Pennsylvania Mercury Rule Workshop Meeting

"Sorbent Technology for Mercury Control"

Sorbent Technologies Corporation

Sid Nelson Jr.

November 18, 2005

First, Comments on a Previous Presentation

The Impacts of Mercury Emissions from Coal Fired Power Plants on Local Deposition and Human Health Risk

Terry Sullivan
Brookhaven National Laboratory

Presented at the Pennsylvania Mercury Rule Workgroup Meeting

October 28, 2005

Brookhaven Science Associates
U.S. Department of Energy

BROOKHAVEN NATIONAL LABORATORY

Do Coal Fired Power Plants Produce Mercury Hot Spots?

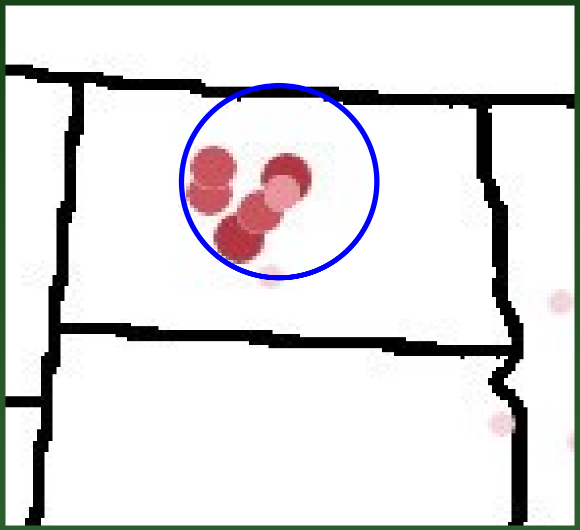
Conclusions on Risk

1. Inappropriate Plants for Pennsylvania

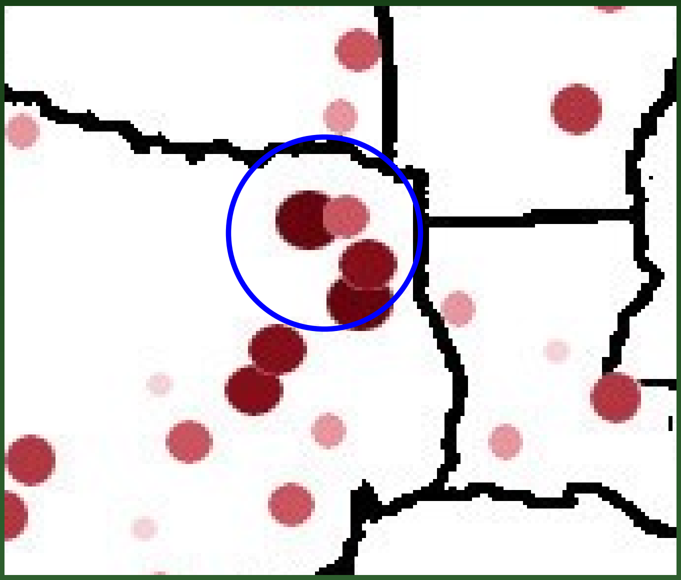
Plant	Coal	Hg Emitted	Ecology
1. “Plant A” Coal Creek	N.Dakota Lignite	83% elemental	Treeless plain
2. Monticello	Texas Lignite	40% elemental	Treeless plain
3. Kincaid	Wyo.Subbituminous	80% elemental	Treeless plain
Pennsylvania	Bituminous	~15% elemental	Forested

2. Inappropriate Plants for Hot-Spot Analysis

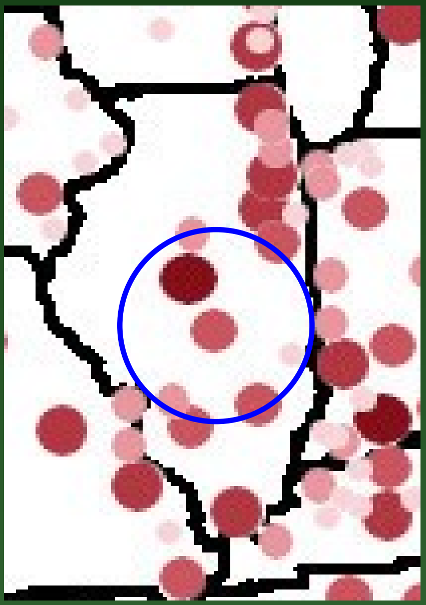
With allowance Trading, will the benefits of large Hg reductions be equally shared?



Coal Creek Plant
North Dakota



Monticello Plant
Texas



Kincaid Plant
Illinois

Each chosen plant is surrounded by many other plants, creating a “fog” of Hg & an inability to isolate any hot-spots

Circles are power plants with size & darkness proportional to Hg emissions

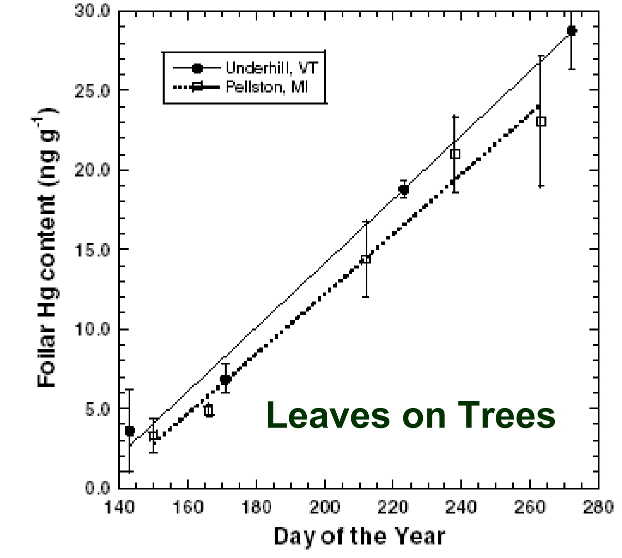
3. Measured the Wrong Thing!

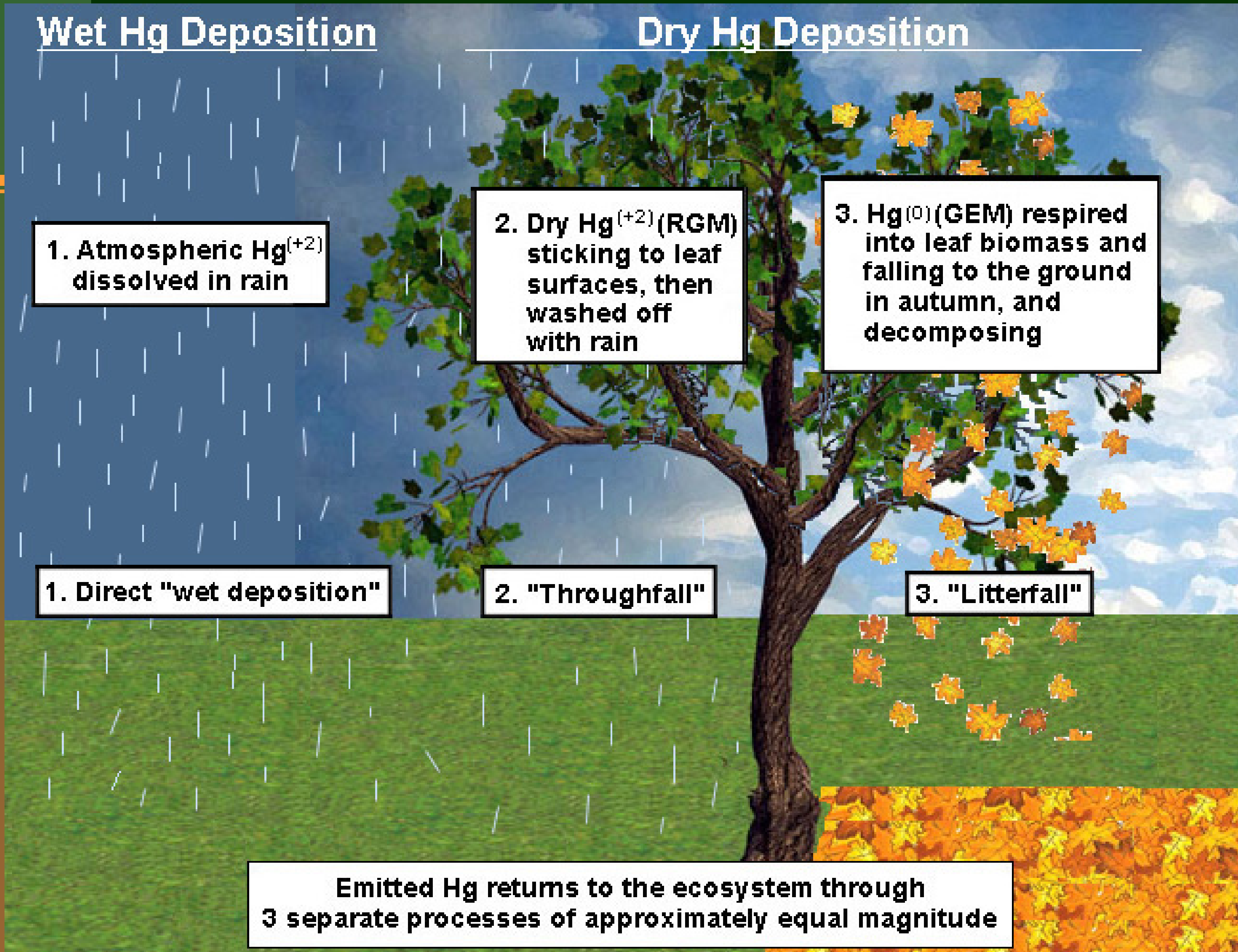
Proper: Hg in fish of one variety & one age/size

For soils: 2/3 of Hg is deposited through trees; yet no soil sampling under trees

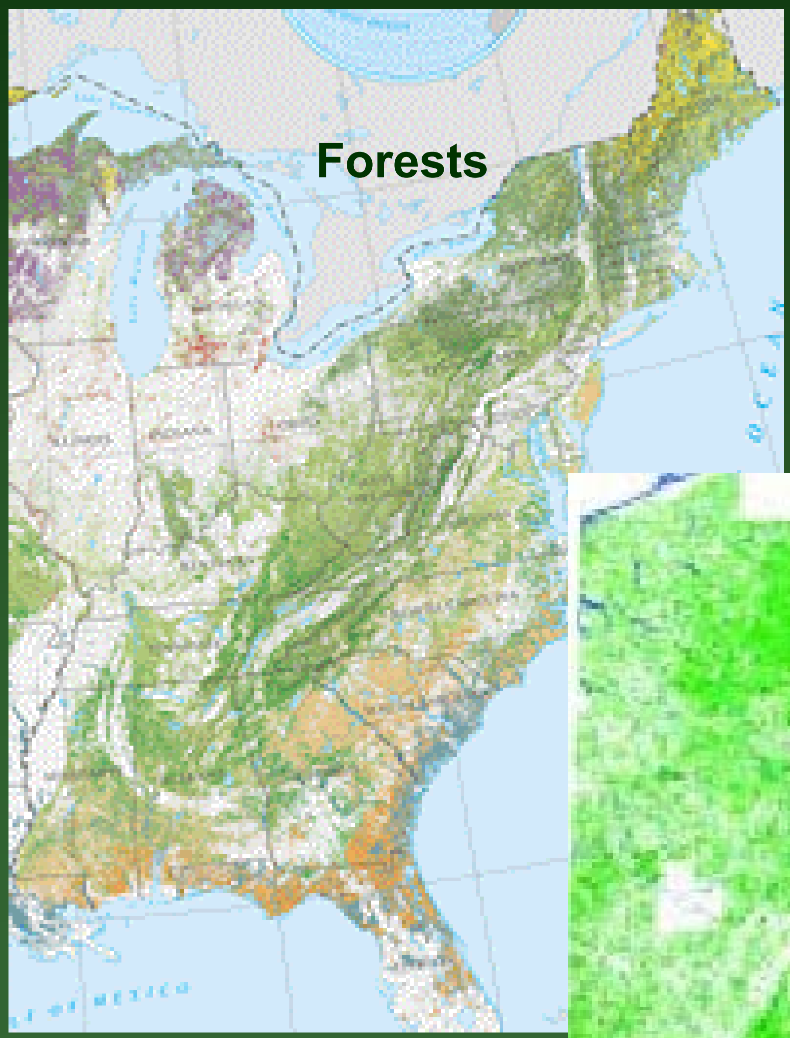
Vegetation: need multiple samples of same variety near the end of a growing season

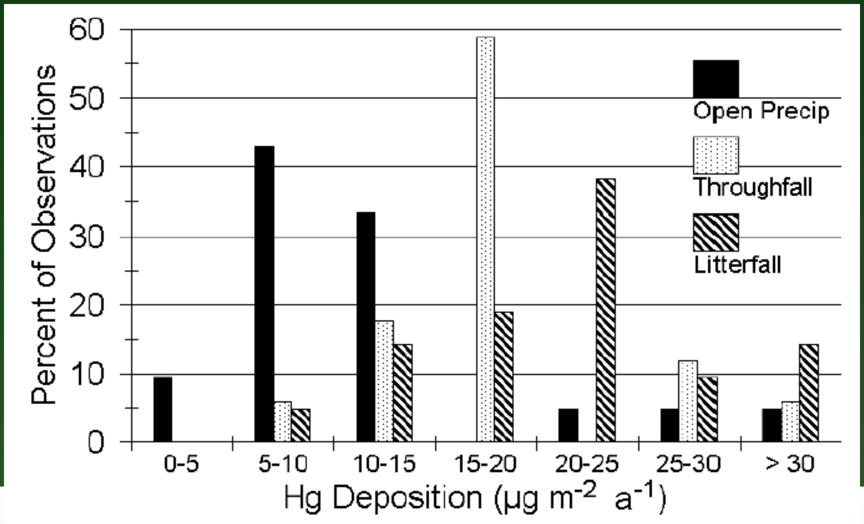
(Photographs from Sullivan presentations.
Graphs: Grigal, D., "Inputs and outputs of mercury from terrestrial watersheds: a review," Environ. Rev. 10:1 (2002).)

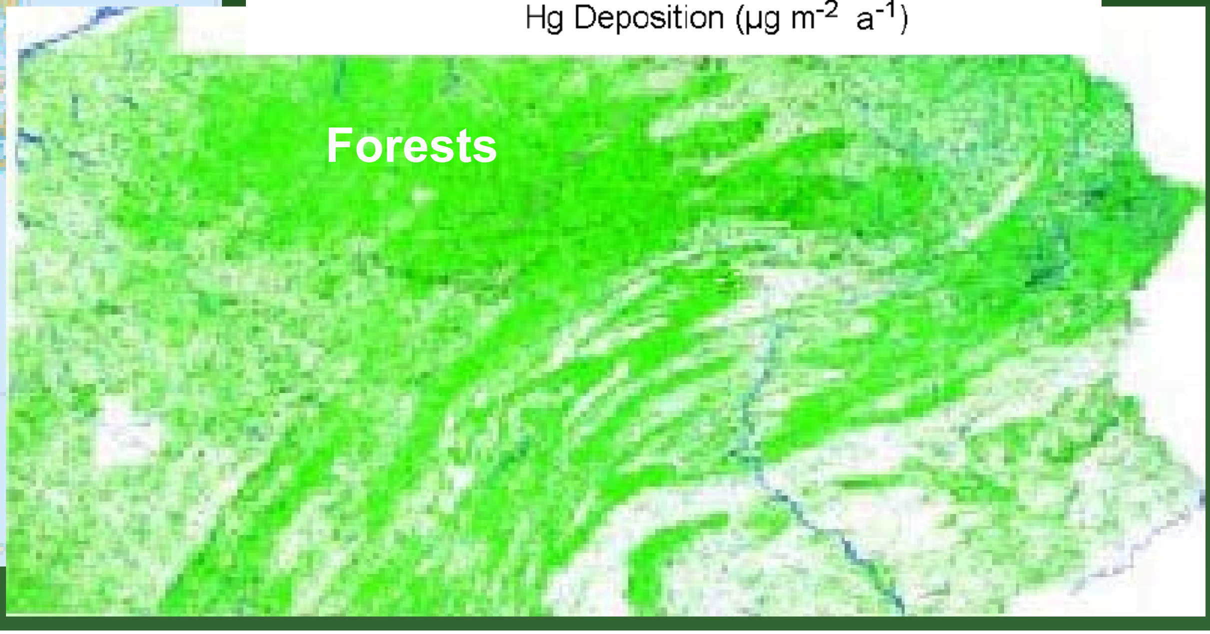



Wet Hg Deposition
Dry Hg Deposition
1. Atmospheric Hg(+2) dissolved in rain
2. Dry Hg(+2)(RGM) sticking to leaf surfaces, then washed off with rain
3. Hg(0)(GEM) respired into leaf biomass and falling to the ground in autumn, and decomposing
1. Direct "wet deposition"
2. "Throughfall"
3. "Litterfall"
Emitted Hg returns to the ecosystem through 3 separate processes of approximately equal magnitude

