"Aw criminy, another PowerPoint *after lunch and before a break??*"

Contaminated Sediments – Interpretation of Results

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22-23 September 2009

Sources of Sediment Contaminants

- Existing and historical point sources discharges
  - Industrial discharge
  - Sewage treatment
- Atmospheric deposition of contaminants
  - Fuel combustion
  - Waste incineration
- Nonpoint source runoff
  - Harvested croplands (agricultural runoff)
  - Landfills, toxic waste storage and disposal sites
  - Urban stormwater
  - Inactive and abandoned mining sites

SQGs of note

- Fresh water TEL/PEL
- Fresh water TEC/PEC
- Salt water ERL/ERM

- Got to the NOAA Screening Quick Reference Tables – Google: NOAA SQuiRT

Screening Quick Reference Table for Inorganics in Sediment

These tables were developed for internal use for screening purposes only: they do not represent official NOAA policy and do not constitute criteria or clean-up levels. All attempts have been made to ensure accuracy; however, NOAA is not liable for errors. Values are subject to changes as new data become available.

Analyte		Freshwater Sediment									Marine Sediment						
All concentrations in parts per billion unless specified otherwise		"Background"	ARCS *H. azteca* TEL [a]	Consensus TEC [e]	TEL [b]	LEL [g]	Consensus PEC [e]	PEL [b]	SEL [g]	UET	T20 [c]	TEL [d]	ERL [f]	T50 [c]	PEL [d]	ERM [f]	AET [h]
Aluminum (%)	Al	0.26%	2.55%														1.8% N
Antimony	Sb	160								3,000 M	630			2,400			9,300 E
Arsenic	As	1,100	10,798	9,790	5,900	6,000	33,000	17,000	33,000	17,000 I	7,400	7,240	8,200	20,000	41,600	70,000	35,000 B
Barium	Ba	700										130,100#					48,000 A
Cadmium	Cd	100-300	583	990	596	600	4,980	3,530	10,000	3,000 I	380	680	1,200	1,400	4,210	9,600	3,000 N
Chromium	Cr	7,000-13,000	36,286	43,400	37,300	26,000	111,000	90,000	110,000	95,000 H	49,000	52,300	81,000	141,000	160,000	370,000	62,000 N
Cobalt	Co	10,000				50,000+											10,000 N
Copper	Cu	10,000-25,000	28,012	31,600	35,700	16,000	149,000	197,000	110,000	86,000 I	32,000	18,700	34,000	94,000	108,000	270,000	390,000 MO
Iron (%)	Fe	0.99-1.8 %	18.84%			2%			4%	4% I							22% N
Lead	Pb	4,000-17,000	37,000	35,800	35,000	31,000	128,000	91,300	250,000	127,000 H	30,000	30,240	46,700	94,000	112,000	218,000	400,000 B
Manganese	Mn	400,000	630,000			460,000			1,100,000	1,100,000 I							260,000 N
Mercury	Hg	4-51		180	174	200	1,060	486	2,000	560 M	140	130	150	480	700	710	410 M
Nickel	Ni	9,900	19,514	22,700	18,000	16,000	48,600	36,000	75,000	43,000 H	15,000	15,900	20,900	47,000	42,800	51,600	110,000 EL
Selenium	Se	290															1,000 A
Silver	Ag	<500				500 +				4,500 H	230	730	1,000	1,100	1,770	3,700	3,100 B
Strontium	Sr	49,000															
Tin	Sn	5,000										48 *					> 3,400 N
Vanadium	V	50,000															57,000 N
Zinc	Zn	7,000-38,000	98,000	121,000	123,000	120,000	459,000	315,000	820,000	520,000 M	94,000	124,000	150,000	245,000	271,000	410,000	410,000 I
Lead 210 bq/g dw						0.5 ^			< 9.7 ^								
Polonium 210 bq/g dw						0.6 ^			< 8.7 ^								
Radium 226 bq/g dw						0.1 ^			< 13 ^								
Sulfides										130,000 M							4,500 MO

