Goodarzi, F.

- Mercury speciation and reduction, Canada wide Standard of Mercury Emission from Coal-fired Power plants guideline.

Sanei, H.

- Environmental Geochemistry & Petrology of the Lake Sediments in the vicinity of the Alberta coal-fired power plants
- **Sanei, H.**
- Flux of of particles & elements on land and water in British Columbia and Alberta

Huggins, F.

- Speciation of As, Cr and Ni in Canadian feed coals and by-products.
- **Alpay, S.**
- Lake sediment study associated with smelters in Quebec and New Brunswick

Mercury speciation and reduction

Canada Wide Standard of Mercury Emission from Coal-fired Power Plants Guideline

Acknowledgment

Thanks are due to:

The coal- fired power plants in Canada for providing samples and analytical information, collected for their Canada wide standards of mercury, emission study, particularly Mr. W. Peel ATCO power, Mr. J. Shultz, EPCOR Utilities Inc and J. Bolton of TransAlta Utilities, for the first phase of this study in Alberta.

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Mr. J. Reyes of the GSC-Calgary for study of organic in coal and char.

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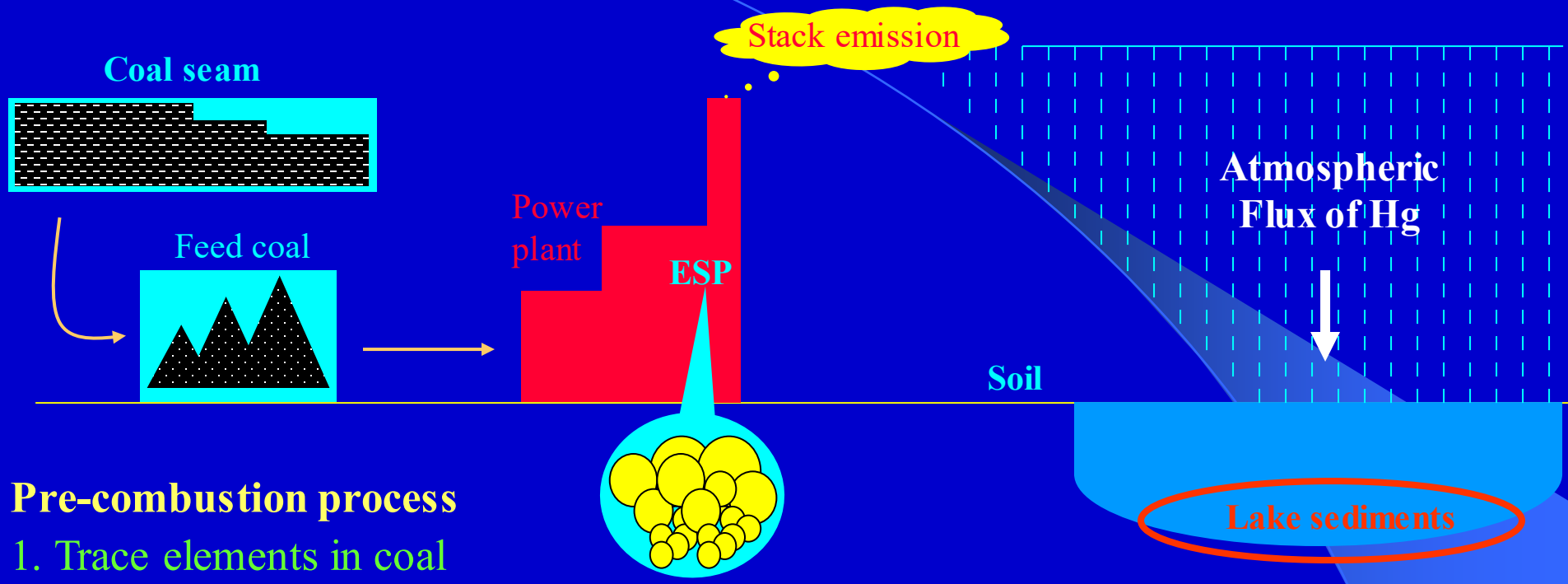
Introduction