So Most PA Hg Not Measured by Sullivan



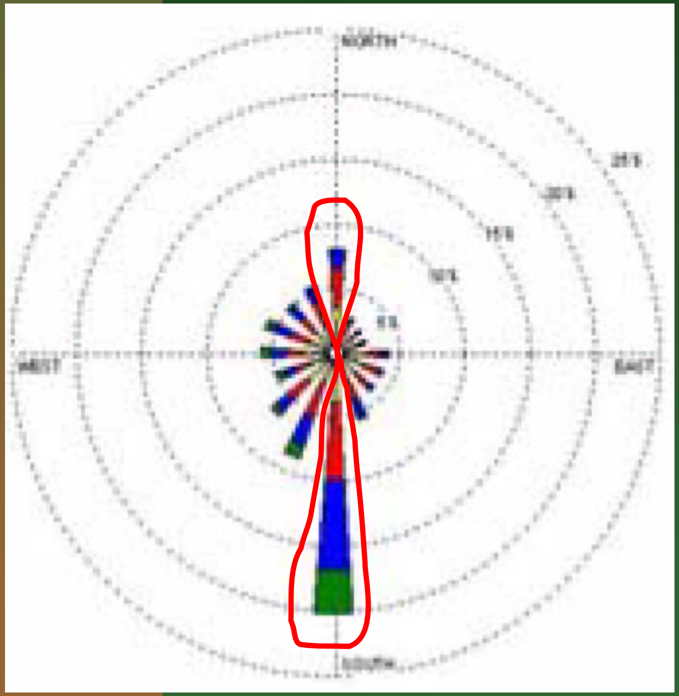


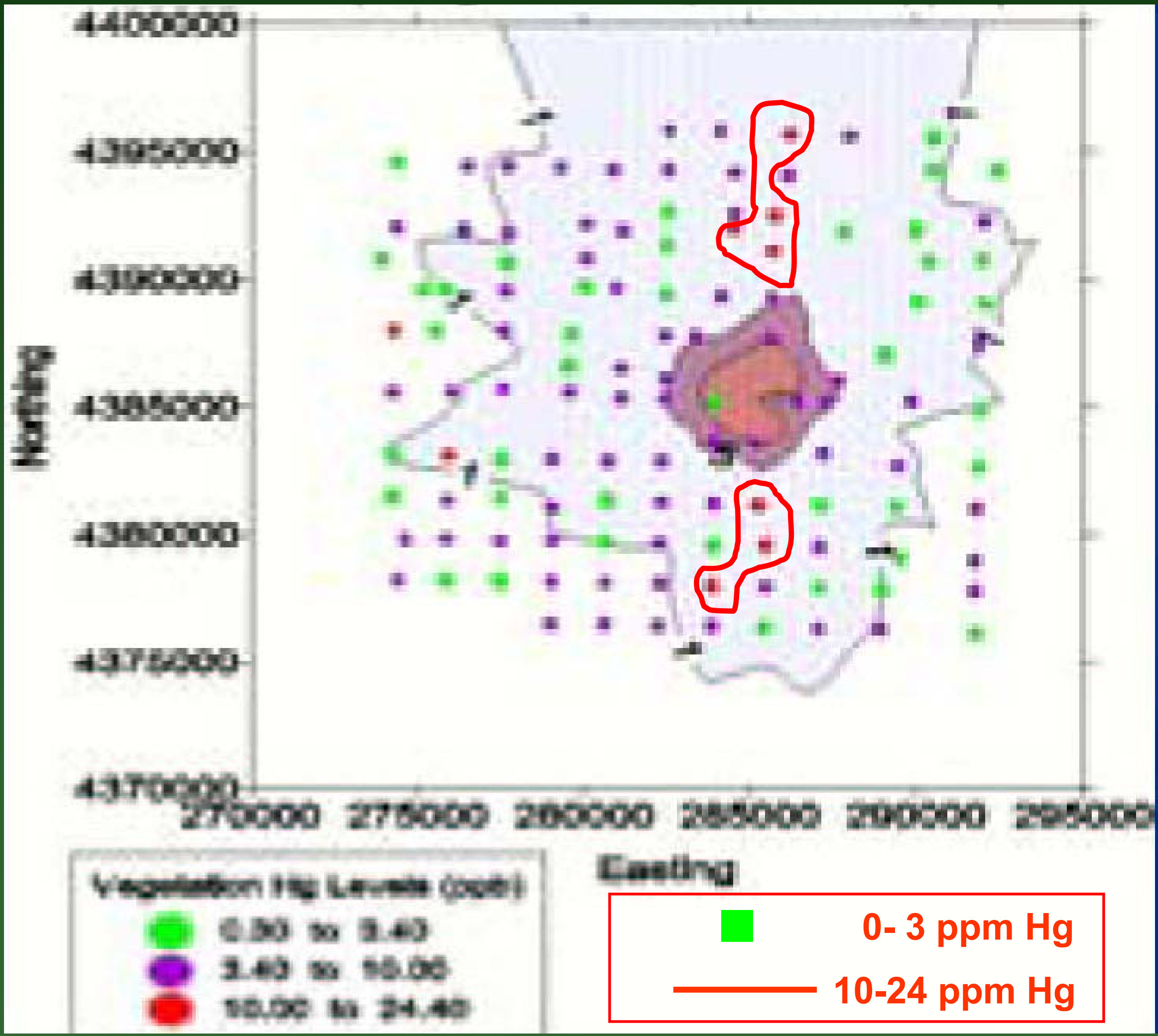


4. Even So, Sullivan Still Found Hot Spots!

Kincaid Plant

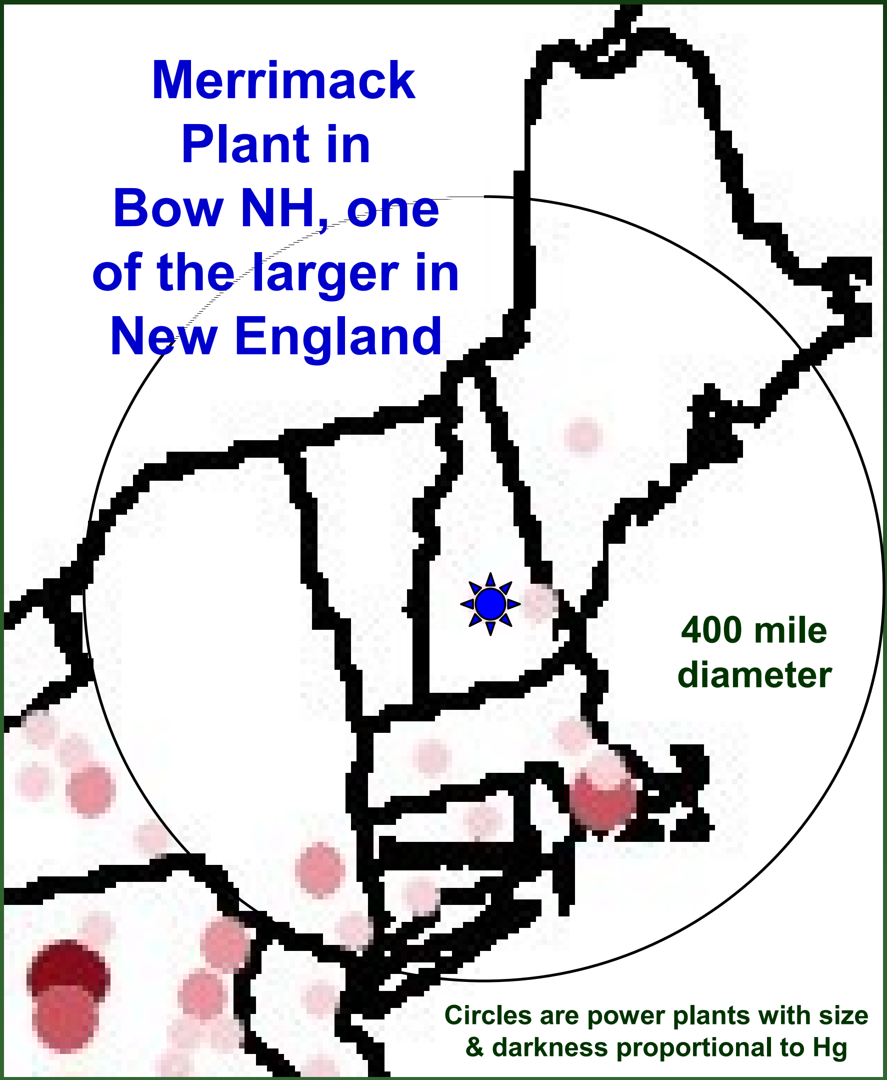
Wind "Rose" of the directional frequency the winds come from





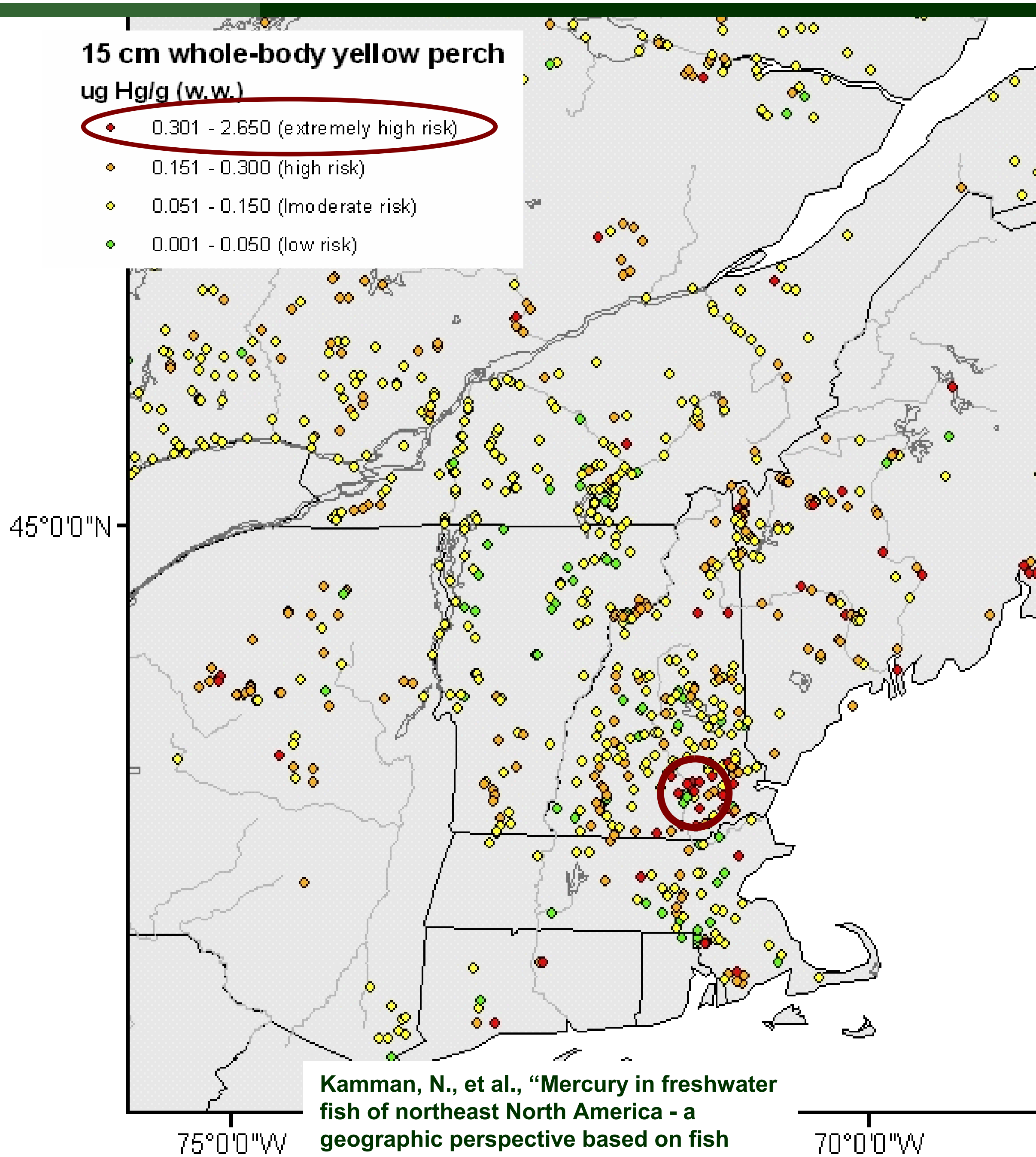
Sullivan, et al., "Assessing Local Risks from Mercury Emissions from Coal-Fired Power Plants through Soil Sampling Approach" Western Coals Symp., Billings MT 2004.

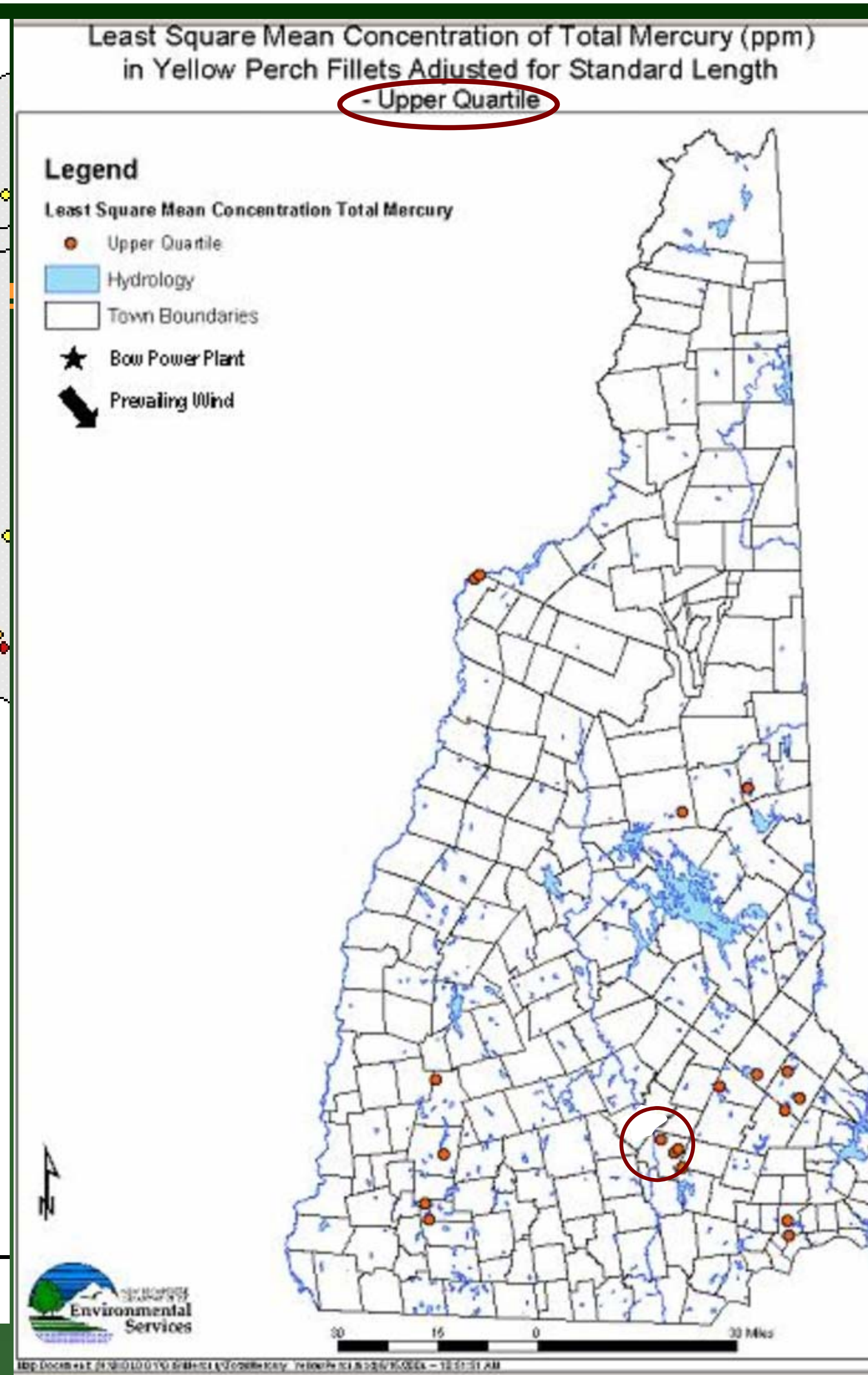
If Done Properly, You Find "Hot Spots"



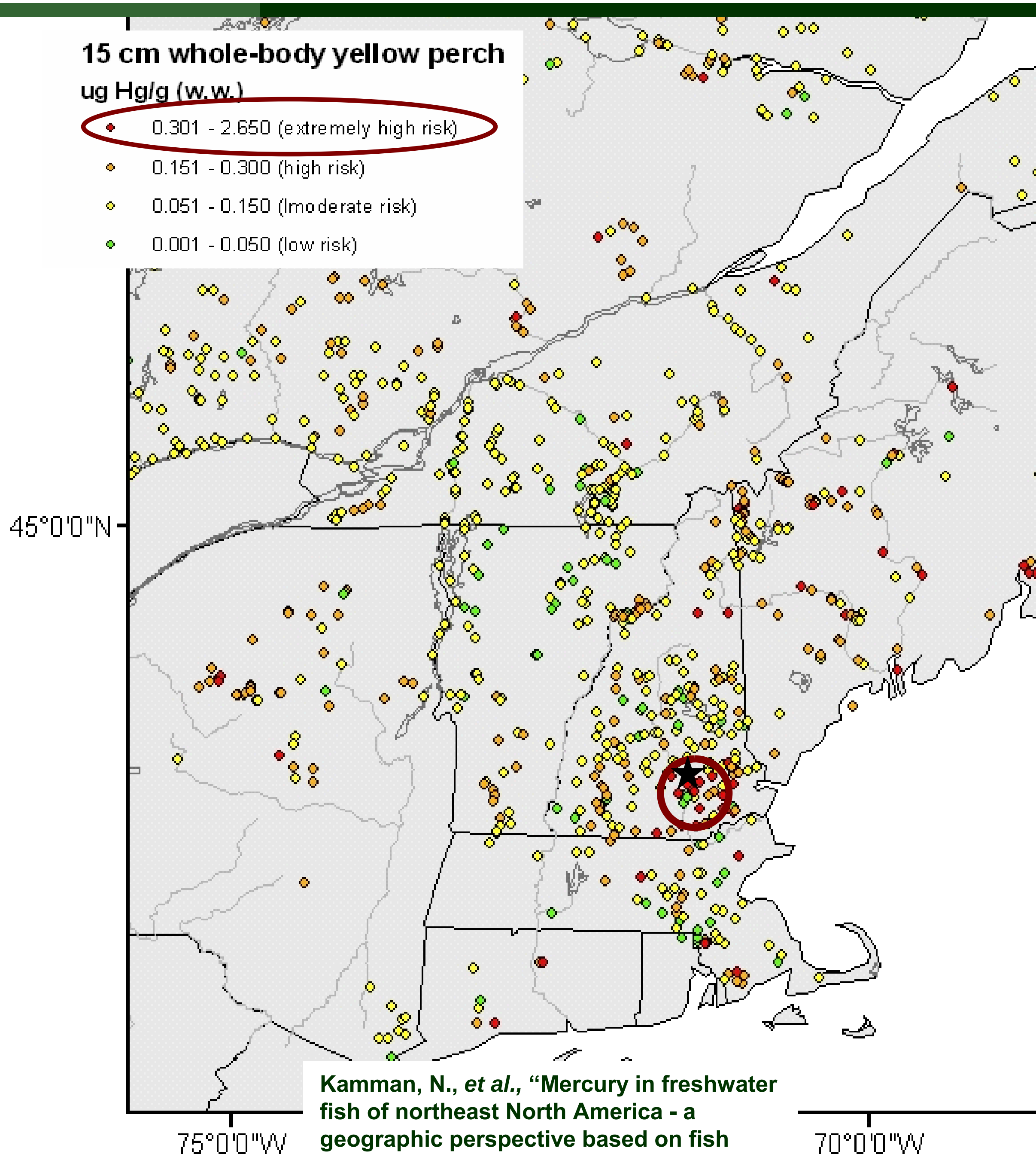
Need to examine around plants that are far from the deposition effects of other plants.

Merrimack is in a forested area and burns bituminous coal.





Kamman, N., et al., "Mercury in freshwater fish of northeast North America - a geographic perspective based on fish tissue monitoring databases," *Ecotoxicology.* Vol.14, no. 1 & 2, 2005.



Kamman, N., *et al.*, "Mercury in freshwater fish of northeast North America - a geographic perspective based on fish tissue monitoring databases," *Ecotoxicology.* Vol.14, no. 1 & 2, 2005.

Fish & Health Effects Analysis Also Fatally Flawed

Erroneous Assumptions = Erroneous Conclusions

Risk Calculation

- Population - Women 16- 49 (children of these women)
- Region -Northeast
- Dose Response Function – log, linear, reciprocal
- Reduction in Hg emissions from Coal plant (90%)
- Reduction in Hg deposition (15.5%)

Reality: U.S. ~ 50%+
PA ~ 75%+

Everglades: Lower MSW Hg = Lower Fish-Eater Hg

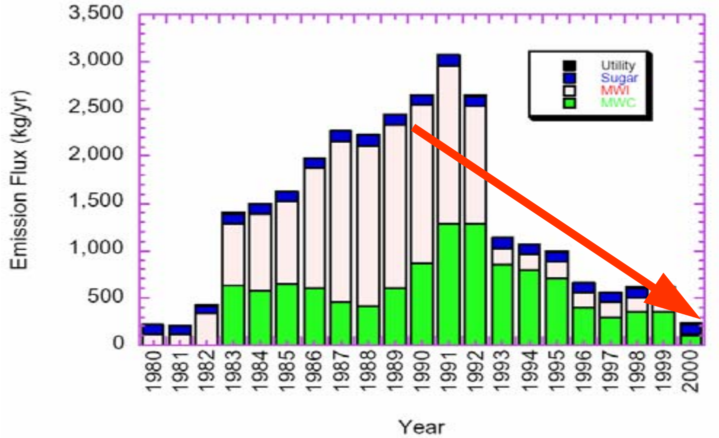


Figure 19. Annual mercury emissions in south Florida, 1980 – 2000, estimated by RMB Associates &

No coal plants in South Florida, with prevailng winds from the South but it did have MSW & MWI.

~80% Lower Hg emissions from 1990 to 2000.

From: "Integrating Atmospheric Mercury Deposition with Aquatic Cycling in South Florida," Florida Department of Environmental Protection, Oct. 2002, Revised Nov. 2003.

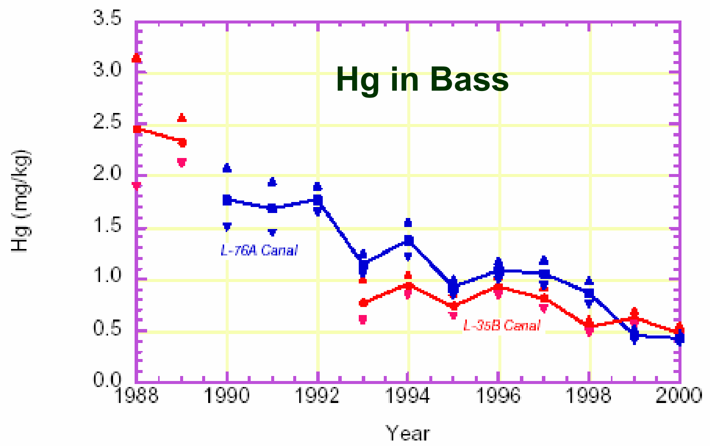


Figure 25. Tissue concentrations of mercury (wet weight) in largemouth bass in the L-67A and L-35B canals in the Florida Everglades. Filled circles show the geometric mean for each year; filled triangles show ± one standard error of the mean.

~80% Lower Hg in biota from 1988 to 2002.

> Changes appear to be quick and proportional.

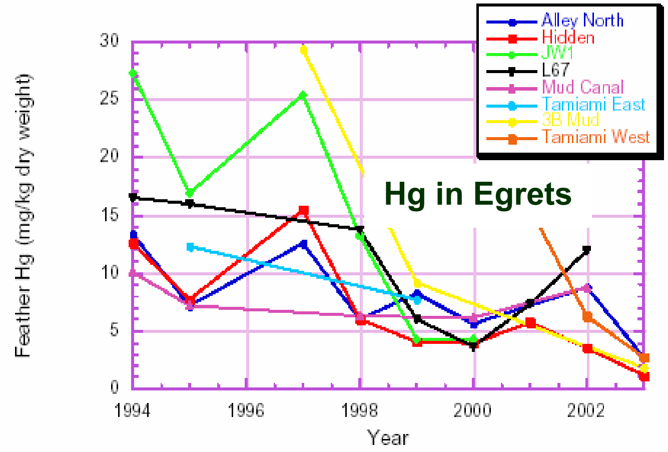
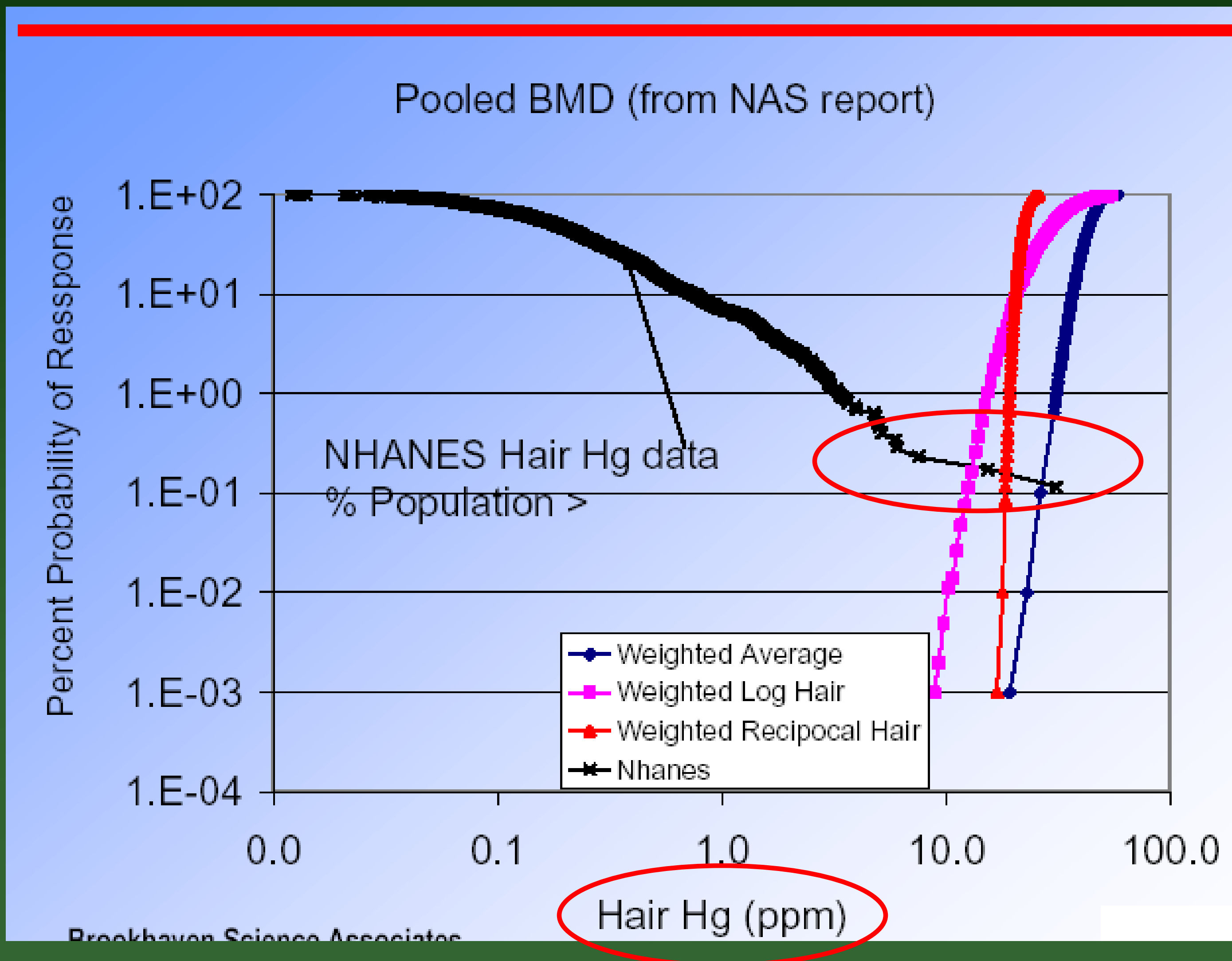


Figure 27. Mercury concentrations in great egret nestlings at various colony locations in the Florida Everglades, 1994 – 2003. Discontinuities in the period of record reflect years when a colony site was abandoned or otherwise not used. Unpublished data courtesy of P. Frederick (2003).