- Based on SLC approach using sensitive species HC5%; ES&T 2005 39(14):5148-5156.
* - Based upon EQp approach using current AWQC CCC
^ - Based on SLC approach to derive LEL and SEL; Env'al Monitor & Ass'ment 2005 110:71-85
+ - Carried over from Open Water disposal Guidelines; treated as if LEL for management decisions.
I – Infaunal community impacts
Bioassay endpoints: M – Microtox; B – Bivalve; E – Echinoderm larvae; O – Oyster larvae; A – Amphipod;

a EPA 905-R96-008
b Arch ET&C 2000, 39(1)20- Also known as Canadian ISQGs and PELs
c ET&C 2002, 21(9)1993-
d Ecotox. 1996, 5(4):253-
e EPA 905/R-00/007
f Env'al Mang 1995, 19(1):81-
g Guidelines for the protection and management of aquatic sediment quality in Ontario Aug 1993

Sediment Quality Guidelines

- Interpret historical data
- Source control
- Design monitoring programs
- Classify hot spots
- Identify potential problem chemicals or areas at a site
- Make decisions for more detailed study

But they do not provide cleanup concentrations

Nor were they ever designed to

Development of consensus-based sediment quality guidelines (SQGs) for fresh water:

- Probable effect concentrations (PECs)
- Threshold effect concentrations (TECs)

Evaluate the predictive ability of SQGs:

- *Hyalella azteca*: 10- to 14-d tests (n=668)
- *Hyalella azteca*: 10- to 42-d tests (n=160)
- *Chironomus tentans*: 10- to 14-d tests (n=632)

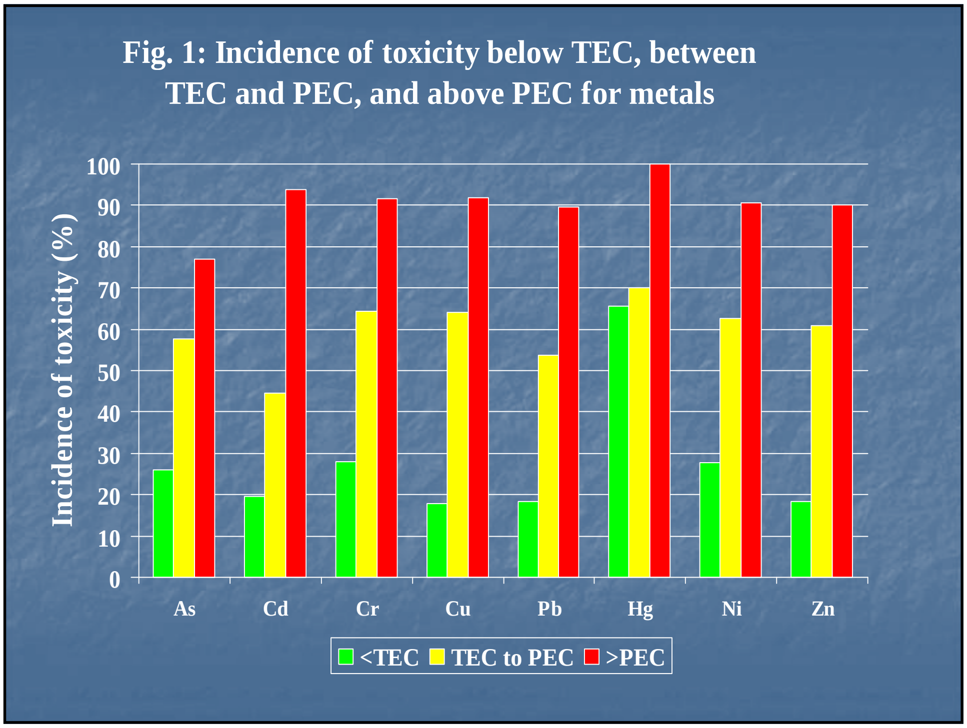


Fig. 1: Incidence of toxicity below TEC, between TEC and PEC, and above PEC for metals
Incidence of toxicity (%)
100
90
80
70
60
50
40
30
20
10
0
As
Cd
Cr
Cu
Pb
Hg
Ni
Zn
<TEC
TEC to PEC
>PEC