Pre-combustion process

1. Trace elements in coal seams
2. Geochemical study of feed coal

In-process studies:

1. Geochemical study of fly ash
2. Geochemical study of bottom ash
3. Stack emission study (gaseous, particles)

Environmental impact:

1. Particulate flux on land
2. Wet deposition of Hg
3. Soil study
4. Lake sediments

Groups	Elements	Input	Output	Out/In	Total Emissions
		kg/day		%	kg/day
Elements of Environmental Concern	As	23.65	0.20	0.85	1.37
	Cd	1.24	0.02	1.42	
	Hg	0.54	0.31	55.3	
	Ni	98.20	0.48	0.30	
	Pb	95.2	0.36	0.38	

Mercury mass balance calculation for six Canadian stations.

	Station #1	**Station #2**	**Station #3***	**Station #4**	**Station #5**	**Station #6**
Coal feed rate (tonne/h, dry base)	143	335	351	347	400	138
Average mercury content of the coal (mg/kg, dry base)	0.07	0.05	0.058	0.08	0.074	0.05
Average mercury emission rate in flue gas (g/h)	10.9	15.7	12.74	12.84	12.74	6.95
Mass of mercury normalized to 100%,						
fraction found in the ash (%)	6.17	13.55	40.3	42.45	57.58	3.33
and fraction found in the flue gas (%)	93.83	86.45	59.7	57.55	42.42	96.67
*Station #3 assumes a split of 40% bottom ash and 60% ESP ash						

Mercury speciation based on averaged of three days of sampling for six Canadian stations.

Parameter	Station #1	Station #2	Station# 3	Station #4	Station #5	Station #6
Total Mercury						
g/h	10.89	15.66	12.742	12.835	12.738	6.947
Particulate Mercury						
g/h	0.01	0.01	0.037	0.076	0.32	0.005
Reactive Gaseous Mercury						
g/h	1.27	3.03	2.676	3.683	1.491	0.345
Total Particulate and Gaseous						
g/h	1.28	3.04	0.625	3.759	1.803	0.351
Gaseous Elemental Mercury						
g/h	9.61	12.62	10.029	9.075	10.928	6.596

How to reduce elements such as Hg ? Would it be environmentally friendly?