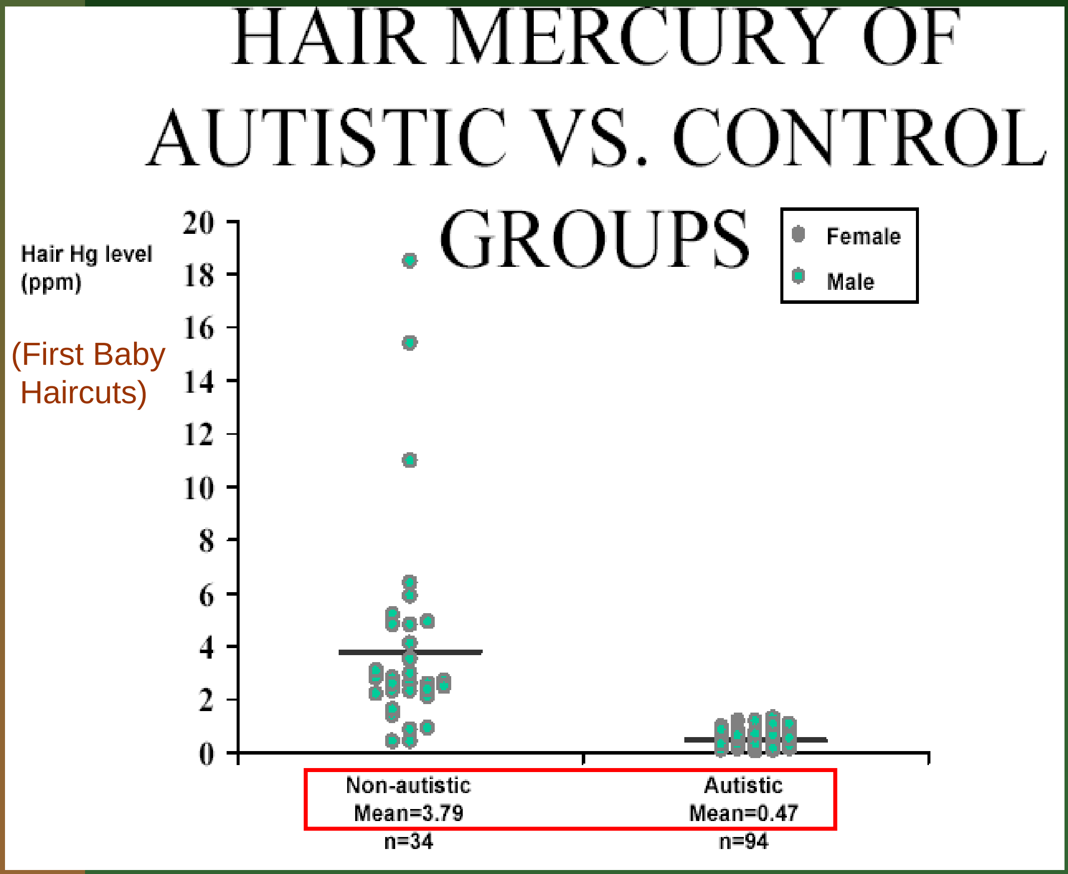
Regional Hg Emissions
+
Precipitation
=
Hg Deposition
V
Hg in Fish
V
Hg in Fish-Eaters (Women & Fetuses)

It will be the same with coal-fired power plants, especially in Pennsylvania

Concludes Low Probability of Health Effects



But Again, Sullivan is Looking in the Wrong Place



It's those people who have LOW hair & blood mercury – i.e. those who cannot properly excrete it – that are the ones most harmed by environmental Hg!

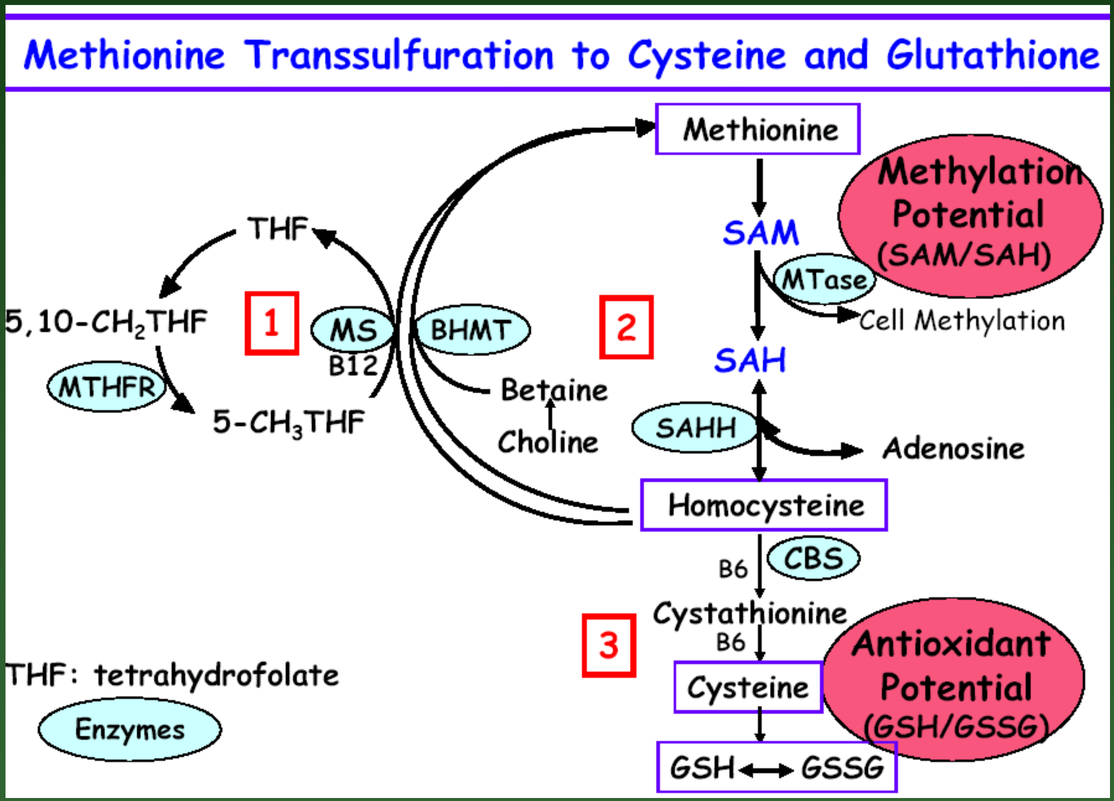
Moreover, hair Hg is a measure of recently-excreted Hg, but the damage is done in utero & in infancy

Holmes, *et al.*, "Reduced Levels of Mercury in First Baby Haircuts of Autistic Children," *Internat. Journal of Toxicology*, 22:277, 2003.

Recently substantially replicated by J. Adams, MIT, & NIEHS. Plus Adams found 3X Hg in baby teeth.

Subpopulation with Increased Sensitivity

Genetically-impaired methionine metabolism



Less active glutathione to bind with Hg to solubilize it & excrete it

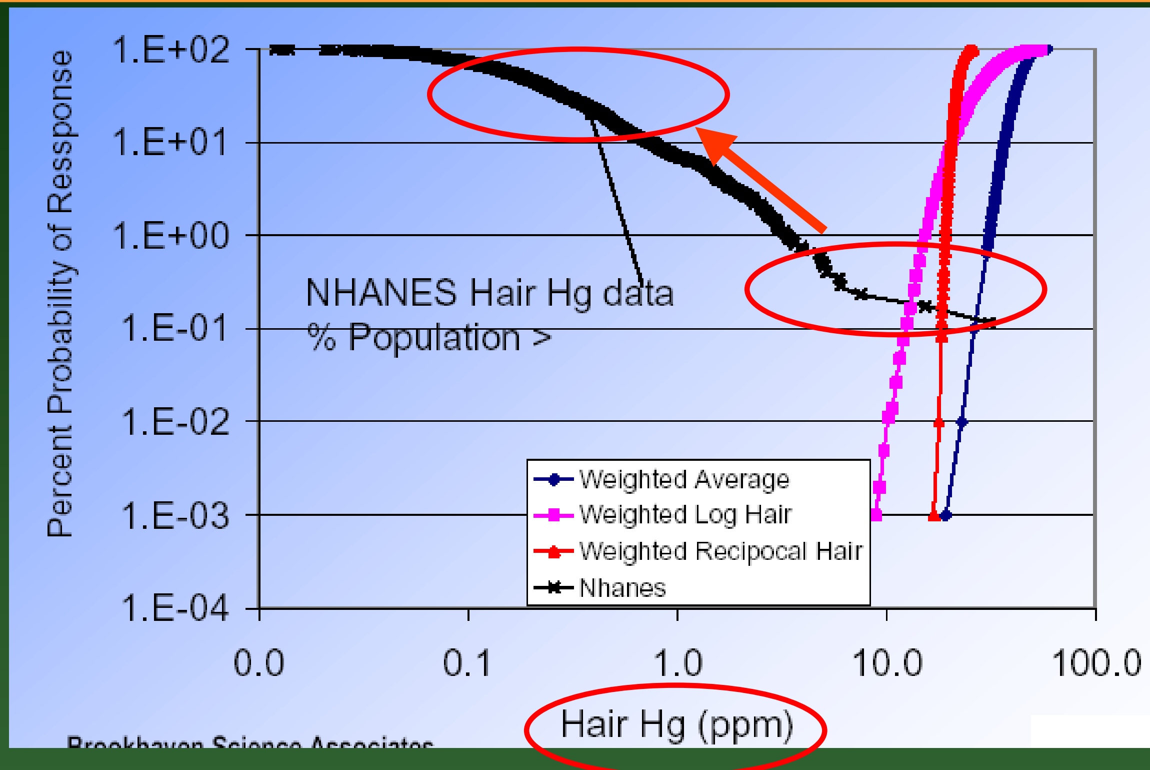
Further, this metabolism is still developing in infants, as is bile production

Antibiotics reduce Hg elimination further

The Hg builds up, crosses the blood/brain barrier, & the neurological damage is done.

S. Jill James, Ph.D., "Pathogenic Implications of Low Glutathione Levels and Oxidative Stress in Children with Autism: Metabolic Biomarkers and Genetic Predisposition," Autism One Conference, 2005.

It's Just <u>Common Sense</u> to Avoid Hg Emissions!



Moreover, its probably not only Hg exposure through fish, and not only autism.

See, e.g., : Palmer, *et al.*, **"**Environmental mercury release, special education rates, and autism disorder: an ecological study of Texas," *Health and Place,* 2005,
where every 1000 lb of Hg emissions was correlated with a 60% increase in autism in Texas, as well as significant increases in special education expenses (ADD, learning disabilities, etc).

Summary & Conclusions in Review

1. The Sullivan plants are simply inapplicable to Pennsylvania.

2. Local-deposition “hot spots” are indeed found if an examination is properly conducted.

3. Reductions in local emissions in the past have translated directly and proportionally into lower local Hg deposition, lowered Hg in fish, & lowered Hg in those who eat the fish.

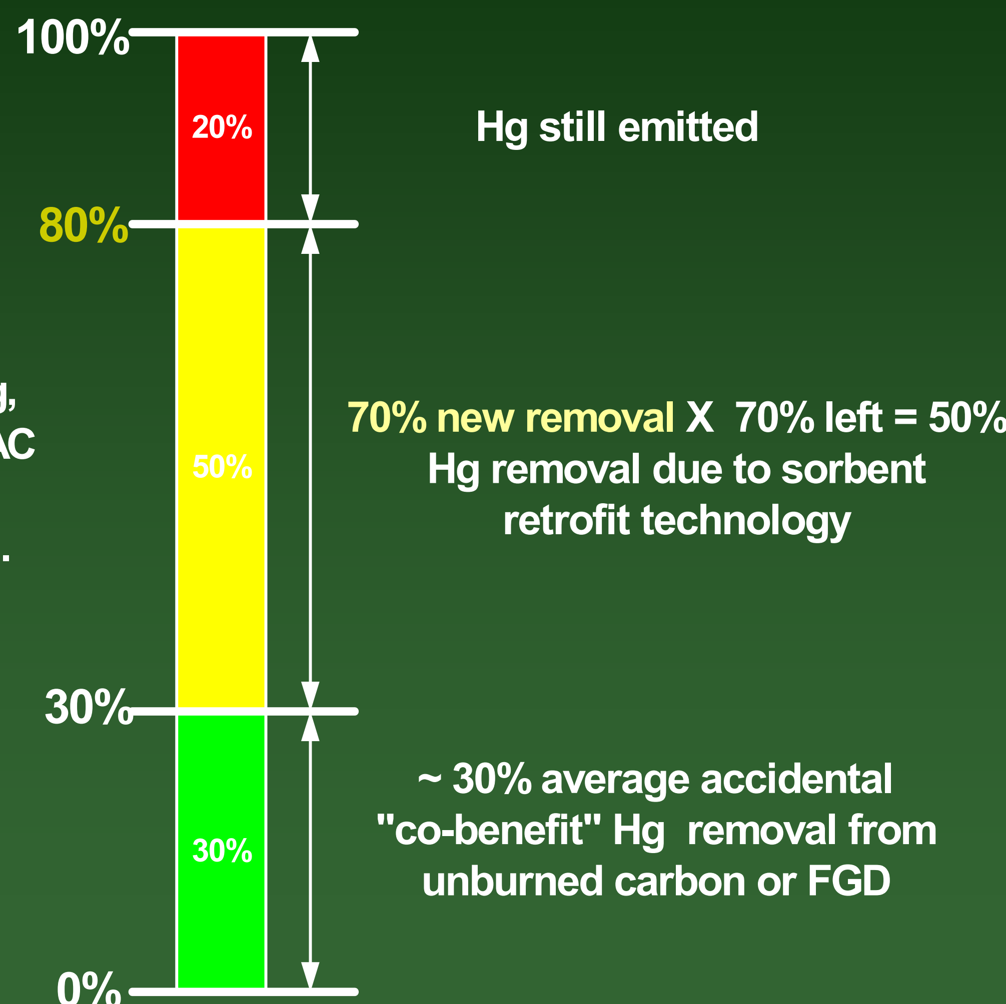
4. A plethora of recent research indicates that a subpopulation appears to exist with extreme sensitivity to low-level Hg during critical neurological development periods.

Summary & Conclusions on Hg Control

- 80% mercury reductions, coal-to-stack (or its lb/GWh equivalent) are technologically & commercially possible for Pennsylvania boilers by 2008
- Such reductions will be relatively inexpensive, painless, & involve no coal rank switches
- 90% mercury reductions, coal-to-stack, are very likely to be similarly inexpensively possible by 2012
- Pennsylvania loses little by building flexibility into its state mercury emission reduction program by, e.g. allowing utility bubbling, annual averaging, etc.

Clarification on Required Hg Removal Rates

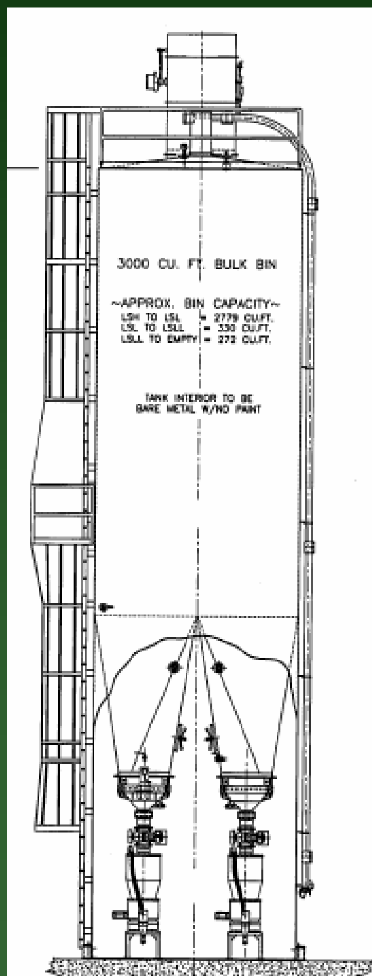
For example, if unburned carbon or an FGD scrubber without SCR already removed 30% co-benefit Hg, only ~70% Hg removal due to the PAC would be required for 80% coal-to-stack total Hg removal.



Similar Misinformation on Controls:

- Not Commercially Available
- No Guarantees
- Not Enough Time or Specialized Labor Available
- Too Expensive
- Not Enough Performance or Experience

1. My Company Can Install the Systems



Our sorbent silo subcontractor has supplied 40 PAC feeding systems for waste incinerators;

We have installed simple injection lance systems at 7 plants; and

We or our Hg measurement subcontractor have temporarily installed and operated Hg S-CEMs at over 20 different power plants.