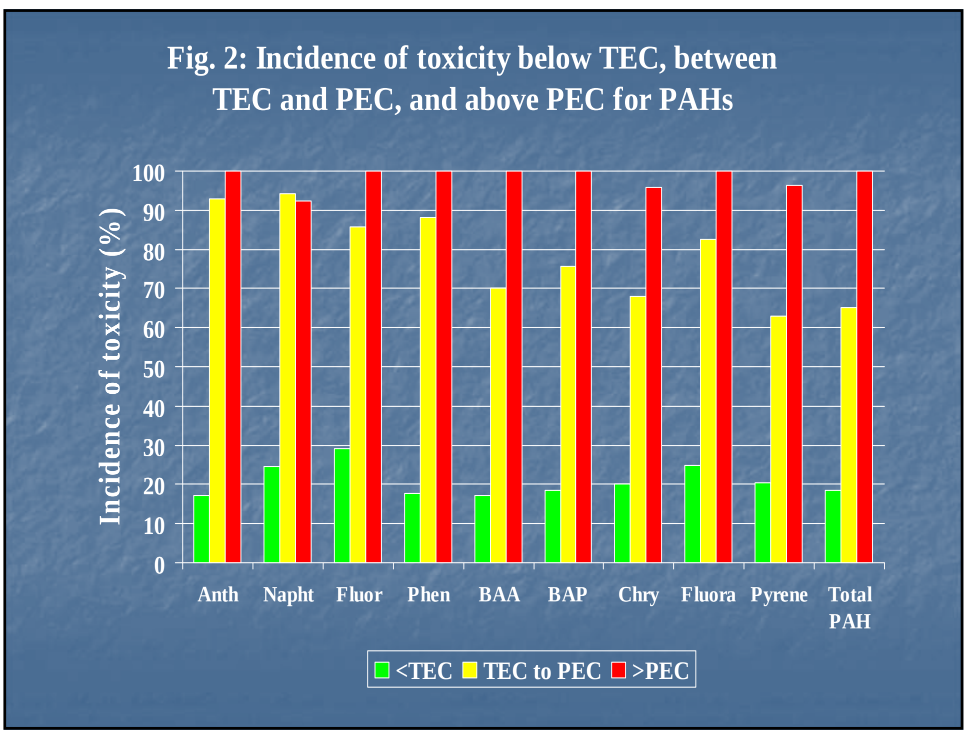


Fig. 2: Incidence of toxicity below TEC, between TEC and PEC, and above PEC for PAHs
Incidence of toxicity (%)
100
90
80
70
60
50
40
30
20
10
0
Anth
Napht
Fluor
Phen
BAA
BAP
Chry
Fluora
Pyrene
Total PAH
<TEC
TEC to PEC
>PEC

Background or Reference

An average or expected amount of a substance in a specific environment.

- Difficult to establish an acceptable background or reference sediment
- Less contamination
- Similar physical characteristics

Is it ecologically worse to find several contaminants above the PEC or is it equally bad to find just one above the PEC? Does it make more sense to assess contaminants individually or as a composite in terms of ecological impacts?

Predictive Ability of SQGs:

- Evaluate approaches for evaluating effects of chemical mixtures on toxicity in field-collected sediments.
  - Mean PEC quotients:
    1. Divide concentration of chemical by PEC.
    2. Sum individual quotients.
    3. Calculate mean quotient/sample.
- Evaluate ability of PECs to predict sediment toxicity in a freshwater database on a national and regional basis.

USGS

$$\text{ERM-Q} = \frac{1}{n}\sum_{i=1}^{n}\frac{COC_i}{ERM_i}$$

PEC Quotients

<0.1 = 18%

0.1 - <0.5 = 16%

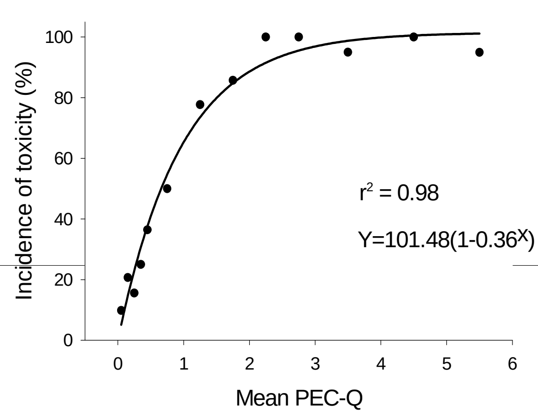
0.5 – 1.0 = 37%

>1.0 = 54%

>5.0 = 71%

From: Ingersoll et al., 2001

Relationship between mean PEC-Q and the incidence of toxicity in freshwater sediments (n=347).



