run & Little Scary Creek had…

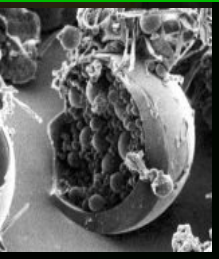


- Elevated levels of Se and other trace metals.
- Lowered levels of WBC; # cells correlated with tissue levels of As, Cu, Se, and Zn.
- Higher levels of some salts (Cl or K) in blood serum.

The sunfish populations, however, had…

- Continuous age-class representation (YOY to 8-yr fish).
- Persistent populations, suggesting successful reproduction.

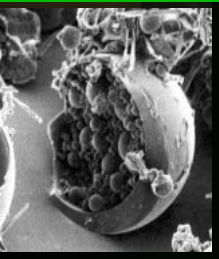
- Similar L-W relationships, CF, and LSI compared to reference fish.



Fish Tissue Criteria: Challenges and Opportunities

- Challenges
  - Uncertainty of "being in compliance".
  - Things change (temporal variation).
  - Predicting response of tissue levels after reductions.
  - Are tissue levels above criterion value equivalent to population impact?
  - Site-specific adjustments: how, and how long?

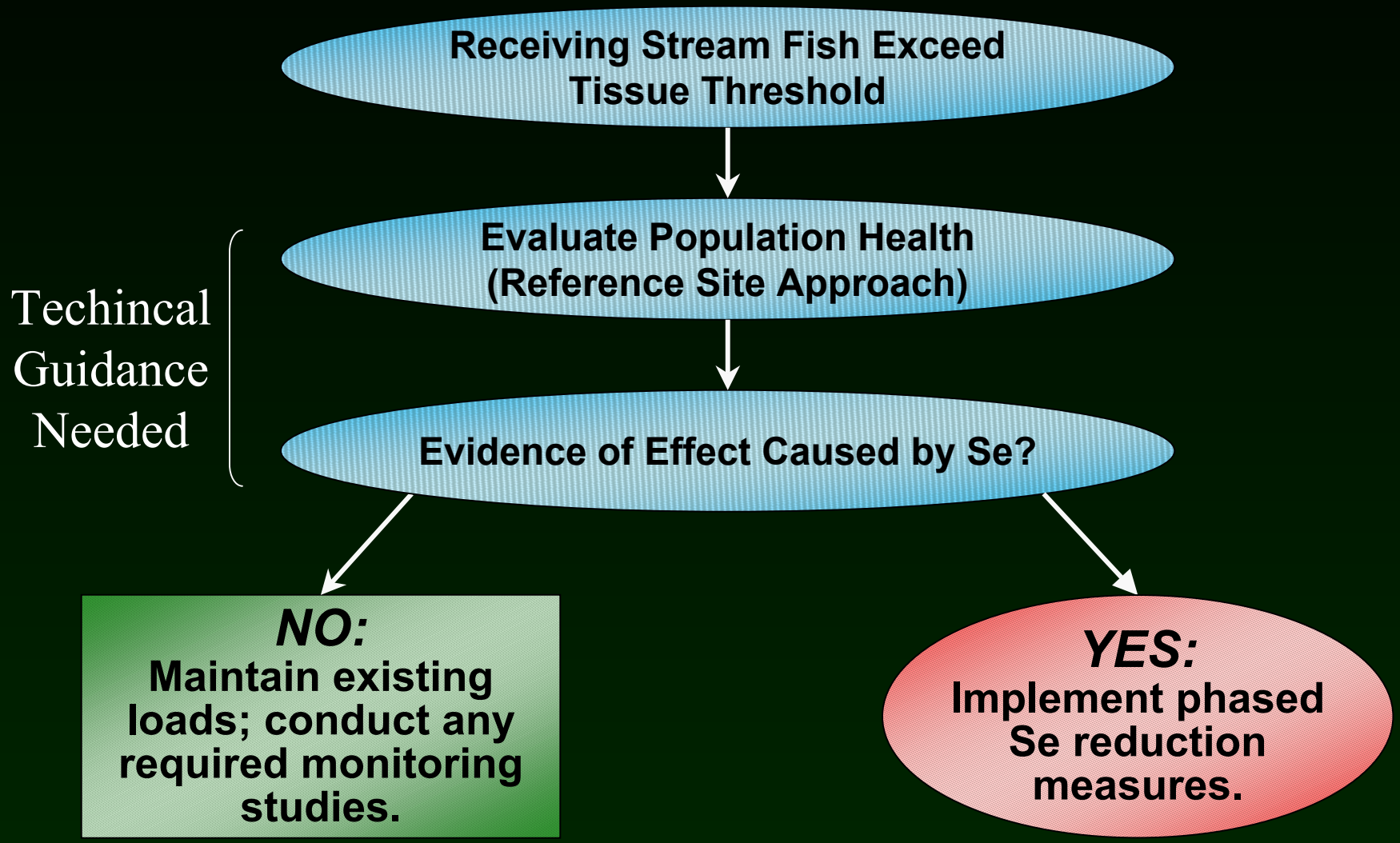



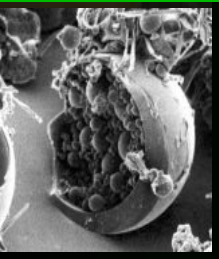


Fish Tissue Criteria: Challenges and Opportunities

- Opportunites
  - Monitor the biological endpoint that may be affected.
  - Development of database / model across sites: what drives Se bioaccumulation?
  - Current USEPA chronic criterion (5 µg/L) is NOT affects-based.
  - Being active in the regulatory process.

Proposed Pathway: Site-Specific Adjustments





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