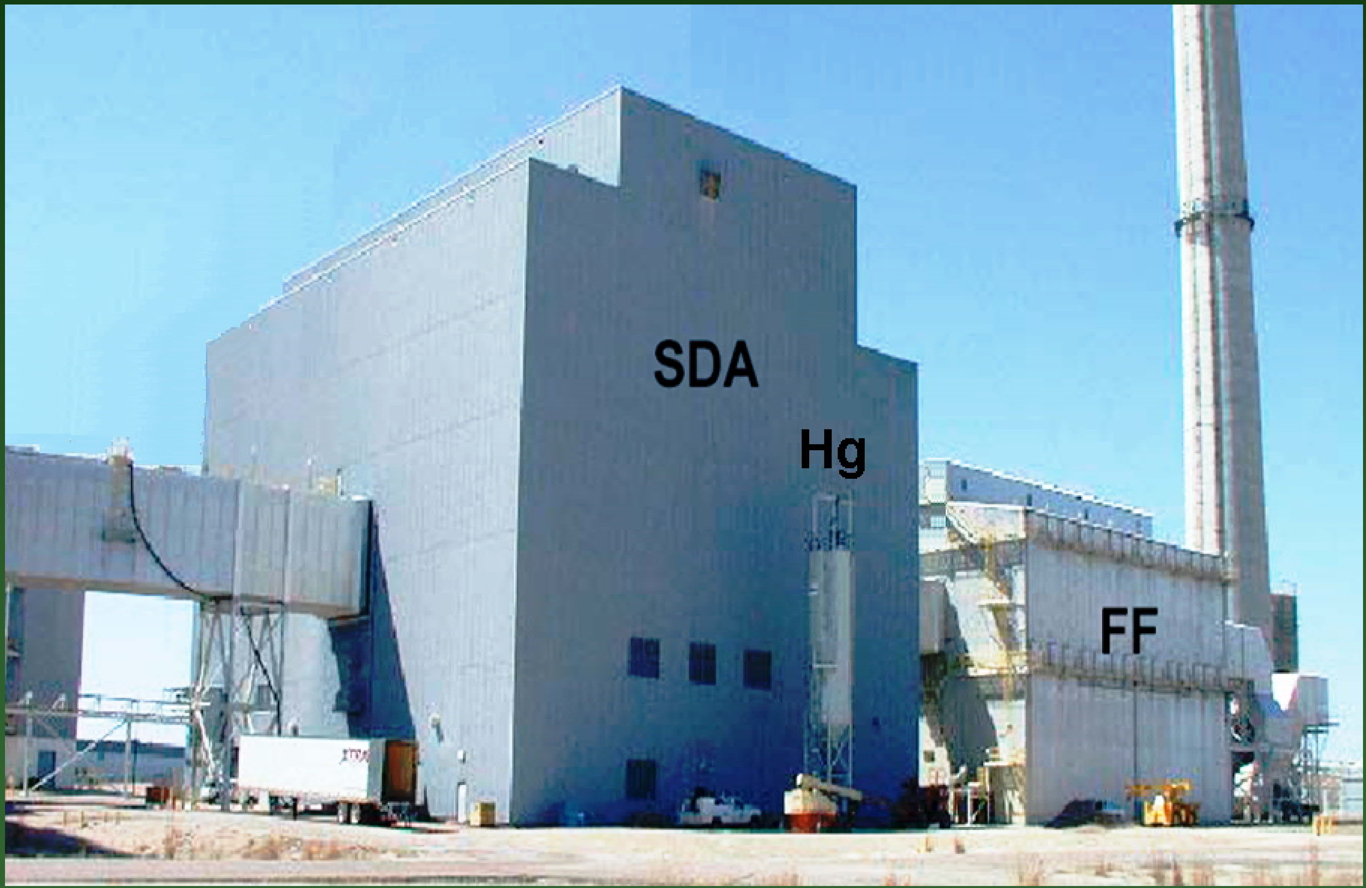
Extremely Low Capital Costs

	$/kW
SO_2 Scrubbers	$200
NOx SCR	$120
Toxecon™ Baghouse	$60+
PAC Injection alone	~$2

With PAC Injection alone:

- Almost no installation time needed
- Little trade labor needed
- No losses if scrubbers installed later
- Take advantage of future sorbents
- Costs are incurred only when operating

ACI versus a Dry Scrubber or Fabric Filter

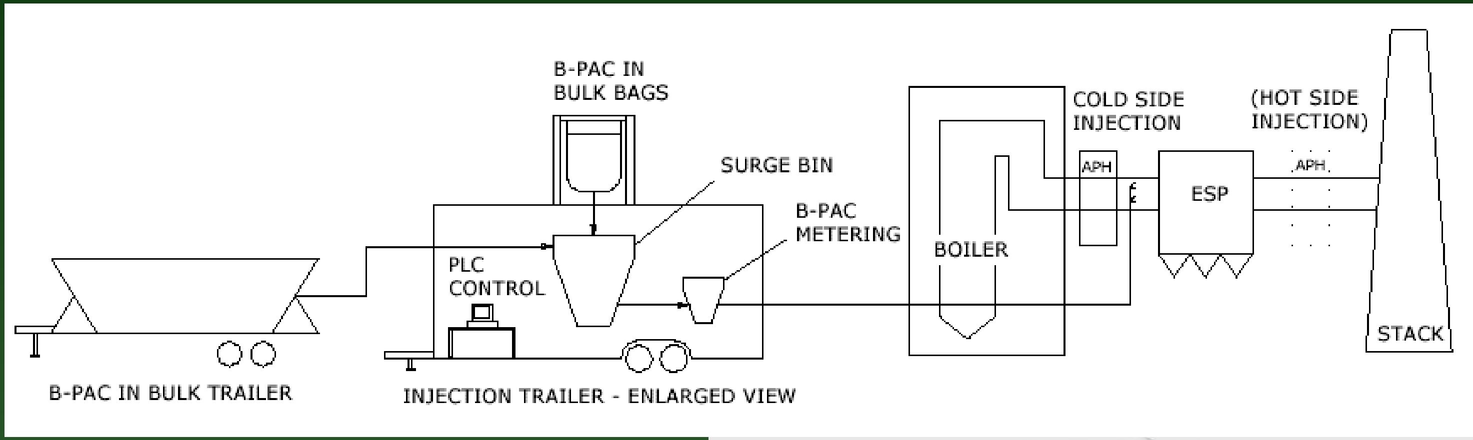


From: Sjostrom, S., "Carbon Injection at Four Facilities," DOE/NETL Mercury Control Program Review, July 14, 2004.

2. We Can Supply B-PAC Hg Sorbent Day-to-Day

- First B-PAC™ plant can serve numerous power plants now and we plan to increase capacity x10 next year

3. We Do Full-Scale Trials at the Actual Plant



Our mobile injection trailer can easily moved from site to site and hooked up for inexpensive <u>full-scale</u> B-PAC injection trials.

Can be used on CS-ESP gas streams of up to about 400 MW.

From an Actual Sorbent Technologies SD/FF Bid:

PERFORMANCE GUARANTEES

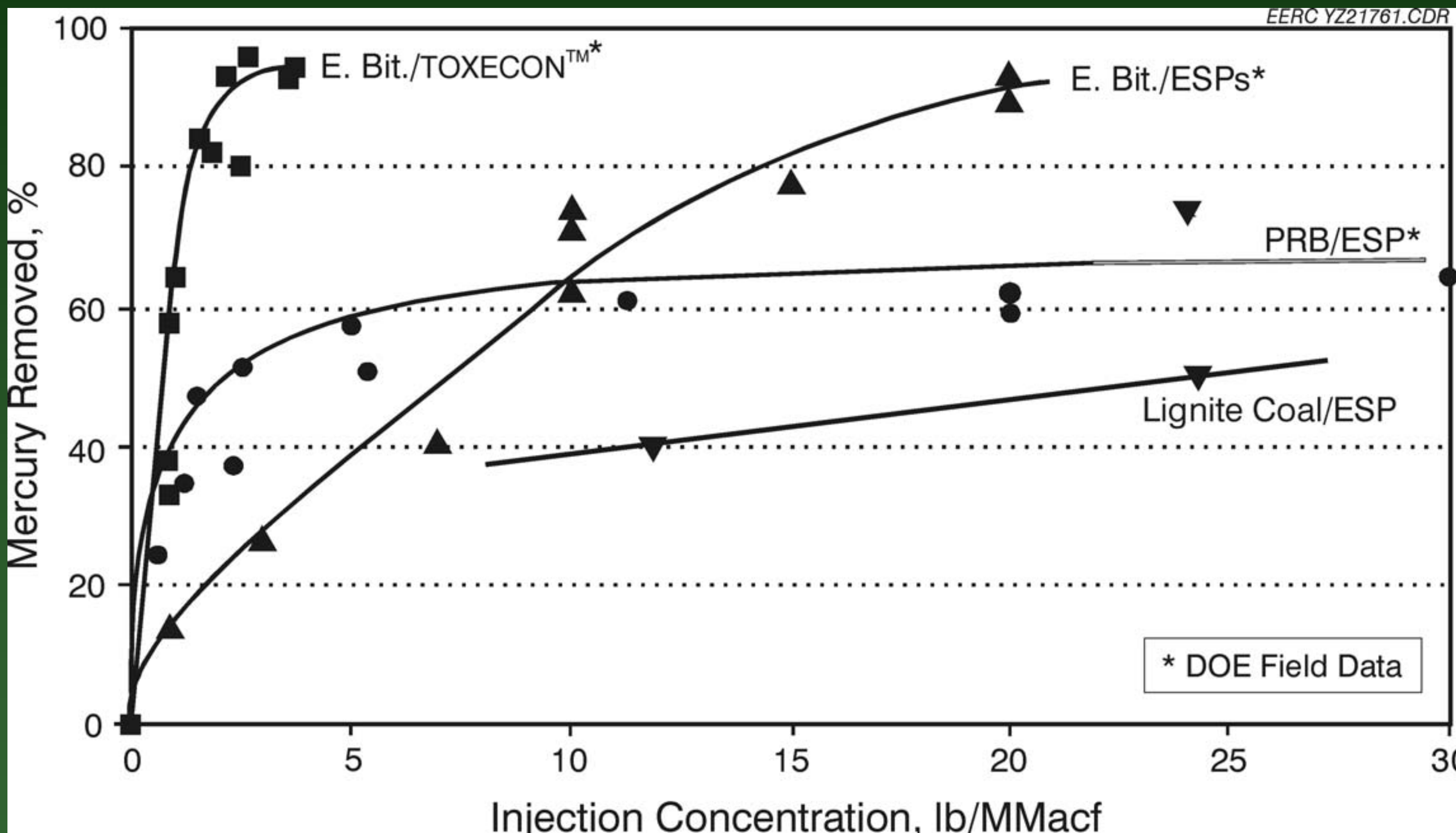
Sorbent Technologies will guarantee the more restrictive of ninety (90) percent removal or to a level of 20×10^{-6} lb of Hg/MWH of total mercury in the flue gas using brominated B-PAC™ powdered activated carbon at a rate not to exceed 230 lbs/hr based on the design flow rate of about 1,535,000 ACFM for each boiler. The removal rate is from the air preheater outlet to the stack. The mercury removal guarantee is valid only when the units are firing the coals described in the Customer Specification, when the air heater outlet flue gas temperatures are maintained at below 370°F, when the fabric filters are operating properly, and when the relative SO3 mass flow rates at the air preheater are no greater than that specified. If no certified continuous mercury emissions analyzers are available, compliance shall be determined by others using certified CEMs or another method as determined by the March 15 utility mercury regulation. This guarantee shall be met according to page D-4 of Schedule D.

Quote from a recent new-installation bid. Note that guarantees are very site specific.

Sorbent Technologies Progress

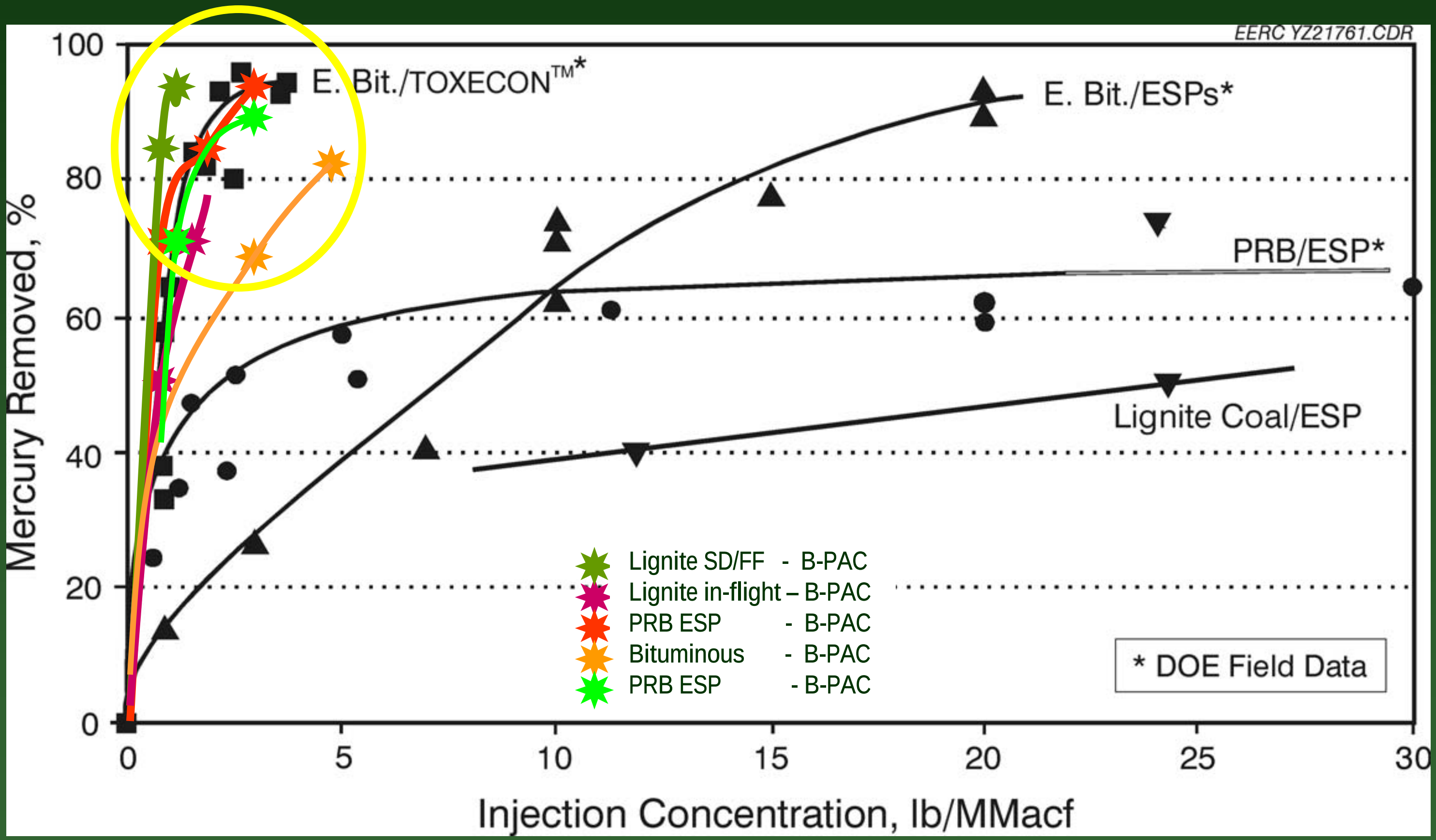
- ~~Not Commercially Available~~
- ~~Not Enough Time~~
- ~~Not Guarantees~~
- Too Expensive
- Not Enough Performance or Experience

2003: Poor & Costly Hg Removal with Plain PAC



Testimony of Dr. Steven A. Benson, Univ. of North Dakota Energy & Environment Research Center, to the U.S. Senate, Committee on Environment and Public Works, Subcommittee on Clean Air, Climate Change, and Nuclear Safety, June 5, 2003.

2004-5: Brominated PAC (B-PAC) Results



Full-Scale Brominated PAC in Injection Demos
- PRB & Lignite: Great River Energy Stanton 1 & 10 (EERC/URS)
- PRB ESP: Detroit Ed. St. Clair (Sorbent Technologies)
- Bituminous: Duke's Allen Plant (Apogee)

Sorbent Technologies' B-PAC™ Family

- B-PAC™ for standard use
- H-PAC™ for hot-side ESPs
- C-PAC™ for concrete sales

- **All are plain PACs treated with a small amount of Bromine.**

Plain carbon ~ $0.50/lb
B-PAC ~ $0.75/lb

(Unlike Chlorine, HCl, & HF, Br_2 & HBr are not considered by the EPA to be air toxics. HBr is not even included in Toxic Release Inventory reporting.)

Bromine is the 3rd-most-common anion in the ocean.

Seawater contains ~80 ppm dissolved bromine.

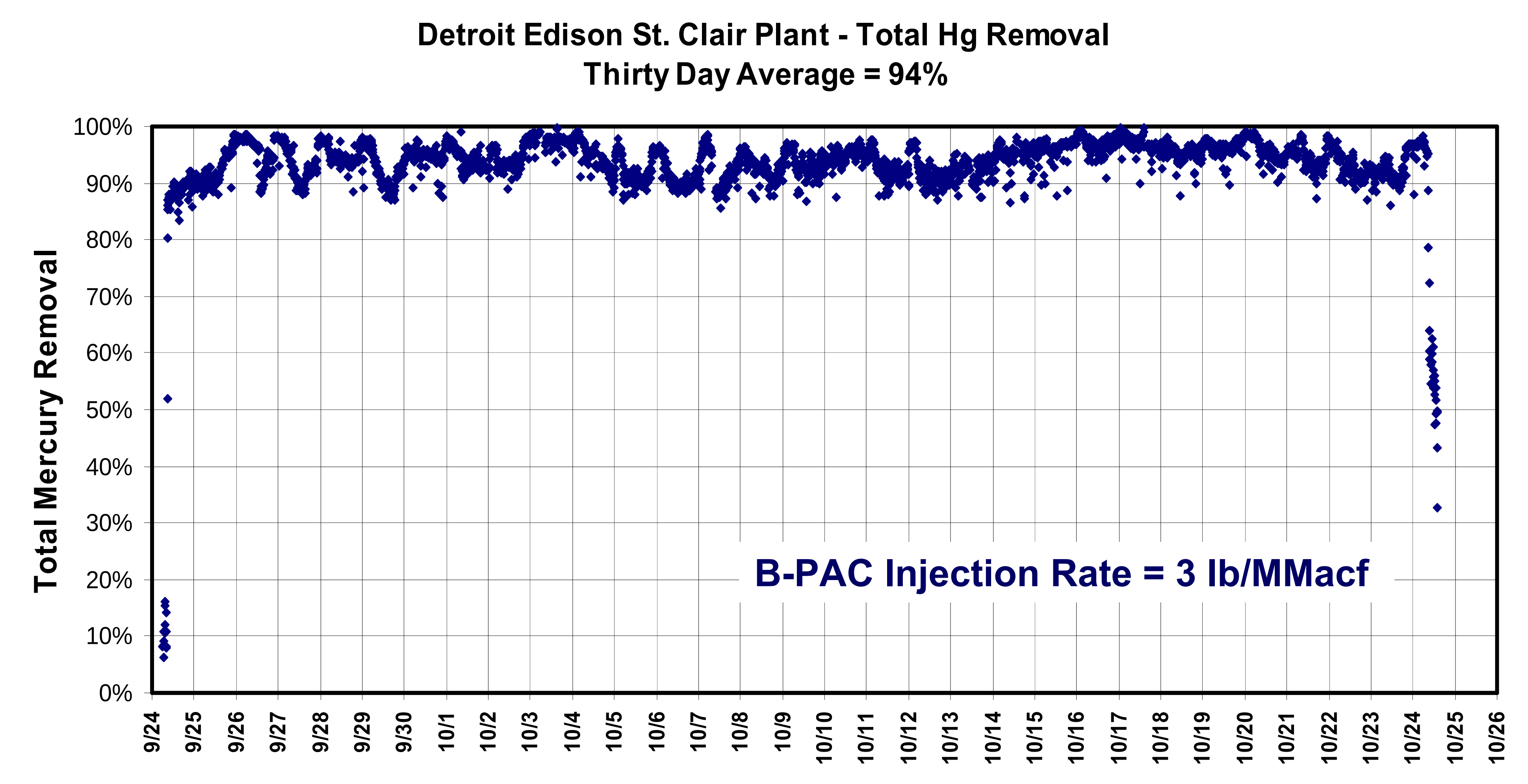
Detroit Ed.'s St. Clair Plant: Subbit. Blend

U.S. DOE NETL co-sponsored project DE-FC26-03NT41990
"Advanced Utility Mercury-Sorbent Field-Testing Program"

Southeast Michigan
Cold-Side ESP
330^{o}F inlet
85 Sub/15 Bitum. Blend
80 MW ESP split
700 (470) ft^2/K acfm
0.06 ppm
Mostly $Hg^{(0)}$

Long-Term Continuous B-PAC Run at St. Clair

30-Day Average Mercury Removal = 90+% from Sorbent

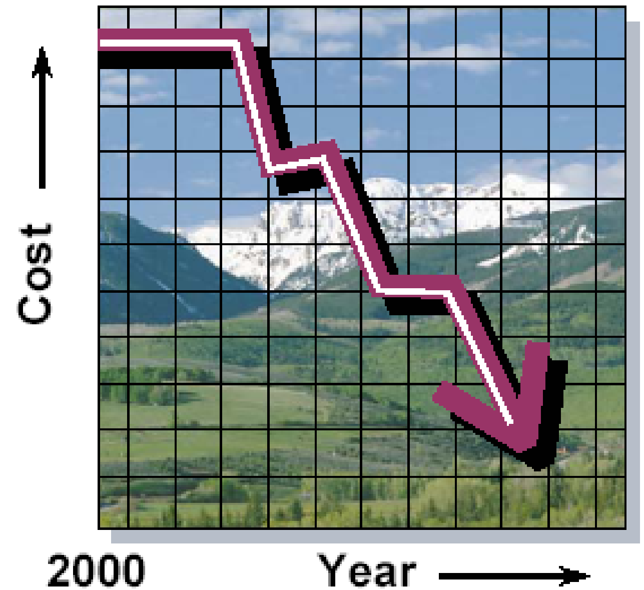


DOE Estimates of ~$60,000/lb Hg Removed

DOE Mercury Control Program Goals

Have technologies ready for commercial demonstration:

- By 2005, reduce emissions 50-70%
- By 2010, reduce emissions by 90%
- Cost 25-50% less than current estimates



Baseline Costs: $50,000 – $70,000 / lb Hg Removed

NETL

Bajura, R., "New Horizons in Coal RD&D," Low-Rank Fuels Symposium, Billings, Mont., June 2003.

Cost Effectiveness with PRB at St. Clair

If 1 lb/MMacf of \$0.75/lb B-PAC is injected into a CS-ESP with 7 µg Hg/Nm^3 provides 70% Hg removal:

$$\left(\frac{1\,lb\ sorbent}{1{,}000{,}000\,acf}\right)\left(\frac{Nm3}{(70\%)\,7\,\mu g\ Hg}\right)\left(\frac{\$0.75}{lb\ sorbent}\right)\left(\frac{1.5\,acf\ @\ 300F}{1\,scf}\right)\left(\frac{35.3scf}{Nm^3}\right)\left(\frac{10^9\ \mu gHg}{2.2\,lb\ Hg\ removed}\right) = \$3{,}700\,/\,lbHg.$$

Cost < \$4,000 /lb Hg removed,

>90% cost reduction from the current technology baseline.