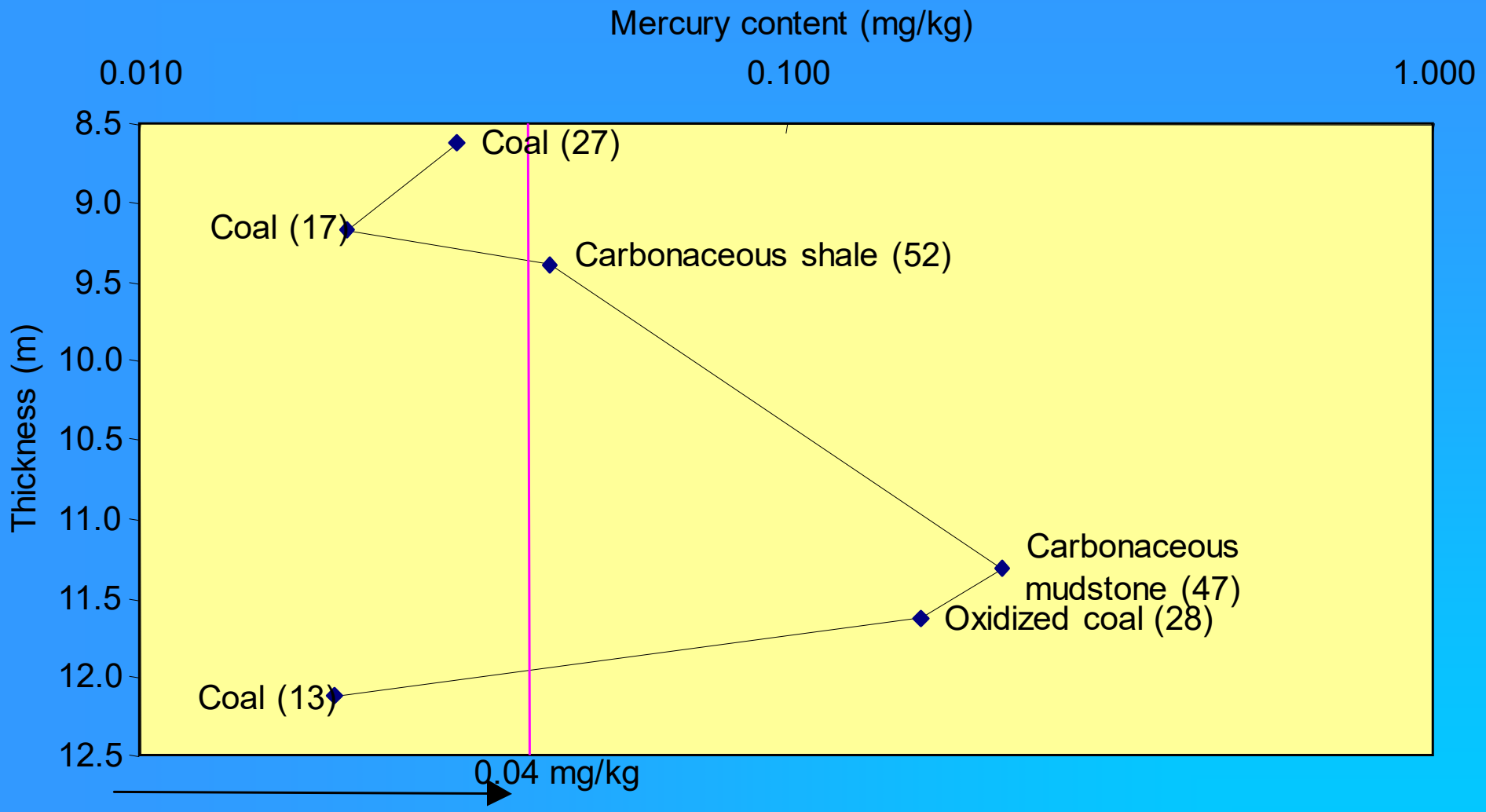
Selective Mining

Nature of Organic Matter in Coal

Selective Mining Approach
What is it?
How it work?