#of PELs / ER-Ms Exceeded

- 1 = 14%/23%
- 2 = 38%/37%
- 3 = 35%/24%
- 4 = 22%/63%

Percent = Highly Toxic

From: Long et al., 1998

AVS

In the aquatic environment, the bioavailability of metals is generally controlled by different water and sediment variables. Sediment characteristics such as organic matter, iron and manganese oxides, carbonates, and clay content can bind metal ions and therefore reduce their availability to aquatic organisms*. In anaerobic sediments, sulfate* reduction by anoxic bacteria leads to the formation of sulfides, which are called acid volatile sulfides (AVS). AVS is operationally defined as the amount of sulfides volatilized by the addition of 1 N HCl and consists mainly of iron- and manganese sulfides*. In their reaction with metals, AVS* form thermodynamically stable metal sulfide precipitates, which results in a decreased concentration of free metal ions and therefore reduced metal bioavailability in the sediment pore water*.*

How Do I Calculate an SQG Using EQP?

Choose a water column effect benchmark: C_{water} = AWQC

We know that: $K_{OC} = C_{organic\ carbon} / C_{water}$

So: $C_{SQG\ (oc)} = K_{OC} * C_{water} = K_{OC} * AWQC$

Are some contaminants worse than others ecologically? Or, if you are over the PEC, then you are equally bad?

PCBs: Often low toxicity in 10-day tox tests but bioaccumulates and biomagnifys. Some CBRs are available. SQGs are low.

PAHs: Toxic to benthic organisms but generally does not accumulate in finfish. Use histopathology or biomarkers

Metals: Toxic to benthic organisms but generally does not bioaccumulate or biomagnify in fish (except Hg and Cd)

Mercury: SQGs show low accuracy. MeHg is the more toxic form. Bioaccumulates and biomagnifies

Dioxin: Most difficult to address. No SQG, need TCDD Toxicity Reference Value after TEC (TEQ) calculation

Finer grained seds = higher contamination but also higher TOC and AVS

Next steps

Typical Measurement Endpoints for Sediment Assessment

Assessment Tool	Exposure	Direct Msr of Effect	Effects from Lit.
Water Chemistry	X		X
Sediment Chemistry	X		X
Tissue Chemistry	X		?
Sediment Toxicity		X	
Benthic Macroinvert. Community Analysis		X	
Histopathology		X	
Biomarkers	X	?	

Toxicity Testing Costs

- 10-day Hyalella test: $1000 for survival endpoint only, $1100 for both survival and growth endpoints
- 10-day Chironomus test: $1000 for survival endpoint only, $1100 for both survival and growth endpoints

If there are more than five samples costs generally start to decrease per sample.

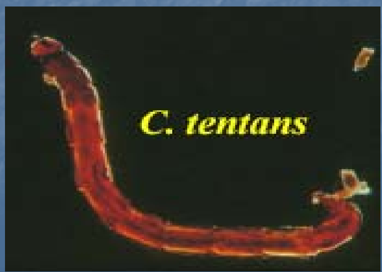
Chemistry costs

- Metals: $180
- SVOC: $320 to $520
- PCBs: $160
- Pesticides: $180
- Conventional Parameters: $200

If there are more than five samples costs generally start to decrease per sample.

USEPA Testing Protocols (USEPA 2000)

- Test Method 100.1: *Hyalella azteca* 10-day (acute) Survival and Growth Test for Sediments
- Test Method 100.2: *Chironomus tentans* 10-day (acute) Survival and Growth Test for Sediments



In Situ Toxicity Tests

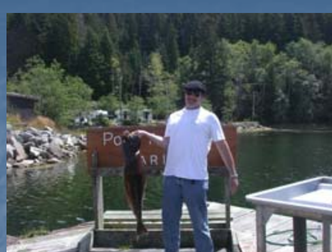
GE Housatonic River:

- 48-hour Daphnia magna (survival)
- 48-hour and 10-day Chironomus tentans (survival)
- 48-hour and 7-day Lumbriculus variegatus (survival and bioaccumulation)
- 48-hour and 10-day Hyalella azteca, 7-14 days old (survival)