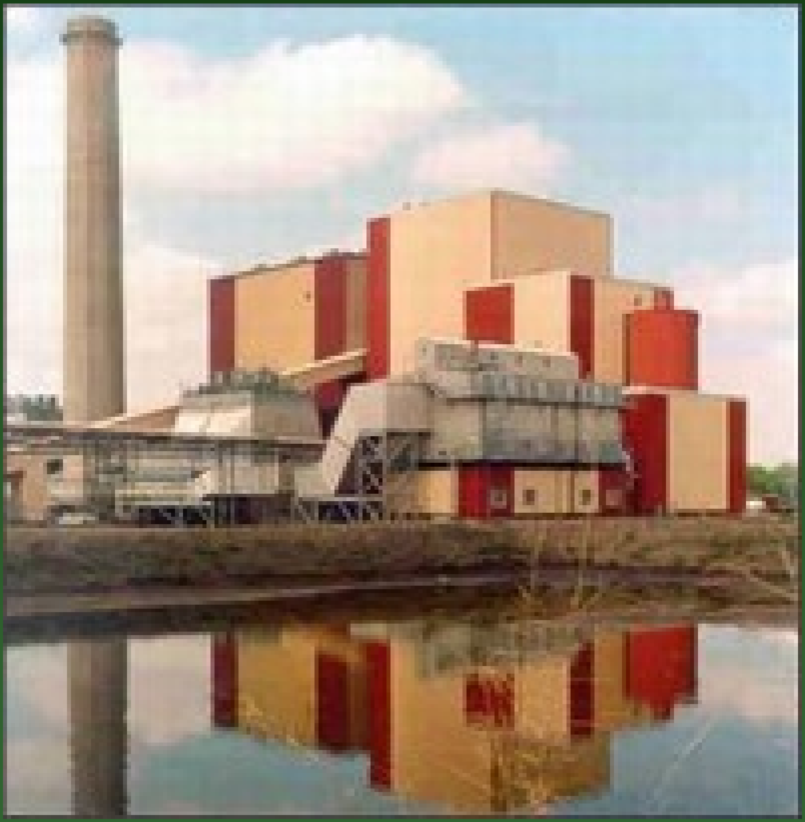
Similarly, if 3 lb/MMacf of B-PAC is injected into a cold-side ESP provides 90% Hg removal:

Cost < \$10,000 /lb Hg removed,

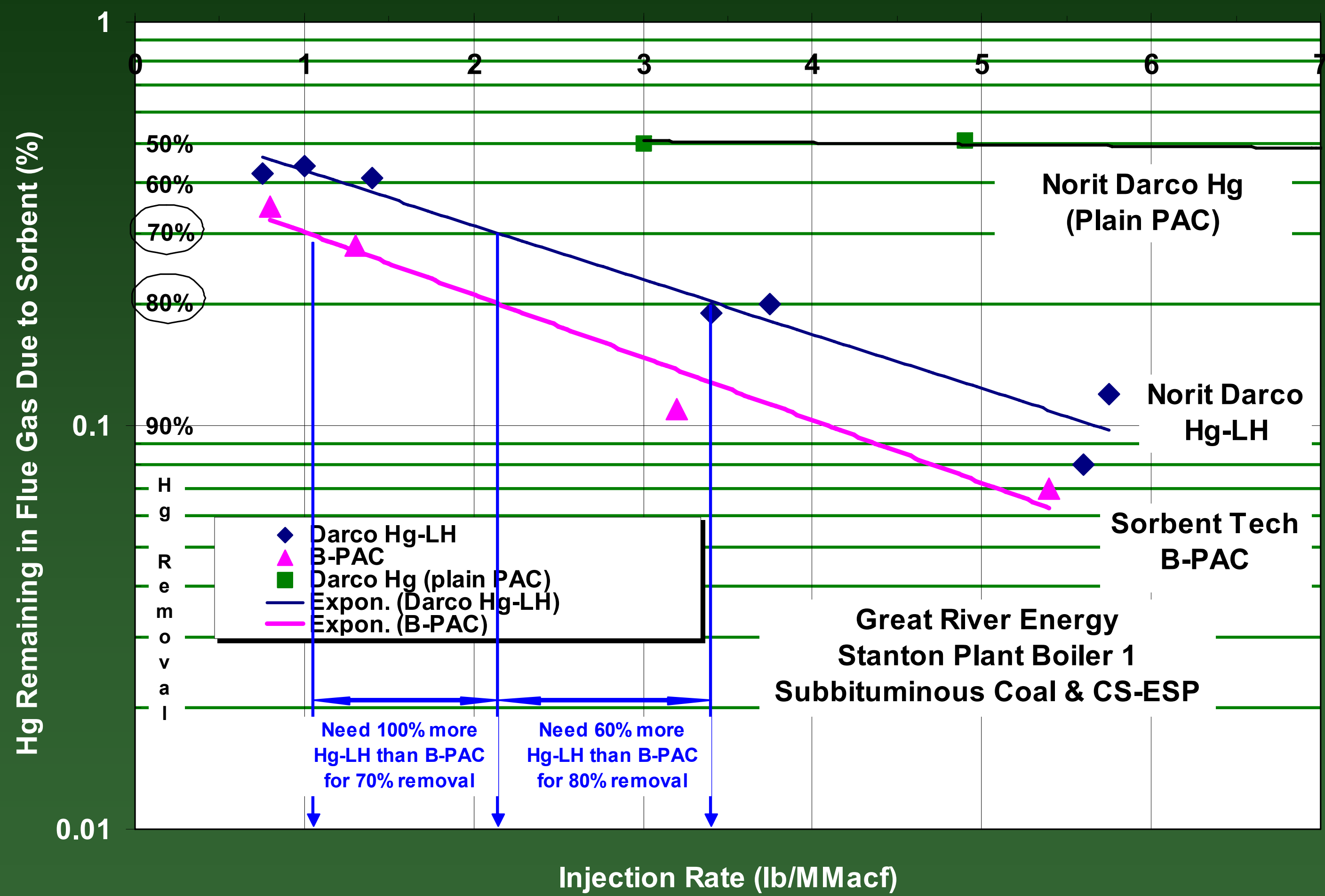
85% cost reduction from the current technology baseline.

Great River Energy's Stanton 1: 100% PRB

- URS Corp./EERC
- 100% Subbituminous coal
- Cold-Side ESP
- Sorbent Technologies, Norit, Calgon PACs in Parametric Tests
- B-PAC chosen for 30-day testing as most cost-effective



B-PAC Most Cost-Effective By Far



Data from: Dombrowski, K., et al., “Full-Scale Activated Carbon Injection for Mercury Control in Flue Gases Derived from North Dakota Lignite and PRB Coal,” Air Quality V, Arlington VA, Sept. 2005.

High-S Bituminous at the Lausche Plant

Mercury (in µg/Nm³)

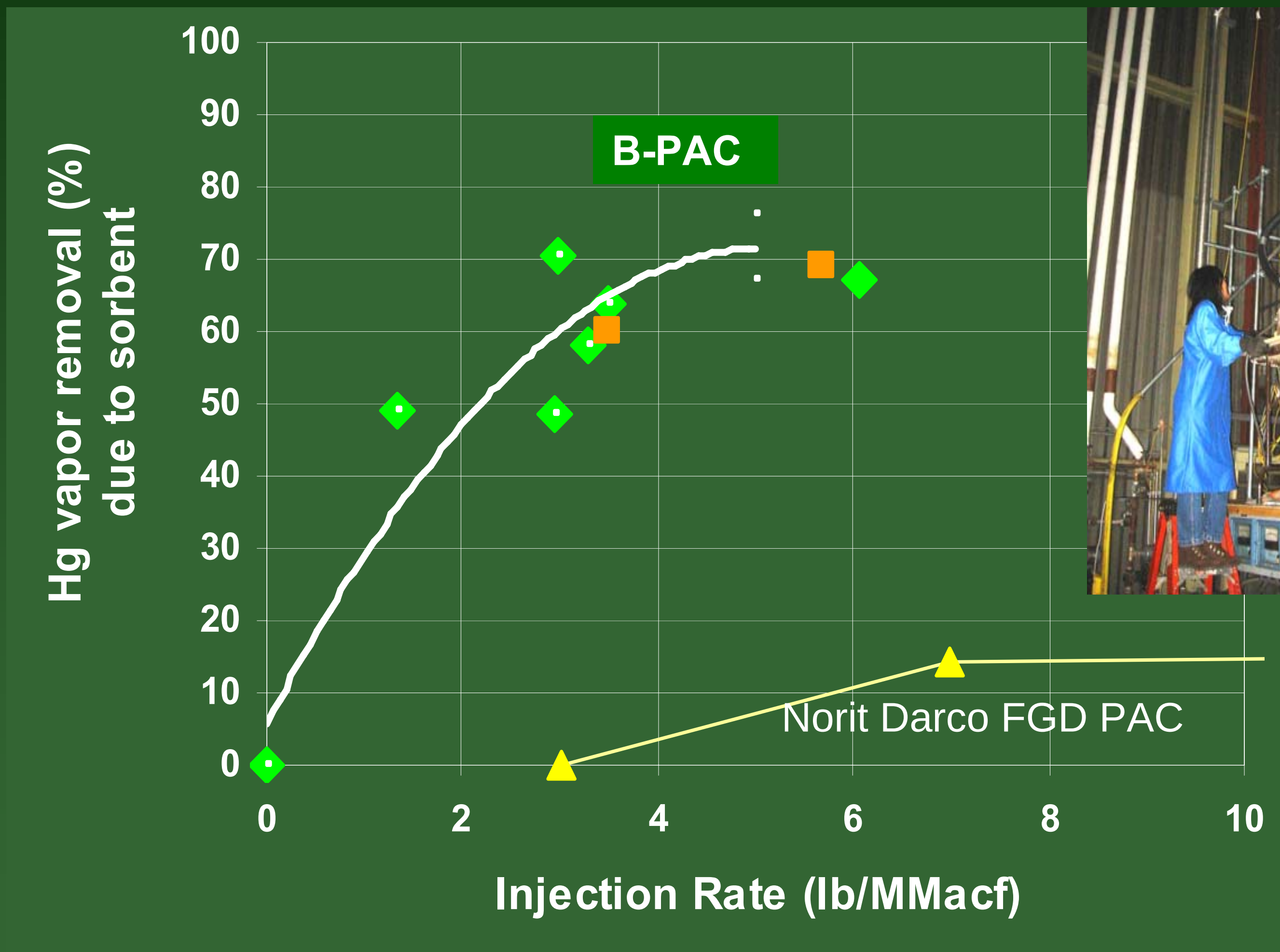
$Hg^{(p)}$	$Hg^{(+2)}$	$Hg^{(0)}$	Hg_{tot}
0	8-9	1-2	10

Lausche Plant Injection Conditions			
Scale	18 MW	Gas	60,000 acfm
SO_2	1000 ppm	ESP temp.	320 ^oF
NOx	250 ppm	SCA	370 ft^2/Kacfm
HCl	25 ppm	Opacity	5%
SO_3	20 ppm	Resid.time	2.5 Sec

- 18 MWe, CS-ESP, High-Sulfur Ohio Bituminous
- January 2003 Test Program
- Hg measurements by Western Kentucky University

Nelson, S., R. Landreth, Q. Zhou, and J. Miller, “Mercury Sorbent Test Results at the Lausche Plant,” 4th DOE-EPRI-U.S.EPA-AWMA “Mega”Symposium, Washington, D.C., May 19-22, 2003.

Lausche Plant Test Results



Costs with High-S Bitum. Coal & CS-ESP

If 4 lb/MMacf of \$0.75/lb Brominated B-PAC™ sorbent injected into 10 µg/Nm³ of Hg at Lausche provides 70% Hg removal:

$$\left(\frac{4\,lb\,sorbent}{1{,}000{,}000\,acf}\right)\left(\frac{Nm3}{(70\%)10\,\mu g\;Hg}\right)\left(\frac{\$0.75}{lb\,sorbent}\right)\left(\frac{1.5\,acf\;@\,320F}{1\,scf}\right)\left(\frac{35.3scf}{Nm^{3}}\right)\left(\frac{10^{9}\,\mu gHg}{2.2\,lb\;Hg\;removed}\right)=\$10{,}300\,/\,lbHg.$$

Cost = \$10,000 /lb Hg removed,

~80% cost reduction from the current technology baseline

If a high-Hg Pennsylvania coal with 20 µg/Nm³ of Hg:

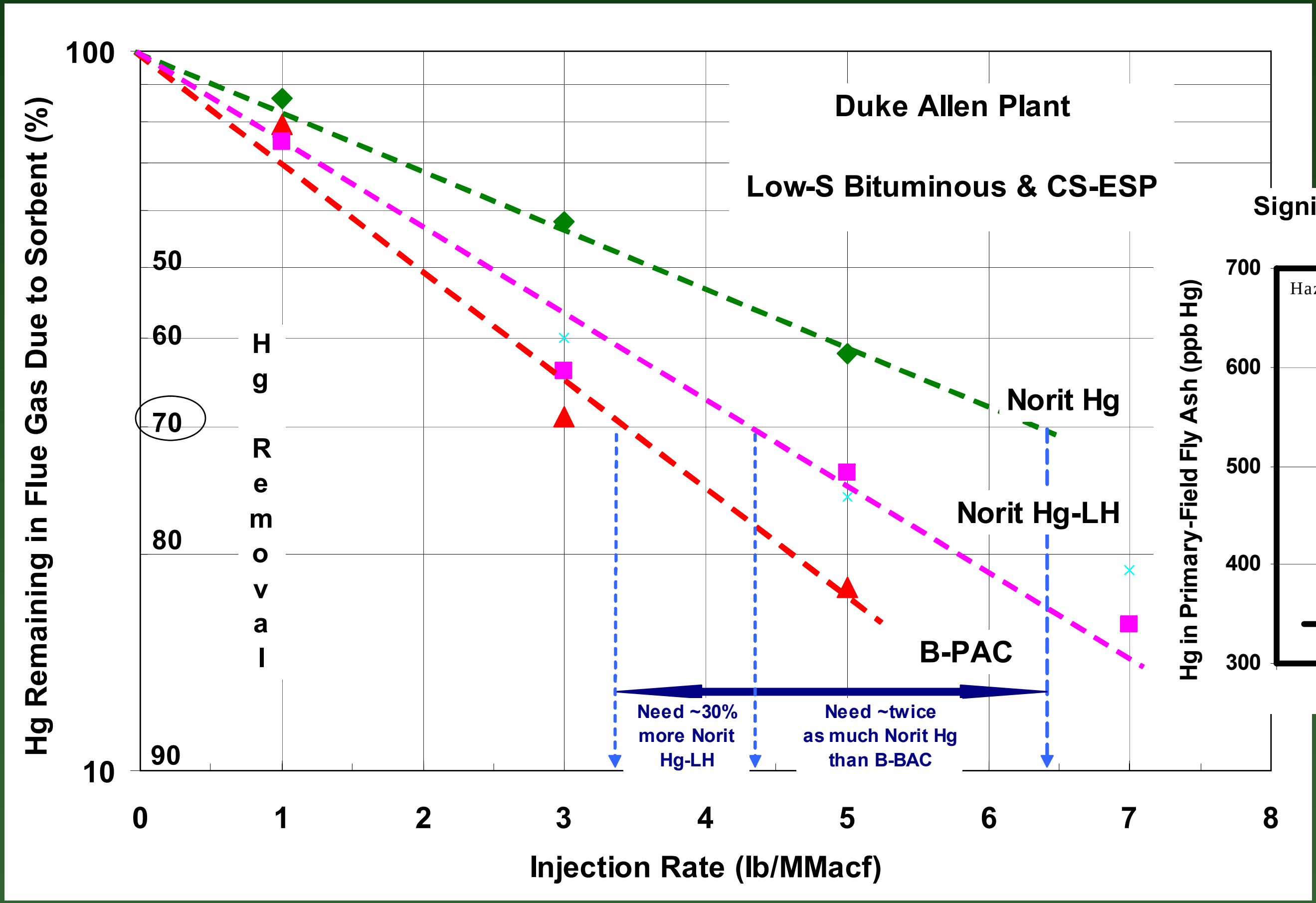
Cost = \$5,000 /lb Hg removed

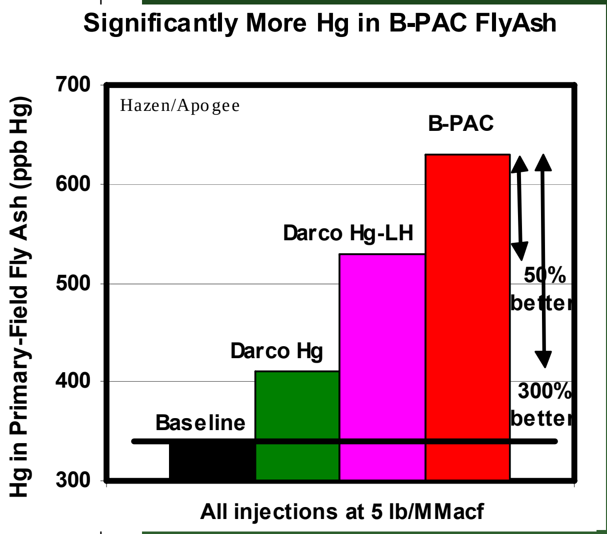
~90% cost reduction from the current technology baseline.

Duke Power's Allen Plant: Low-S Bituminous

- Low-sulfur bituminous coal with a cold-side ESP
- Full-scale, short-term testing
- Measurements by Apogee Scientific

Half as Much B-PAC as Plain PAC is Needed

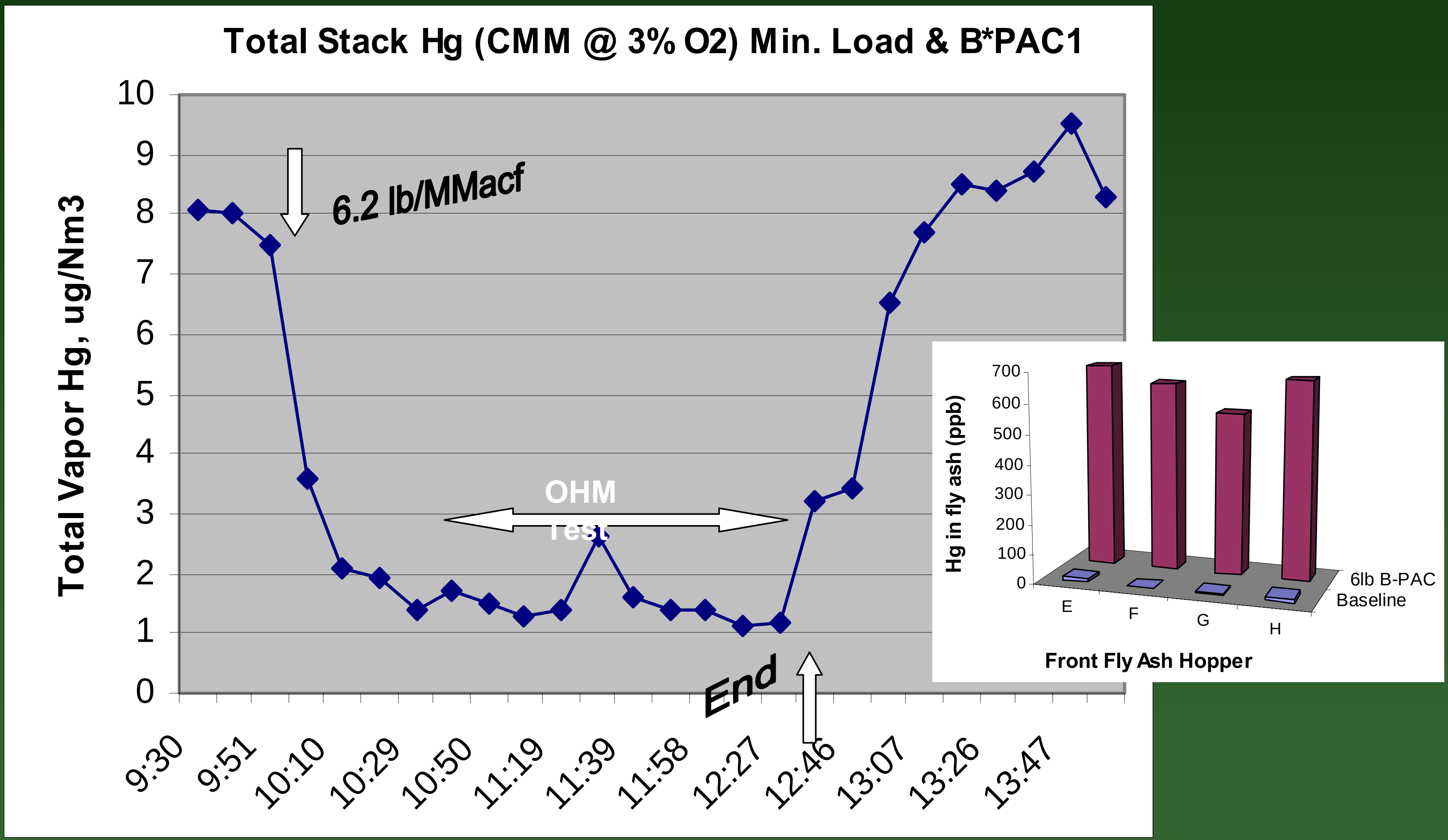




Duke Energy's Cliffside Plant - Bituminous Parametric Testing on a Hot-Side ESP

Coal Type:	Low-S Bitumin.
Boiler:	No. 2 (Unit 2)
Boiler Type:	Tangential
Particulates:	Hot-Side ESP
ESP Stream Size:	40 MWe
ESP Inlet Temp.:	550-700°F
SCA :	240 ft^2/K acfm
Avg. Coal Hg:	0.08 ppm
Avg. Coal Cl:	500 ppm