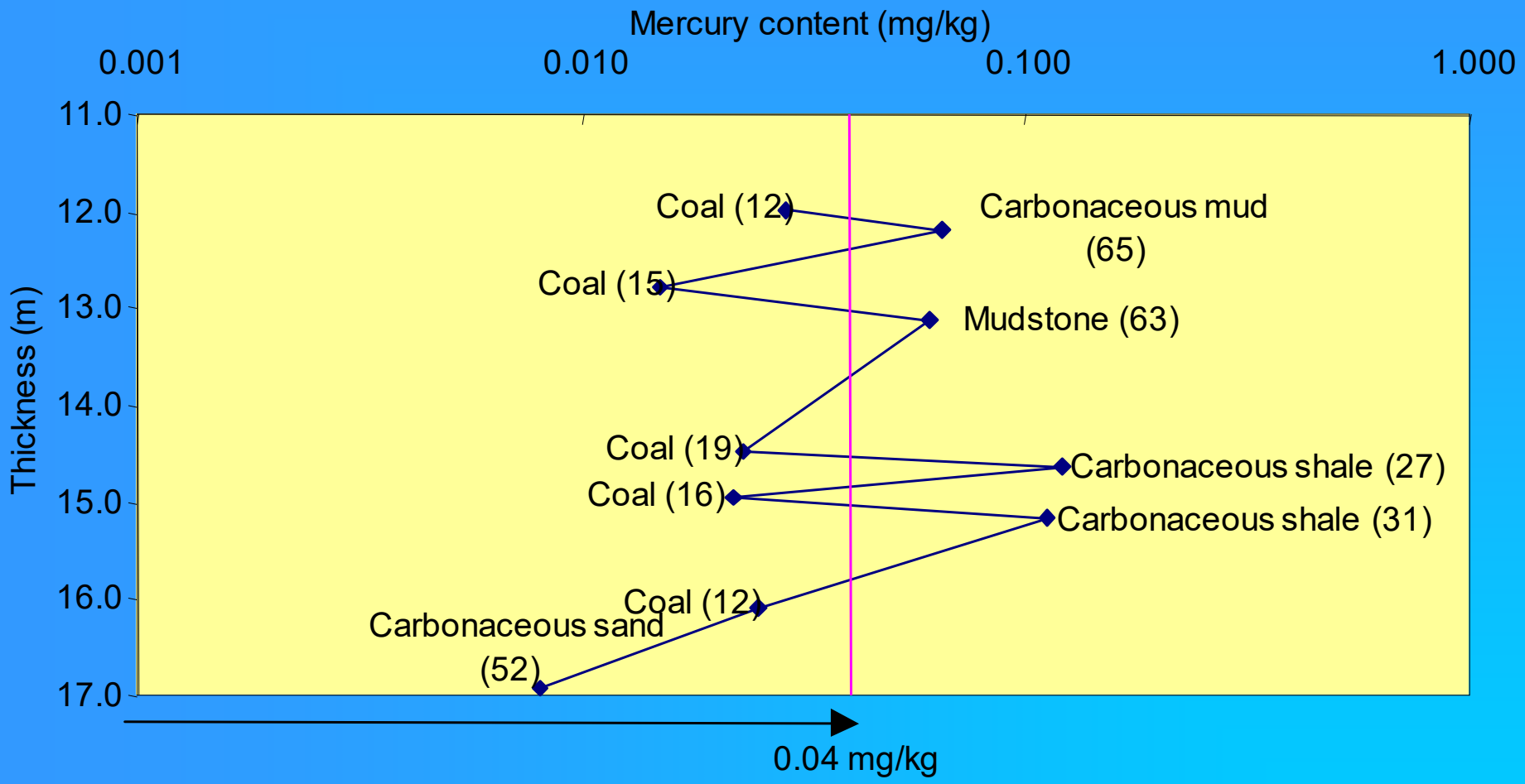
Selective mining of coal seam is removal of high mercury and possibly ash layers associated with a coal seam during open cast mining.