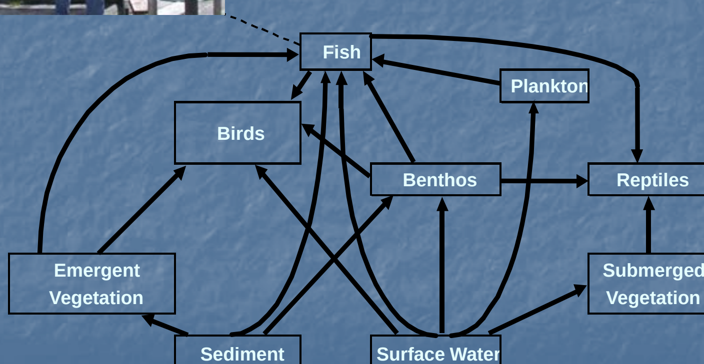
Benthic Invertebrate Risk Assessment

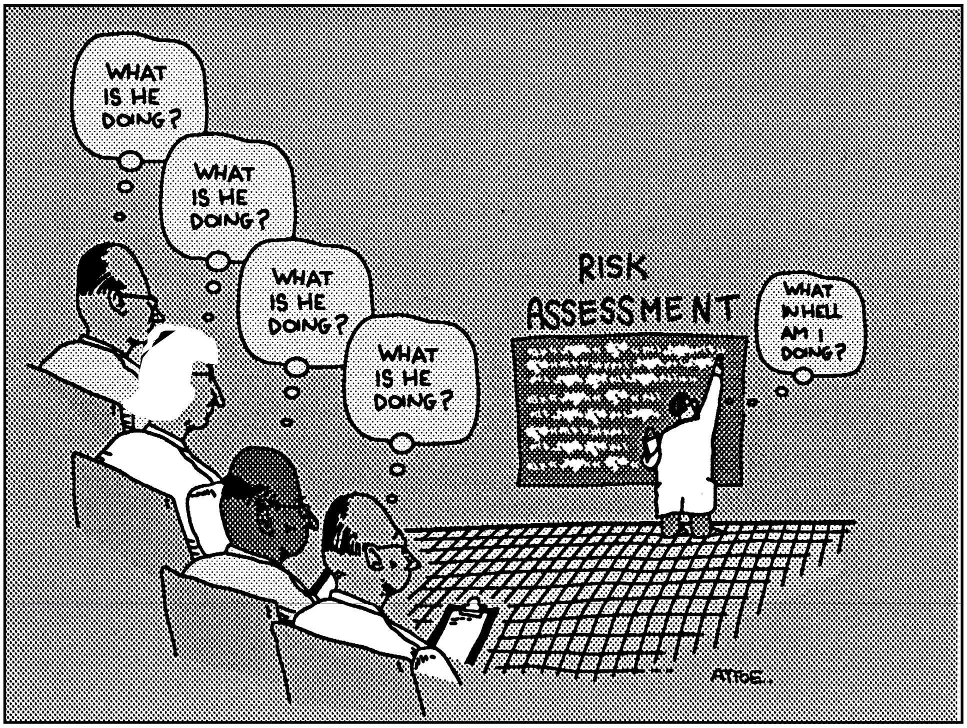
Benthic Community - Issues

- Background/Reference
- Number of replicates
- Number of Composites
- Size of Sampler
- Where to sample
  - =
- The power of the test



Simplified Foodweb





Risk Assessment

Risk assessment is a process where information is analyzed to determine if an environmental hazard might cause harm to exposed persons and ecosystems.

Paraphrased from "Risk Assessment in the Federal Government" (National Research Council, 1983)

What Is Risk?

Definition: Probability of harm or loss

Risk = Hazard x Exposure

- Part of our everyday lives
- Different for each of us
- For example, at EPA, risk is the likelihood or probability of:
  - A case of cancer
  - Some adverse effect such as a birth defect or asthma
  - Adverse effect on wildlife

A risk does not exist unless:

- the stressor has the ability to cause one or more adverse effects, and
- it co-occurs with or contacts an ecological component long enough and at a sufficient intensity to elicit the identified adverse effect.

Uses of Eco Risk Assessment

- Inform agencies & public of baseline risk
- Determine need for remedy
- Identify threshold concentrations for effects and cleanup goals
- Evaluate risk of remedy
- Recommend remedial monitoring endpoints

QUESTIONS