2003 Cliffside Results with H-PAC™



Recent 30-Day Trial on a Hot-Side/Bituminous

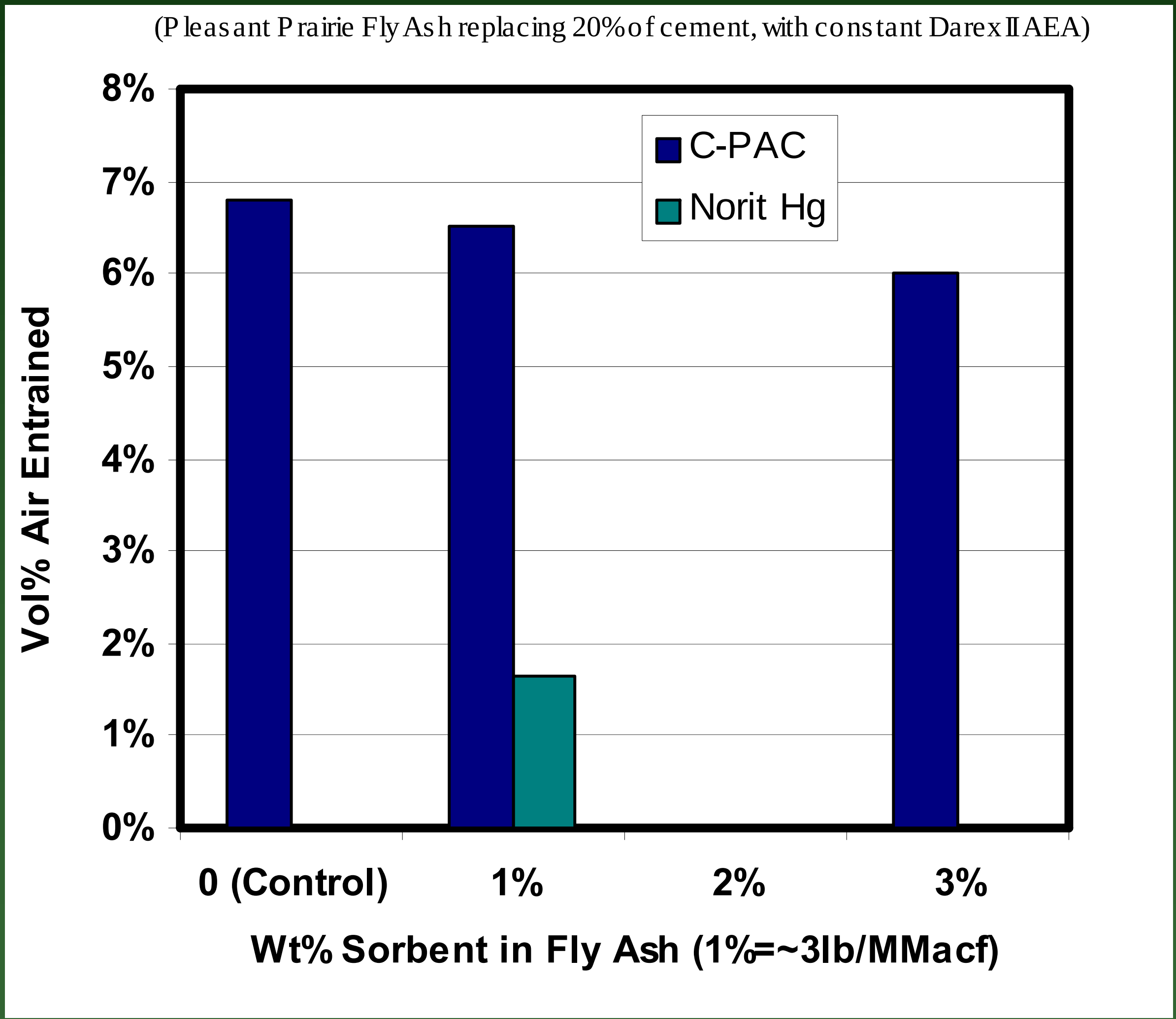
- Duke's Buck Plant burns low-S bituminous coal

Long-Term Test

- H-PAC1 injected at 5 lb/MMacf

Load	Inj.Temp.	lb/MMacf	Time Fraction	Wtd.Avg. %Remov.	lb/TBtus
60 MW	~ 540F	5.0	28%	50%	3.0
140 MW	~ 640F	5.0	50%	50%	3.0
60 MW	~ 540F	10.0	22%	70%	1.8

Even a Version for Fly Ash Sales for Concrete



B-PAC & H-PAC Trials on Lee 1 & 2 in Q1 2006

Then full-scale DOE C-PAC trials at Midwest Generation's Crawford & Will County Plants

Conclusion: B-PAC Appears Widely Applicable

Coal	PM Unit	Hg Removal	lb/MMacf	Plant	Utility	Data
Bitum. Low-S	CS ESP	85%	5.0	Allen	Duke	Apogee/ST
Bitum. High-S	CS-ESP	70%	4.0	Lausche	OhioU	SorbTech
Bitum. HighSO_3	HCS ESP	NA**	4.0	Merrimack	PSNH	SorbTech
Bitum. Low-S	HS ESP	80%*	6.4	Cliffside	Duke	SorbTech
Bitum. Low-S	HS ESP	50%	5.0	Buck	Duke	SorbTech
Subbitum.Blend	CS-ESP	90%	3.0	St. Clair	Detroit Ed.	SorbTech
Subbituminous	CS-ESP	90+%	3.0	St. Clair	Detroit Ed.	SorbTech
Subbituminous	CS-ESP	90%	3.2	Stanton 1	GRE	EERC/URS
Lignite	SD/FF	95%	1.5	Stanton 10	GRE	EERC/URS
Lignite	CSESP***	70%***	1.5	Stanton 10	GRE	EERC/URS

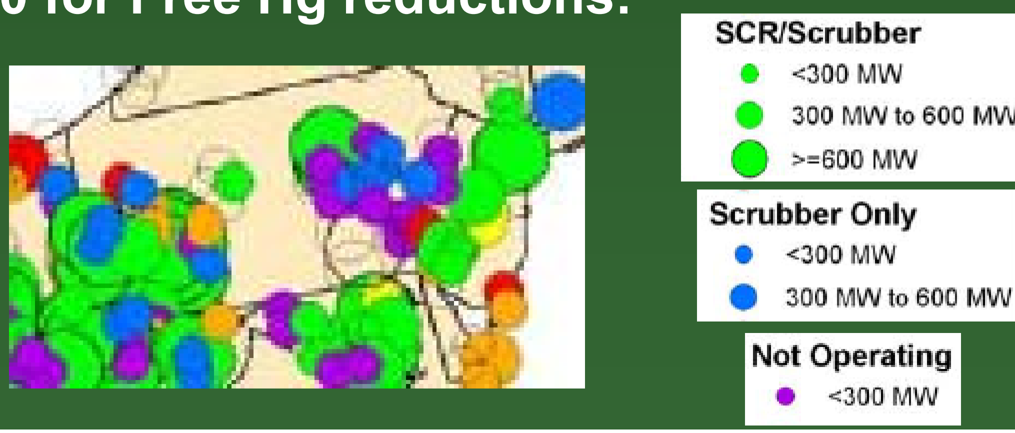
* when under low-load conditions at this plant.
** Public Service of New Hampshire has not yet publicly released this data.
*** actually the in-flight Hg removal across the spray dryer.

Why No Pennsylvania Plants?

Not because we have not tried.
Responses for the latest DOE demonstration solicitation:

Pennsylvania Utility	Response
Reliant	declined
Allegheny Energy	declined
FirstEnergy	declined

Maybe it's all those giant scrubbers they intend to retrofit by 2010 for Free Hg reductions:



Cost of 80% Net Hg Reductions in PA

Conservatively, if 5 lb/MMacf of $0.75/lb B-PAC is injected into a CS-ESP with 15 µg Hg/Nm³ provides 70% Hg removal:

$$\left(\frac{5\,lb\,sorbent}{1{,}000{,}000\,acf}\right)\left(\frac{Nm3}{(70\%)15\mu g\;Hg}\right)\left(\frac{\$0.75}{lb\,sorbent}\right)\left(\frac{1.5\,acf\;@\,300F}{1\,scf}\right)\left(\frac{35.3scf}{Nm^3}\right)\left(\frac{10^9\;\mu gHg}{2.2\,lb\;Hg\;removed}\right)=\$8{,}600\,/\,lbHg.$$

Cost ~ $10,000 /lb Hg removed (including hardware)

<u>For Pennsylvania, ignoring "free" reductions from new scrubbers</u>:
~ 10,000 lb Hg/yr * 70% avg. reduction = 7,000 lb/removed
7,000 lb/yr * $10,000/lb = $70 million/yr

2002 PA Retail electricity: 141,000,000,000 kWh * 8.01¢/kWh = $11.3 Billion [EIA]
So, assuming that utilities do not mark-up Hg control costs with extra profits:

<u>PA electric rate increase for Hg control = ~0.6% or ~40¢/month</u>.

Summary

1. There is no need to emit power plant Hg any longer.

2. Sorbent injection is simple, inexpensive, well-demonstrated, and commercially-available today.

3. Brominated PAC (B-PAC) injection appears to provide safe, efficient, and cost-effective mercury reductions in most power plant retrofit applications.

4. We are seeing 70% to 90%+ Hg removal due to the sorbent alone at these plants, so when combined with existing native removal at Pennsylvania plants, 80% total reductions are certainly doable today.

New STAPPA - ALAPCO Model Hg Rule

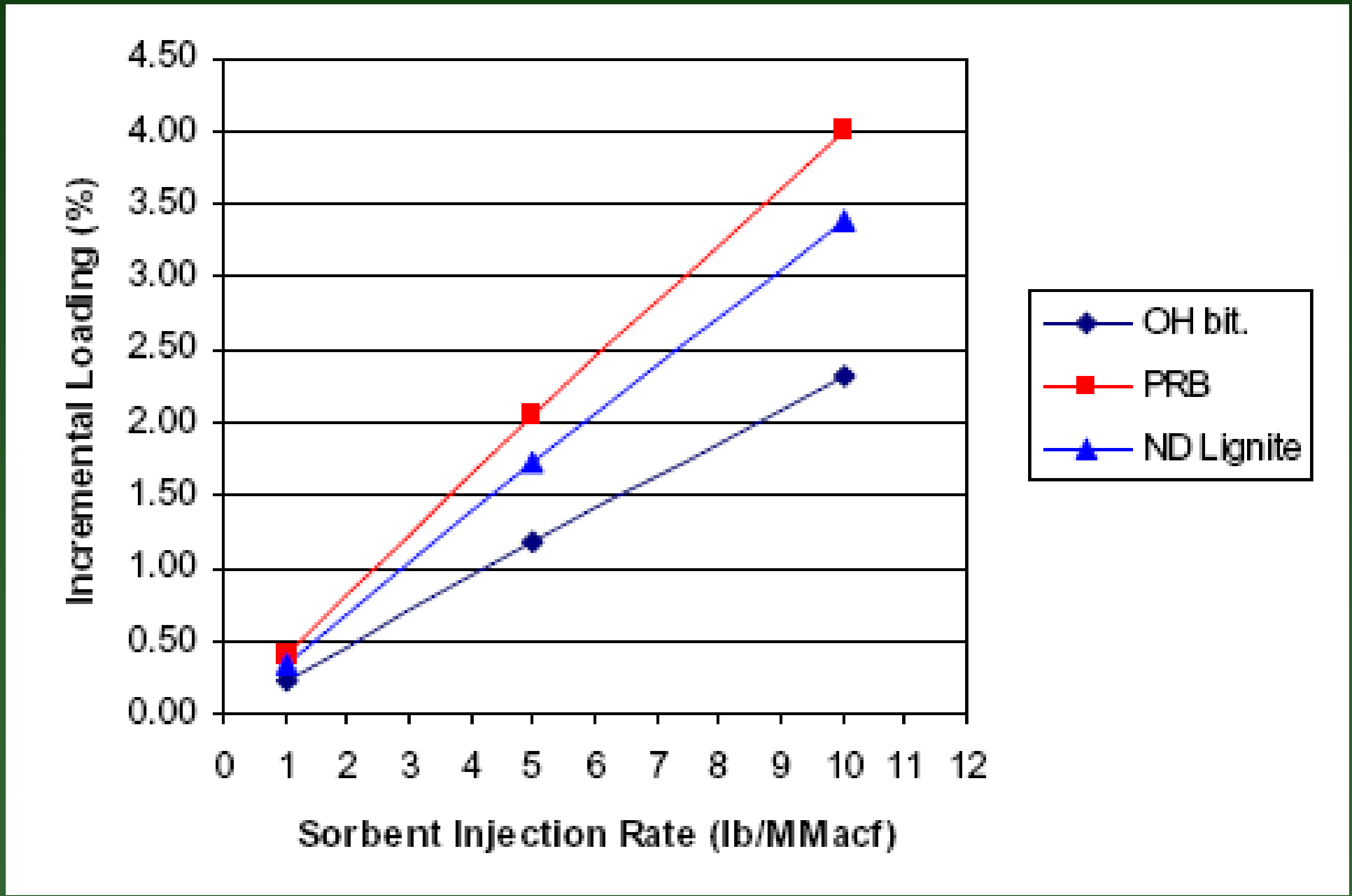
- State & Territorial Air Pollution Program Administrators & the Association of Local Air Pollution Control Officials just released their long-awaited Model State Mercury Rule.
- The Model Rule similarly calls for a Phase 1 requiring 80% Hg removal by 2008 & a Phase 2 with 90-95% by 2012.
- STAPPA & ALAPCO conclude that the technology required for the 2008 deadline exists today & that “hot spots” are a possible danger
- Interstate emission trading for Hg is not allowed because:
  1) not all state citizens are protected if some plants buy allowances rather than reducing their local emissions, and
  2) Hg from CAMR allowances sold to upwind states would simply blow back into the state.
- See: www.4cleanair.org

Supplemental Slides on Balance-of-Plant Effects

Balance-of-Plant Effects

1. Opacity/Particulate Emissions
2. Acid Gas Emissions/Corrosion
3. Dioxin Production
4. Leachates or Revolatilization
5. Fly Ash Use

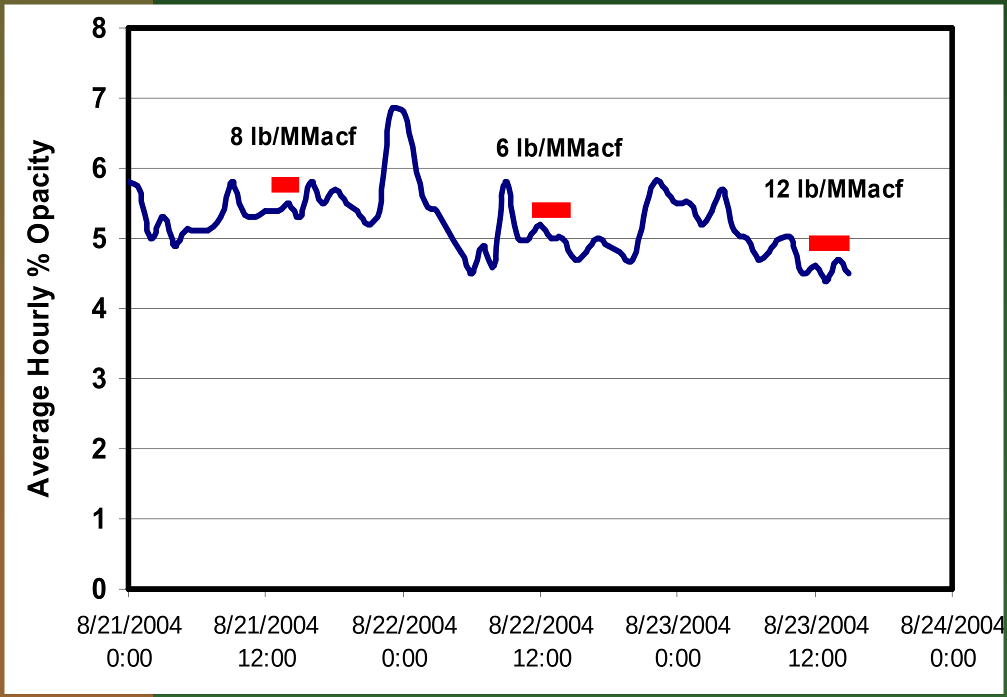
How much fine carbon are we adding?



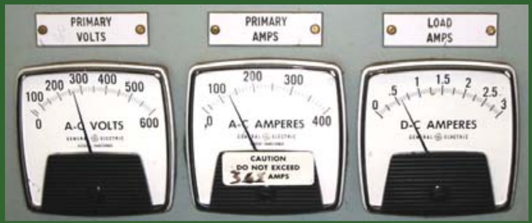
Opacity, Particulates, & ESP Operation

In over 20 Trials to date, particulate increases or ESP effects only noted at Yates (tiny SCA – sparking?) & Coal Creek (Toxecon II)

E.g. St. Clair:



Never any Sparking. All Data at High Load.	Field	G-R Set Primary Volts Before	During	Load on Wire Primary Amps Before	During	Load on Plate Load Amps Before	During
B-PAC	2	220	210	100	80	0.35	0.35
6 lb/MMacf	4	290	290	150	150	0.80	0.80
85% Subbituminous	5	250	250	140	140	0.75	0.75
8/10/2004	6	270	270	150	150	0.75	0.75
Plain PAC	2	225	230	40	40	0.15	0.15
8 lb/MMacf	4	300	300	110	110	0.60	0.60
100% Subbituminous	5	220	220	90	90	0.35	0.35
8/21/2004	6	290	290	150	150	0.75	0.75



Acid-Gas Emissions & Corrosion

Very low off-gassed bromine.

St. Clair Method 26A – Data in ppm.

No Br_2 was ever detected.

Without Sorbent	Baseline 07/28	Inlet–Long-Term 10/21
HF	1.0	0.4
HCl	8.1	3.6
Cl_2	<0.1	0.3
HBr	0.1	<0.1

B-PAC 3lb/MMacf	Parametric 09/09	L-T 10/06	L-T 10/21
HF	2.2	0.1	0.4
HCl	5.9	6.0	4.3
Cl_2	0.1	0.2	0.4
HBr	1.0	0.3	0.2

Carbon Steel Corrosion Coupons

(4 each, 30 days)

	Avg. ΔWt.
Baseline	**+0.13%**
B-PAC	**+0.13%**

No corrosion detected.

U.S. EPA Br-Dioxin Testing with B-PAC

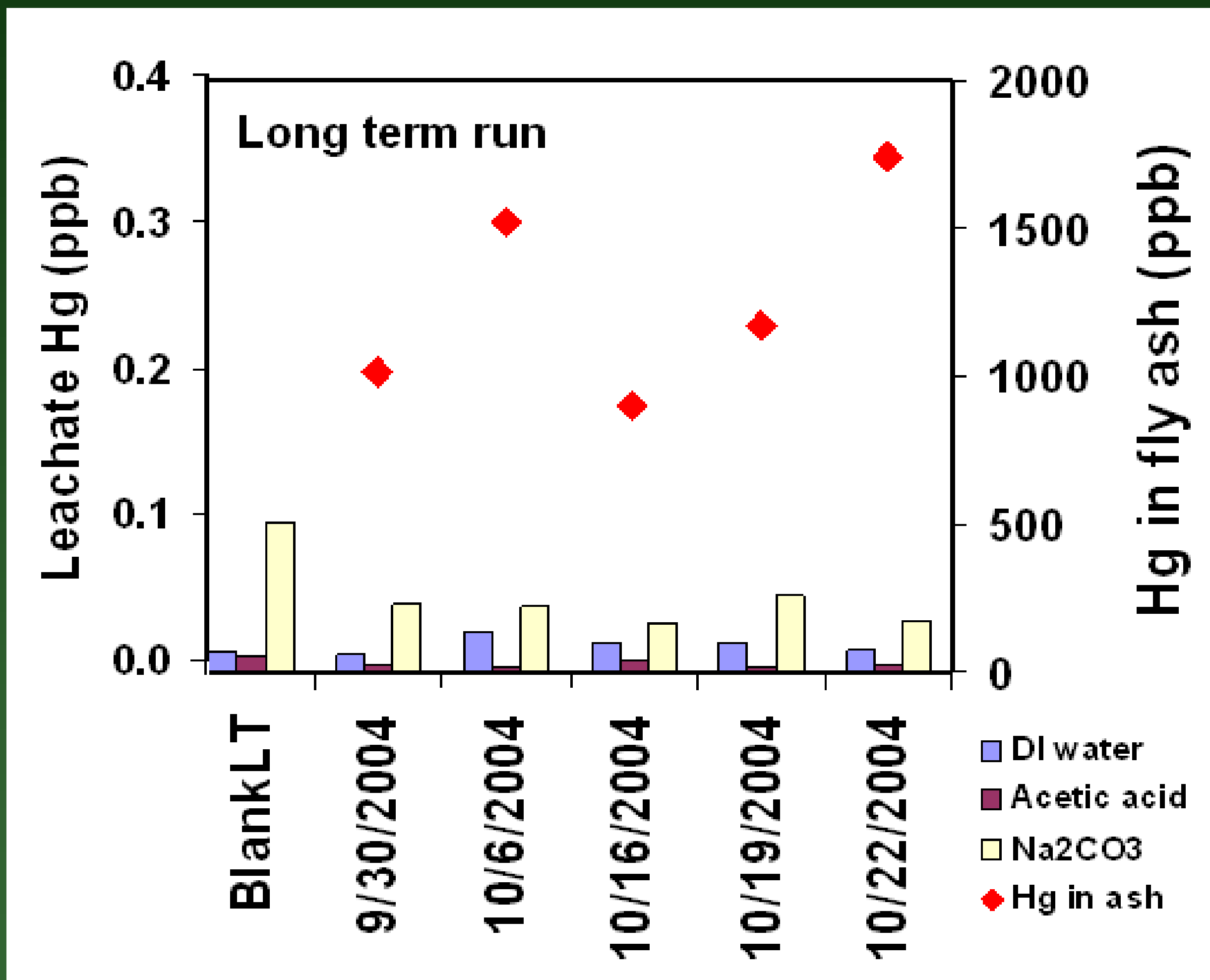
PBrDD/F Total (ng/dscm)	Average	Std Dev	Test #1	Test #2	Test #3
St. Clair, Untreated	**0.5664**	0.3782	0.8507	0.7112	0.1372
St. Clair, Treated	**2.1750**	3.4703	6.1815	0.2299	0.1135
Buck, Untreated	**0.4301**	0.5625	0.0732	0.1386	1.0785
Buck, Treated	**0.5186**	0.6676	0.1145	0.1521	1.2892

	Field Blank	Field Blank	Analytical Blank
St. Clair	0.2104		0.3968
Buck	0.0563	0.0501	0.0559

MWC	Limit PCDD/F Total
small facilities	13
large units without ESP	30
large units with ESP	60

Hutson, N., "Brominated Sorbents: Effects on Emissions of Halogenated Air Toxics," Office of Research & Development, U.S. Environmental Protection Agency, DOE Hg R&D Program Review Meeting, Pittsburgh, July 2005.