Mercury in Alberta's Sub-bituminous Coal

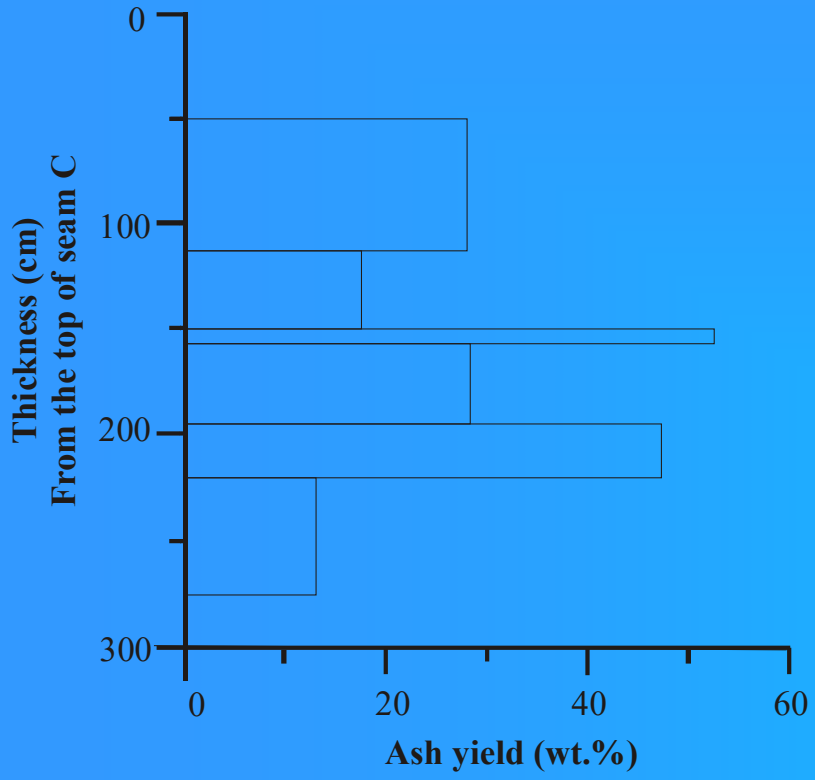


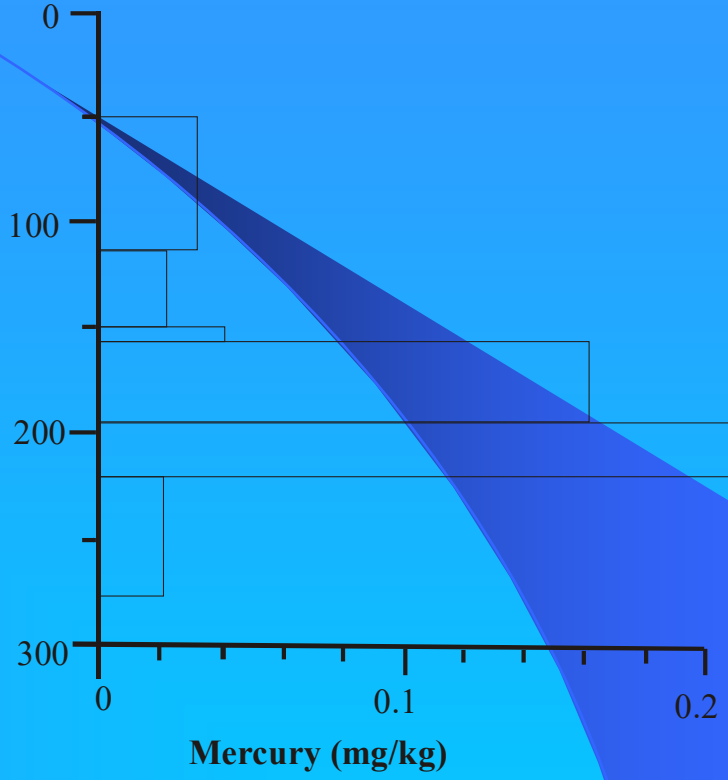
In seam variation of mercury (mg/kg) and % ash (in bracket) of a coal seam.

Mercury in Alberta's Sub-bituminous Coal



In seam variation of mercury (mg/kg) and % ash (in bracket) of a coal seam.





Concentration of mercury (mg/kg) and ash yield (wt.%) for a seam.

Variation of mercury (mg/kg) and ash content (%)in subbituminous coal a seam.

Description	Composition (As Received)		
Lithology	Thickness (cm)	Ash (%)	Hg (mg/kg)
1 Coal	64	27.48	0.031
2 Coal	36	17.16	0.021
3 Carbonaceous shale	6	52	0.043
4 Carbonaceous mudstone	40	28.22	0.162
5 Weathered friable coal	24	47.07	0.216
6 Coal	0.56	12.83	0.020
Weighted average for the whole coal seam	226	25.9	0.074
Weighted average for the whole coal seam after removal of 3,4, 5	156	20.1	0.025