Hg Leachates & Revolatilization

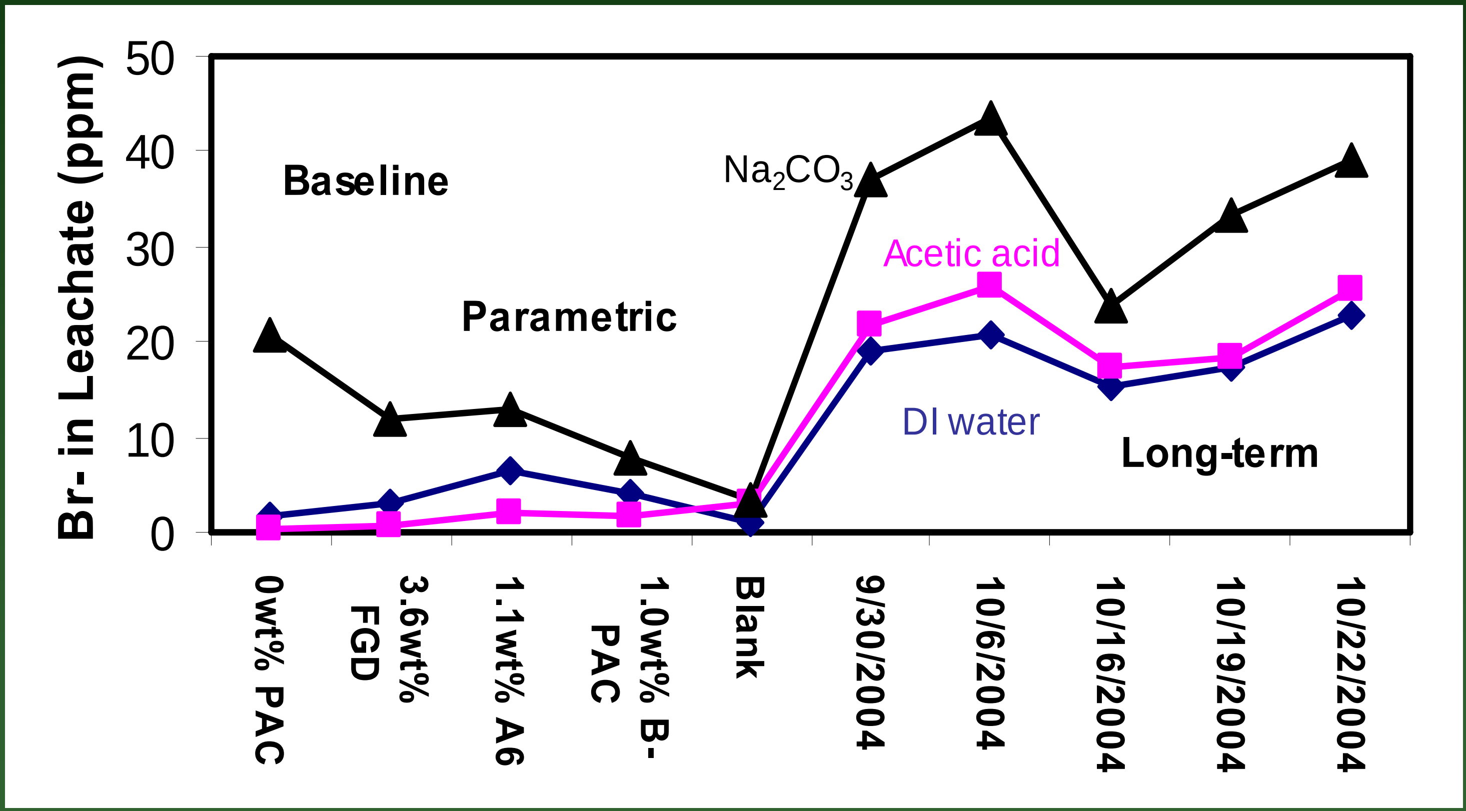


Hg is effectively not leachable.

TCLP, SGLP, & distilled water Leachates of St. Clair fly ash with B-PAC

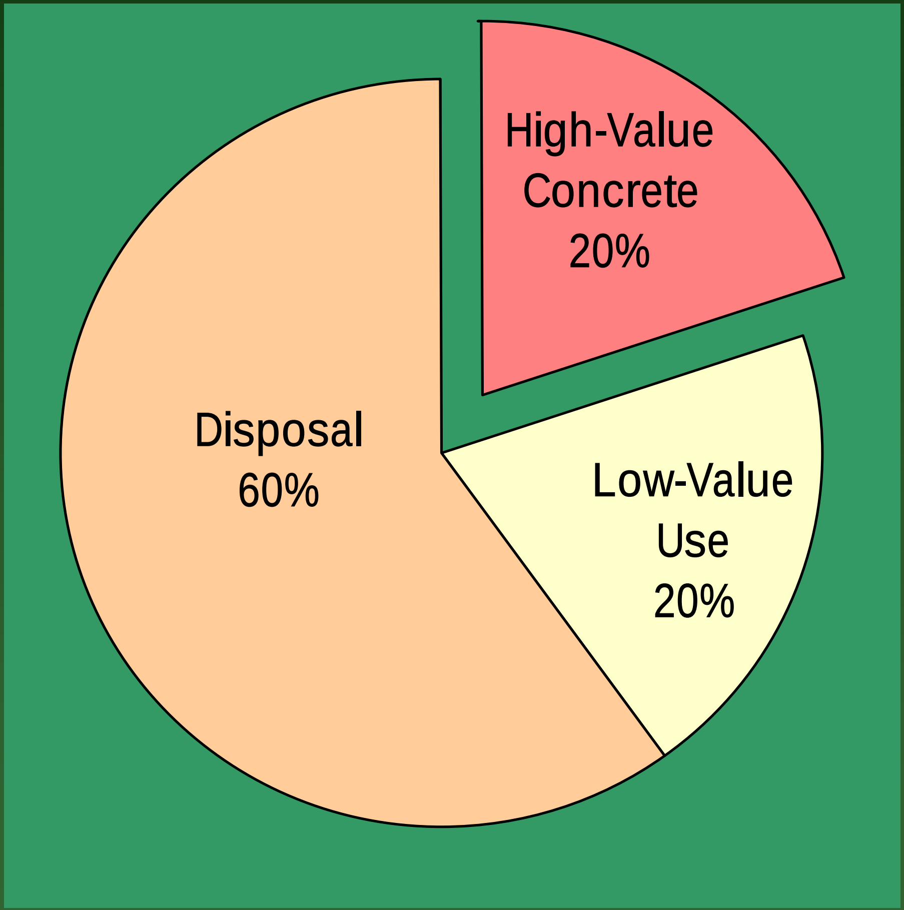
Also: No significant revolatilization ever noted; e.g. measured Hg flux is to the ash pile, not from it (Gustin).

Leachate Br- from St. Clair Fly Ash



Supplemental Slides on Concrete-Friendly C-PAC

Fly Ash Use



Adding 1% to 3% carbon to fly ash does not affect low-value uses such as in flowable fill, embankments, or soil stabilization, but will affect use in concrete.

>12,000,000 Tons per year (~20%) of utility Fly Ash is used to replace expensive Cement in Concrete.

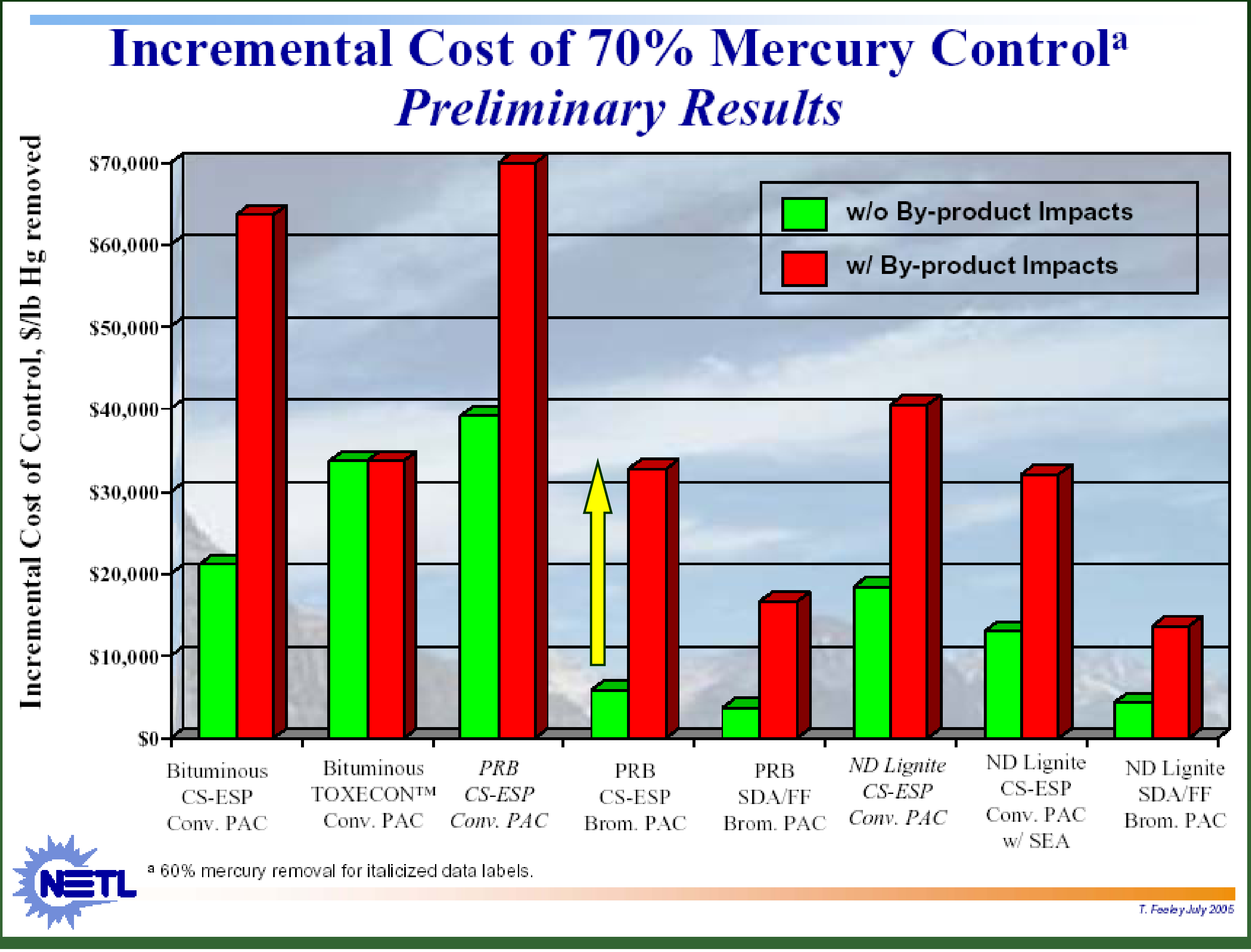
Ash Problems with PAC Hg Sorbents

1. Adsorbs Air Entraining Admixtures (AEAs)
   -- detergents added to concrete slurries to intentionally form bubbles for freeze-thaw abilities
   -- with inevitable variations in the level of the effect

2. Carbon level per se

3. Darkens the fly ash

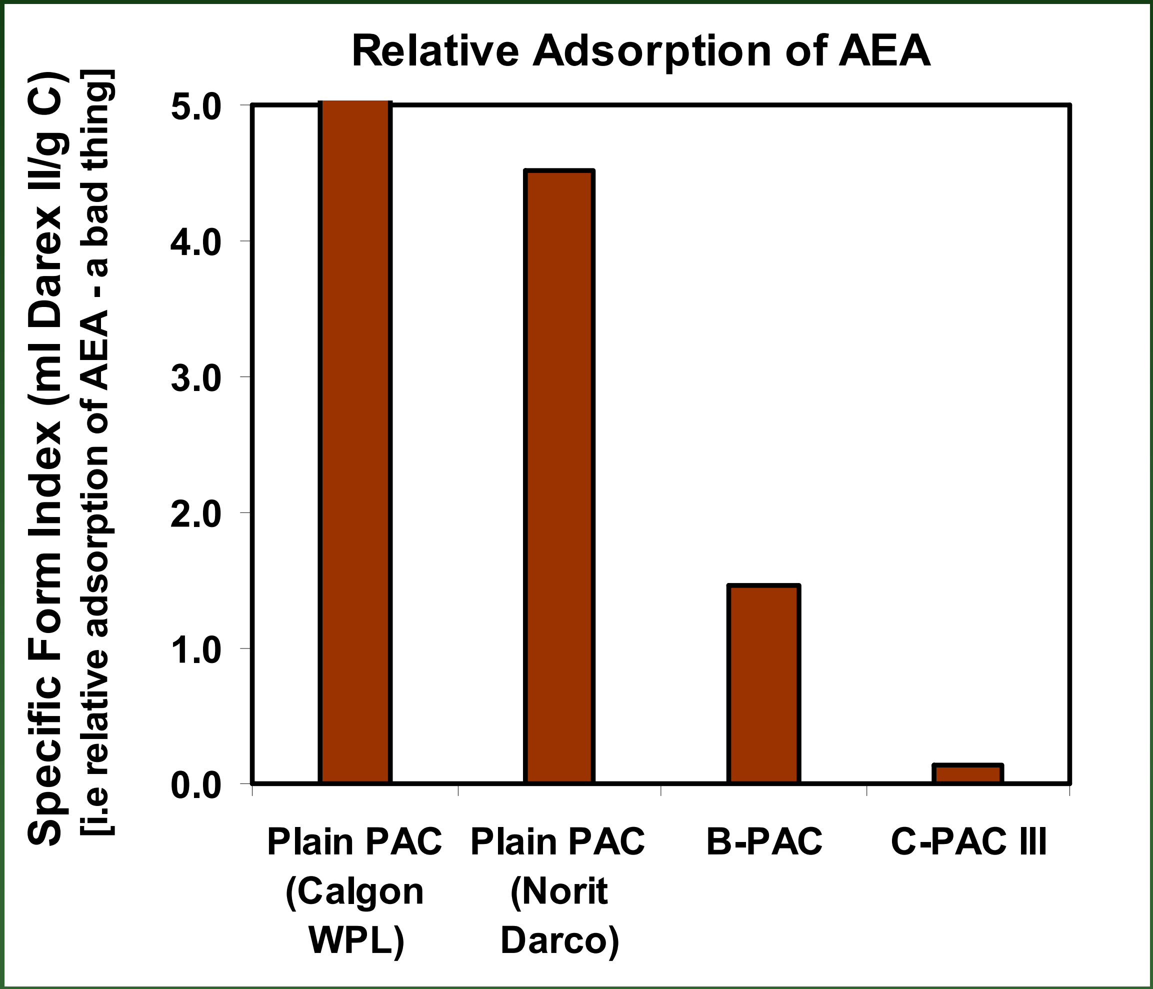
If Cannot Sell for Concrete, Big Costs



Numerous Alternatives

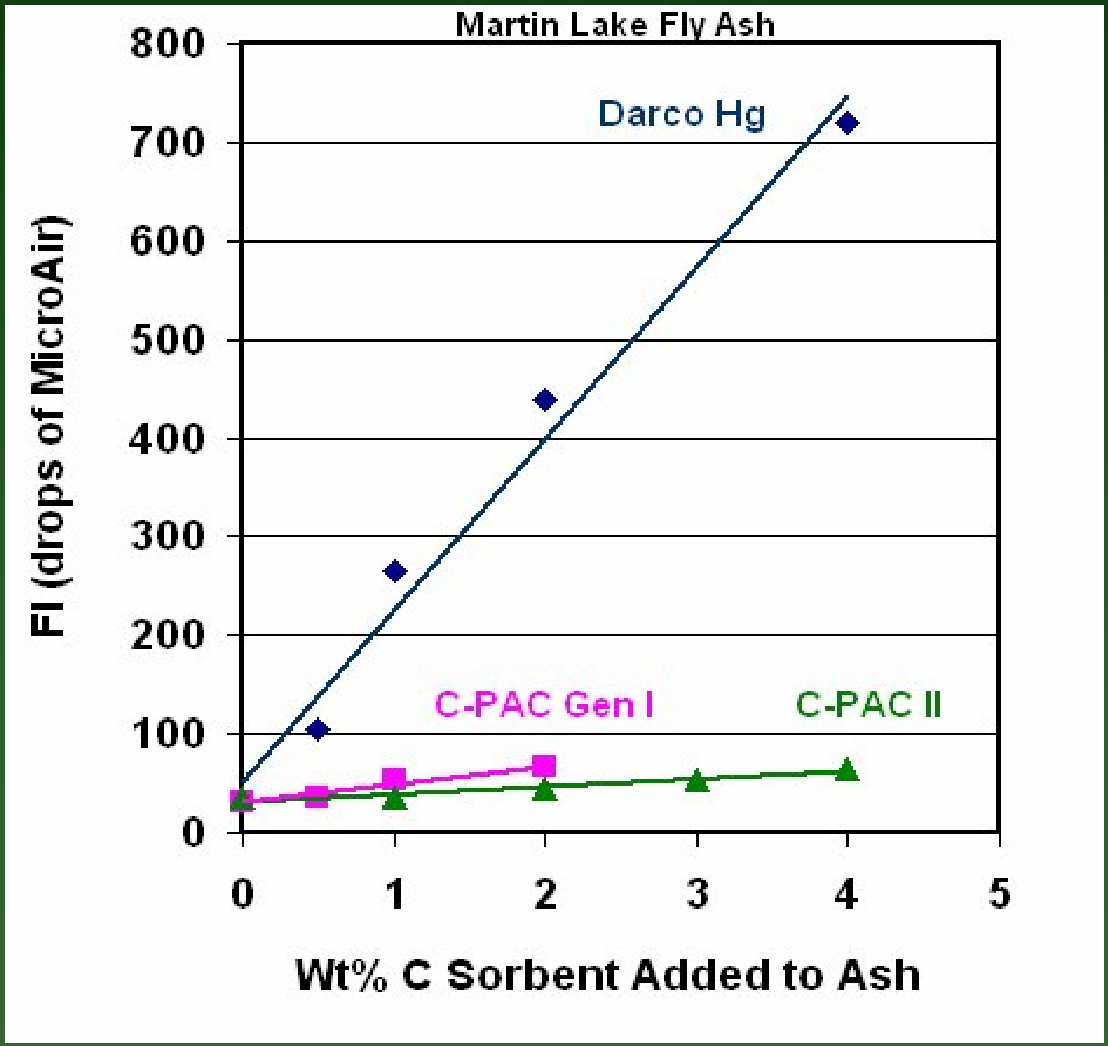
- Don’t mix the PAC with the fly ash (e.g. Toxecon® I or II)
- Post-process the fly ash to remove the PAC (e.g. triboelectrostatically, carbon burn-out, or O_3 passification)
- Use an AEA unaffected by carbon (under development)
- Use a sorbent that does not affect AEAs (e.g. non-carbon sorbents under development or C-PAC™)

C-PAC has a Miniscule Foam Index

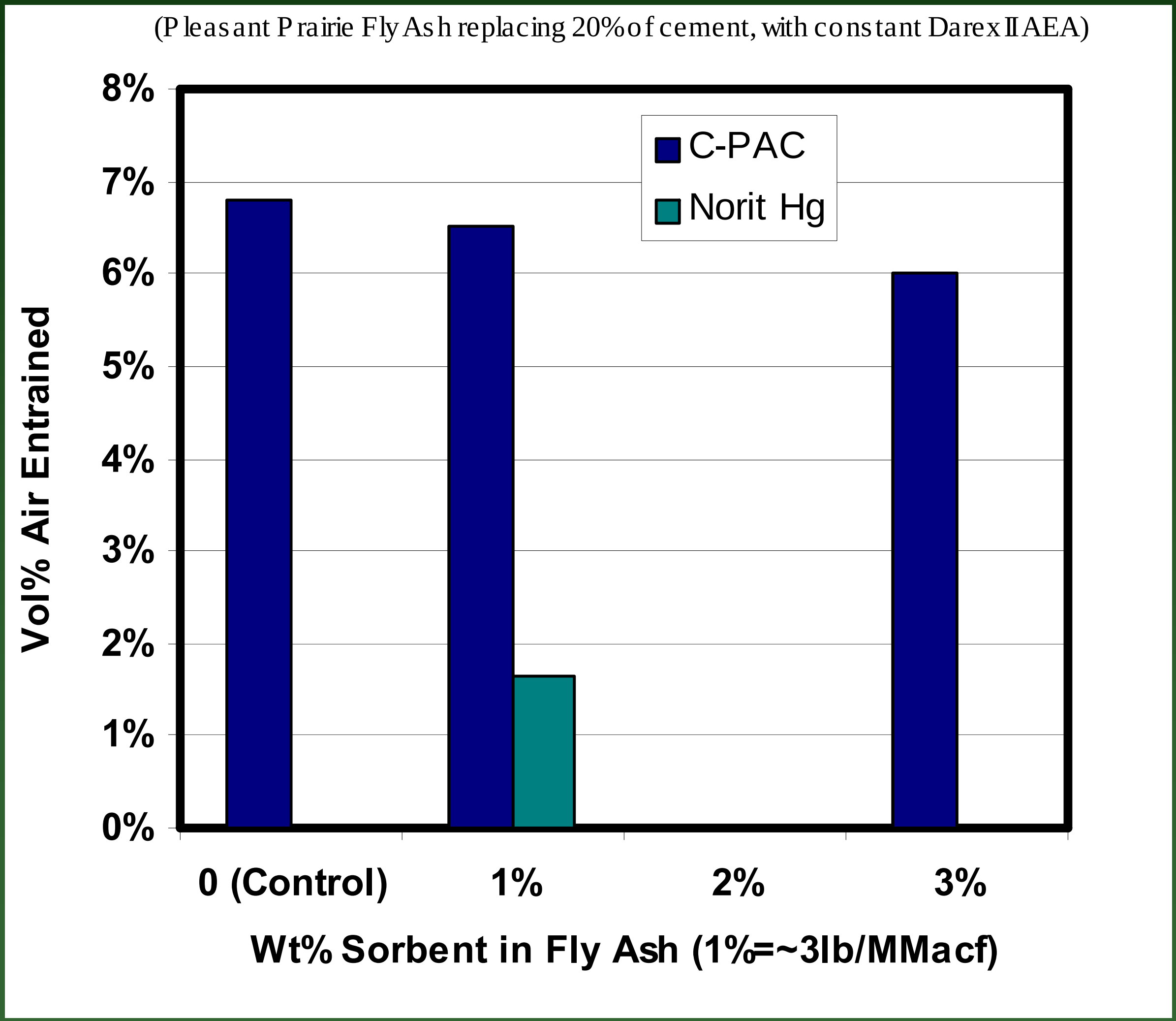


Tested with typical 20% substitution of Pleasant Prairie Plant fly ash for cement & 1-wt% PAC in the fly ash.

Headwaters Verification of Low Foam Index

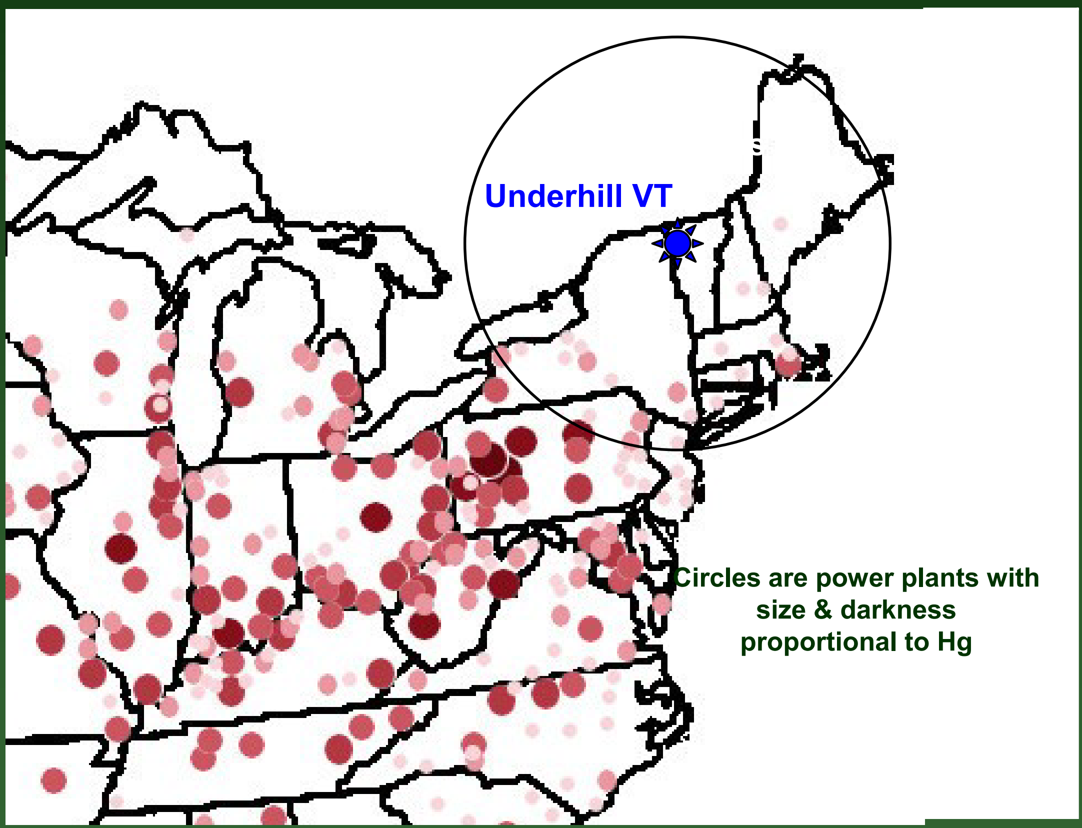


Concrete Air with C-PAC II is Unaffected



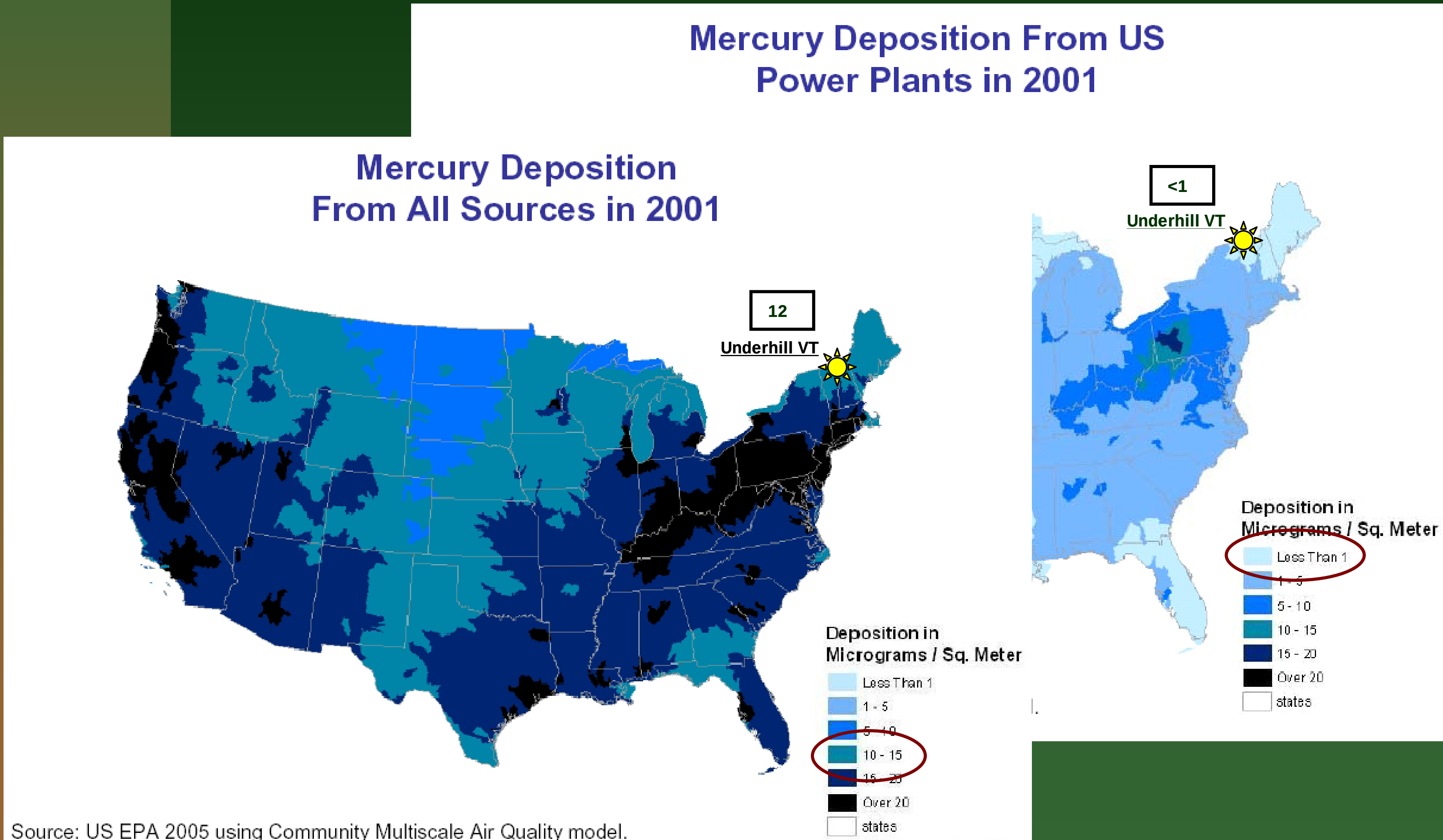
Supplemental Slides on Transport & Deposition

EPA, EPRI, & EEI Claim Most U.S. Hg is Foreign



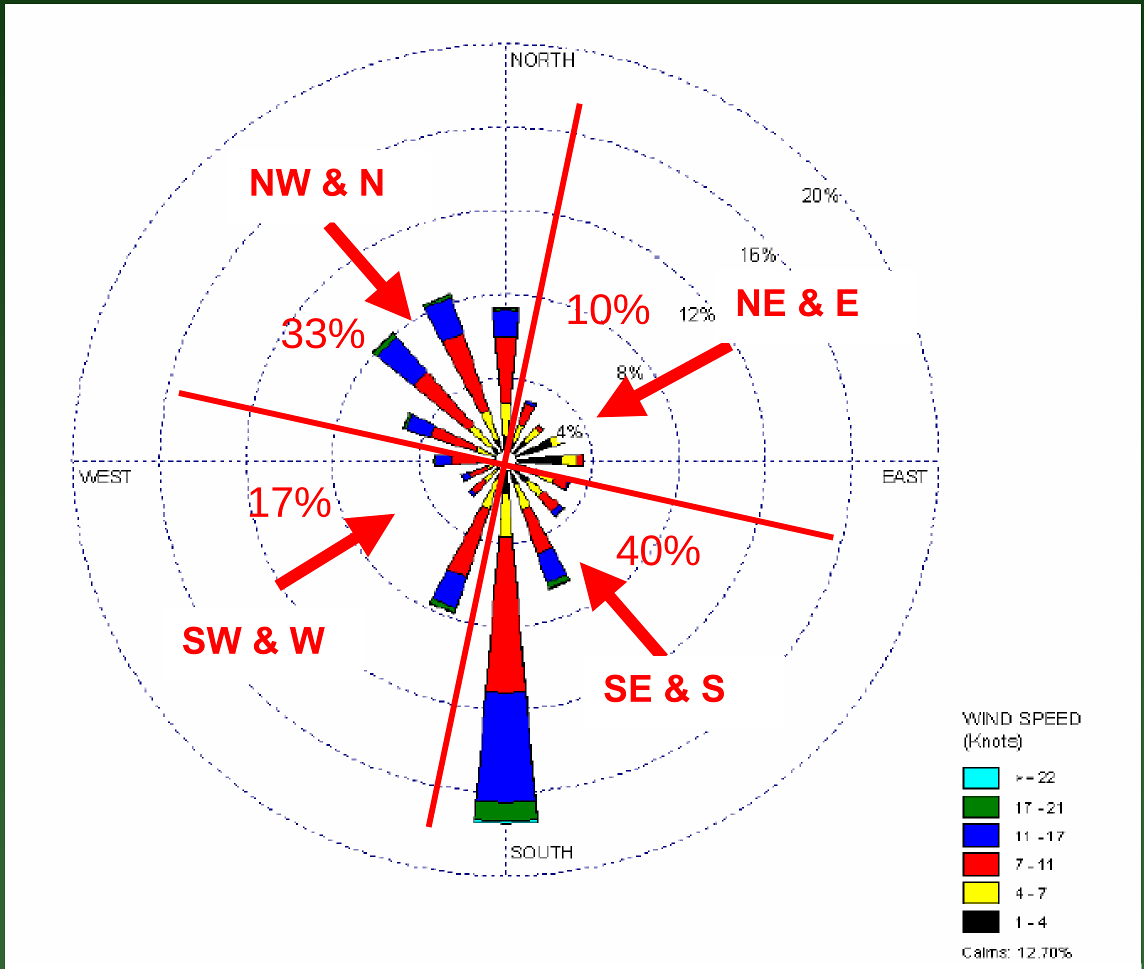
Take Underhill, Vermont, for example, near Burlington, far from U.S. power plants and, supposedly, a locale that should be dominated by ubiquitous foreign-source Hg.

EPA: “<10% Underhill Hg is from U.S. Coal”



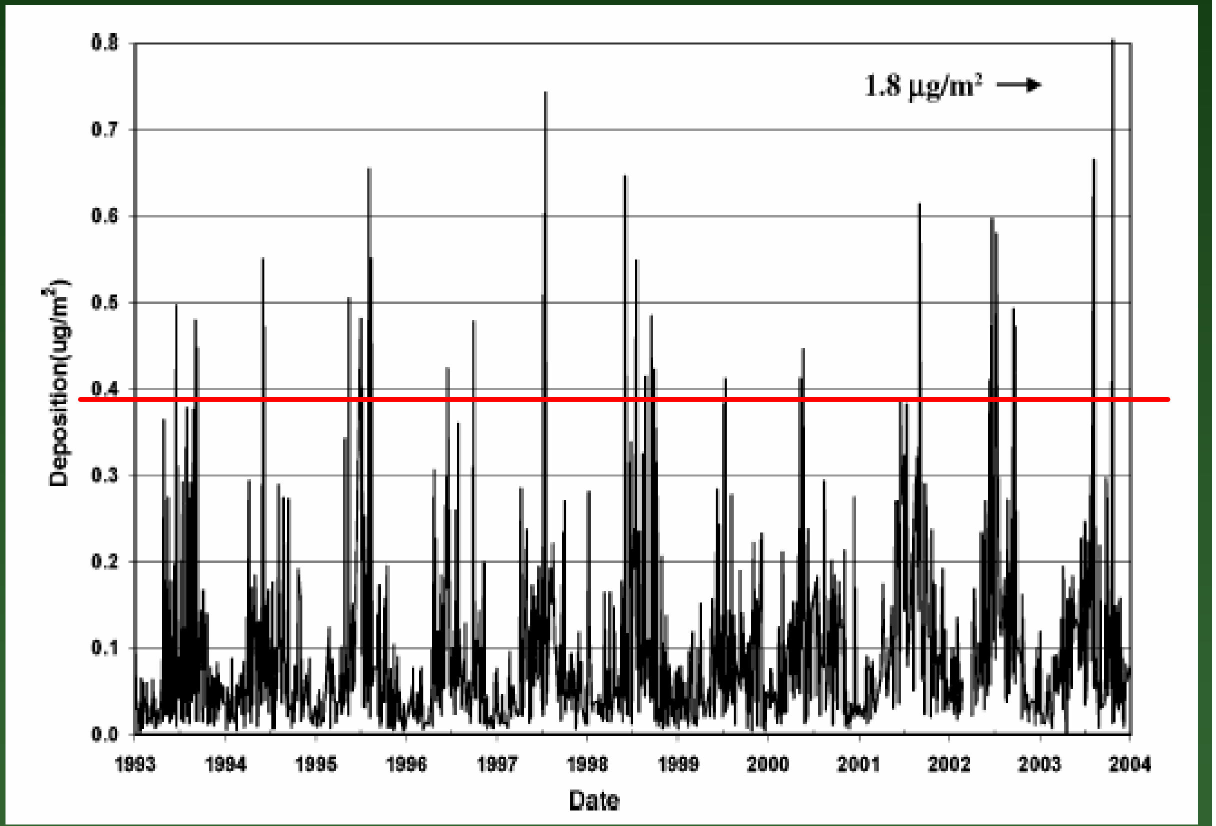
Source: US EPA 2005 using Community Multiscale Air Quality model.

Air Masses Typically Blow in from NW & SE



Burlington, Vermont 6 Year (1991, 1998-2000, 2002-2003) Composite Wind Rose

Wet Hg Deposition is in Discrete Rain Events



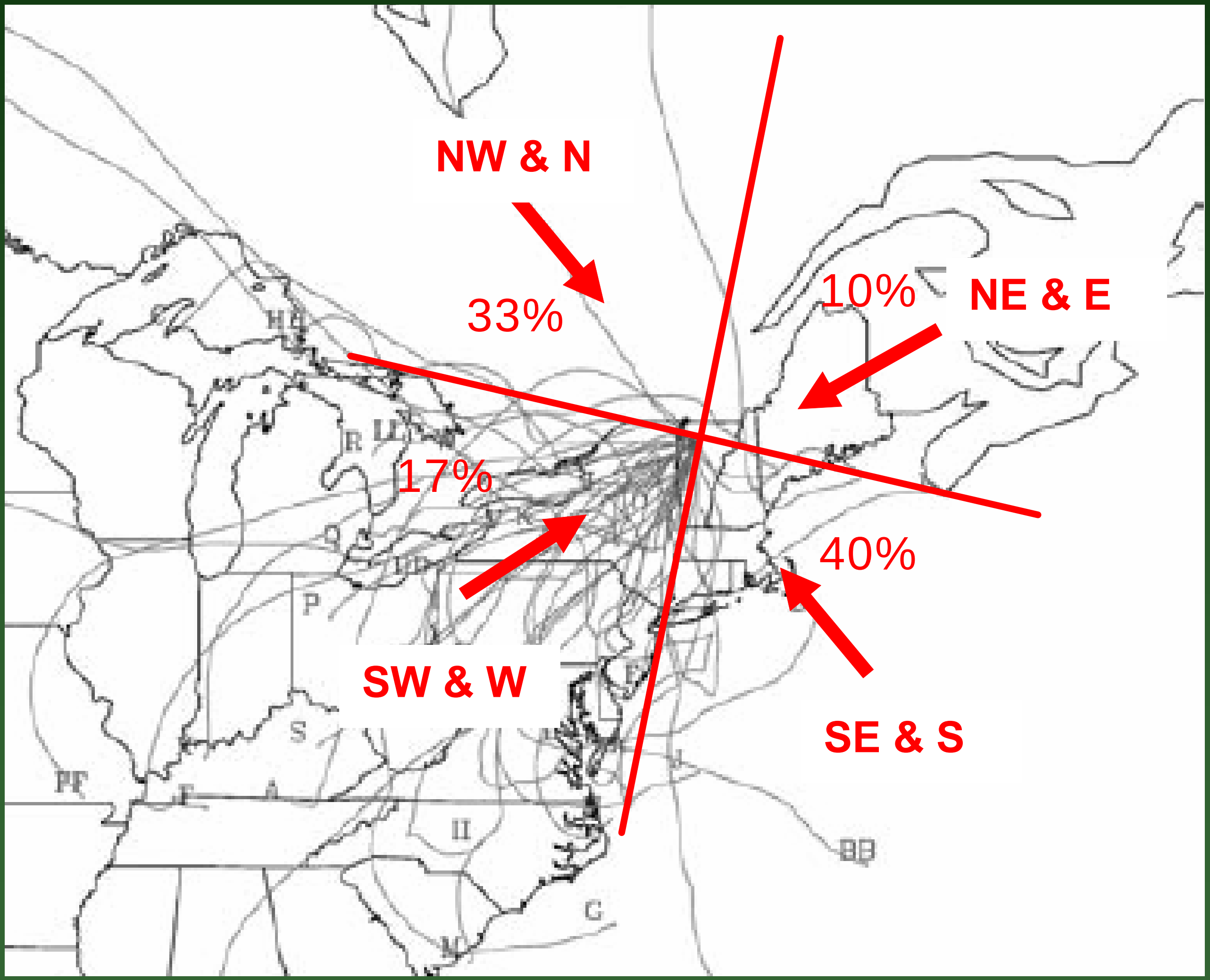
Keeler, G., *et al.*, "Long-Term Atmospheric Mercury Wet Deposition at Underhill, Vermont," Ecotoxicology, 14, 71–83, 2005.

82 *Keeler et al.*

Table 2. Top deposition events (> 0.4 μg/m²) at the PMRC site from 1993–2003

Trajectory ID	Event start date	Precipitation depth (cm)	Hg concentration (ng/l)	Hg wet deposition (μg/m²)
A	4/25/1993	2.1	17.7	0.4
B	6/15/1993	2.0	24.8	0.5
C	7/29/1993	1.8	21.3	0.4
D	8/24/1993	3.6	10.4	0.4
E	8/31/1993	4.4	10.8	0.5
F	9/9/1993	2.0	22.6	0.4
G	5/31/1994	2.4	23.0	0.6
H	6/6/1994	3.9	12.0	0.5
I	5/14/1995	1.6	30.9	0.5
J	7/1/1995	5.6	8.7	0.5
K	8/3/1995	6.0	11.0	0.7
L	8/11/1995	2.7	20.8	0.6
M	6/13/1996	3.8	11.2	0.4
N	7/26/1996	2.4	15.0	0.4
O	9/28/1996	3.1	15.5	0.5
P	7/9/1997	4.9	12.3	0.6
Q	7/14/1997	3.5	21.1	0.7
R	7/15/1997	2.0	26.2	0.5
S	5/31/1998	4.9	13.1	0.6
Not Shown	7/16/1998	2.6	21.0	0.5
T	8/24/1998	2.3	17.7	0.4
U	9/15/1998	5.2	9.4	0.5
V	9/26/1998	2.3	18.5	0.4
W	9/30/1998	2.6	13.4	0.4
X	7/5/1999	4.4	8.7	0.4
Y	7/9/1999	2.3	17.8	0.4
Z	5/8/2000	4.9	8.5	0.4
AA	5/18/2000	1.7	26.8	0.4
BB	6/16/2001	3.0	13.0	0.4
CC	7/10/2001	2.6	14.8	0.4
DD	8/31/2001	5.0	12.2	0.6
EE	6/11/2002	4.9	8.4	0.4
FF	6/21/2002	3.9	15.5	0.6
GG	7/5/2002	2.6	15.2	0.4
HH	7/8/2002	4.7	12.4	0.6
II	9/14/2002	4.0	12.3	0.5
JJ	9/22/2002	4.4	10.6	0.5
KK	8/4/2003	4.6	14.5	0.7
LL	10/20/2003	5.1	35.3	1.8

All of Hg Came from SW Plants, Not <10%



Three-day HYSPLIT meteorological back-trajectories of air masses from the 39 top Hg rainfalls

When Hg was deposited, it came from air from only the SW, where the U.S. plants are!