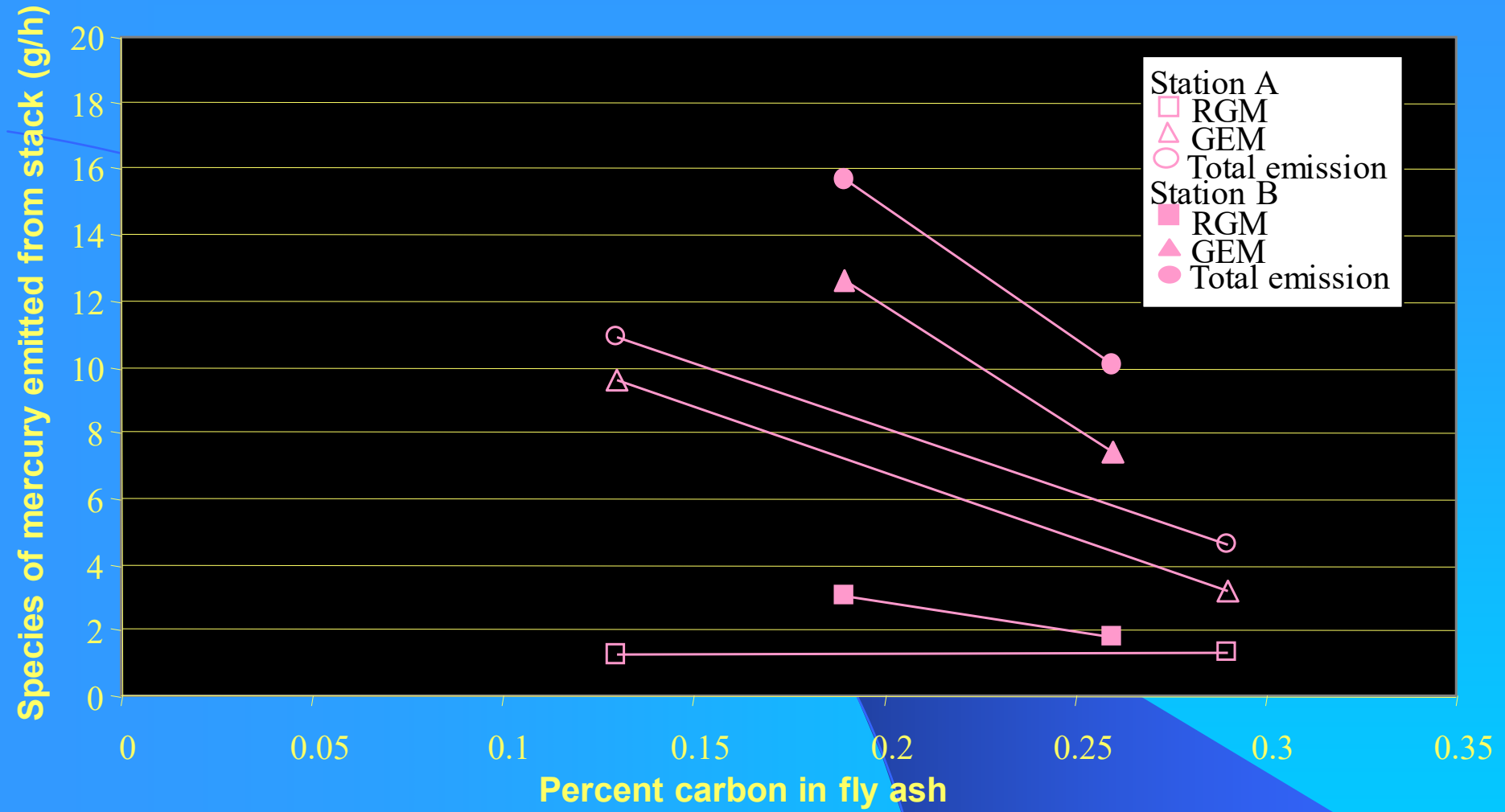
Reduction of Emitted Mercury

Mass balance (%) of mercury and fraction (%) found in flue gas and ash, speciation of stack emitted mercury (g/hr) and carbon content of fly ash (%) in stations A and B.

		Hg (%)		Hg (g/h)	Hg Speciation (g/h)			(%)
Station	Type of feed	Fraction in ash	Fraction in flue gas	Total emission	GEM	RGM	PM	Carbon content
A	seam	6.2	93.8	10.89	9.61	1.27	0.07	0.13
	selected	21.8	78.2	4.60	3.20	1.33	0.043	0.29
B	seam	13.5	86.5	15.66	12.62	3.03	0.01	0.19
	selected	23.2	76.8	10.07	7.36	1.77	0.60	0.26

TGM: total gaseous mercury
GEM: gaseous elemental mercury
RGM: reactive gaseous mercury
PM: particulate mercury

Reduction of Emitted Mercury –Influence of Selective Mining

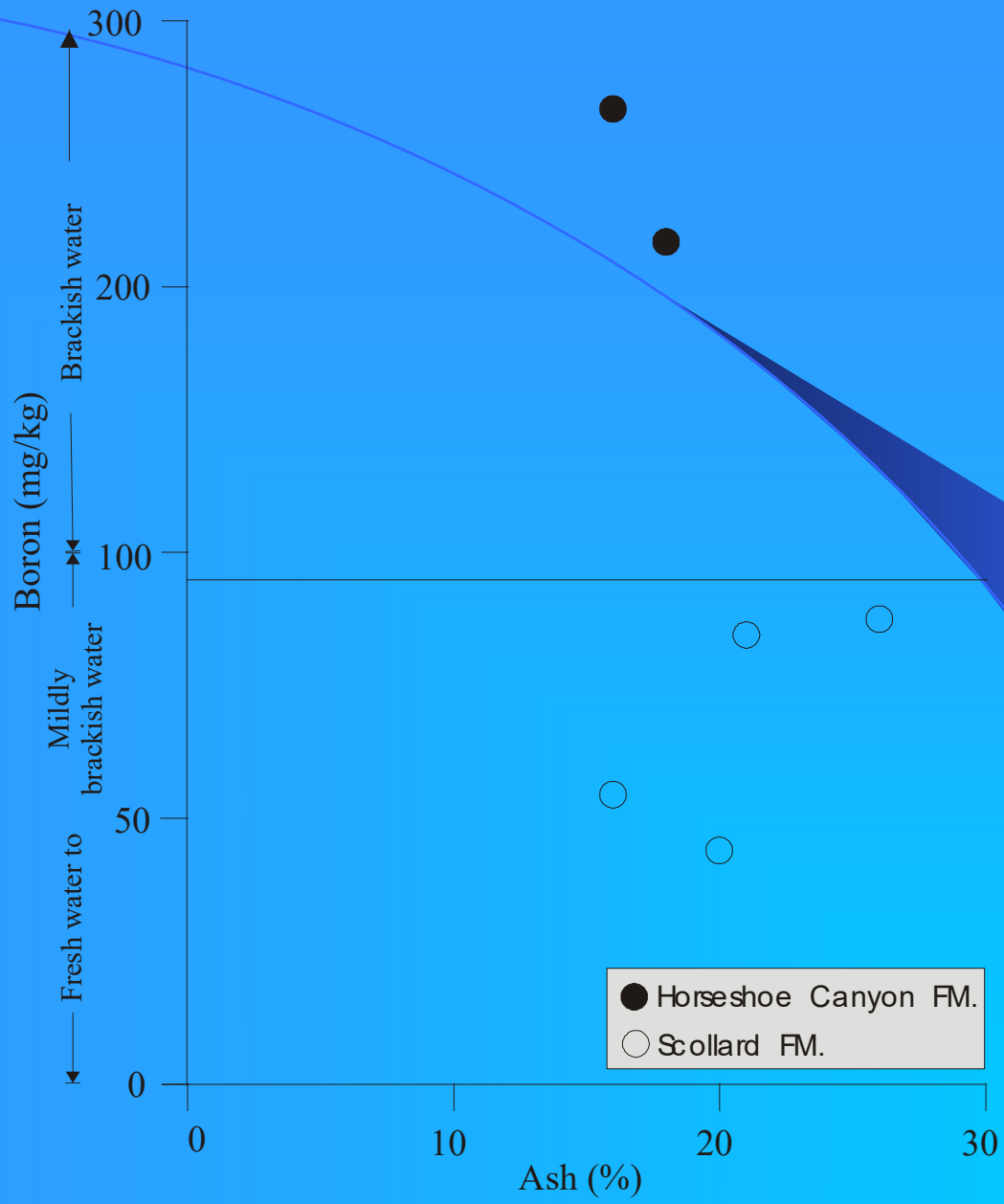


Reduction of Mercury –Influence of Selective Mining

We were able to reduce emitted mercury form 94 kg/y to 39 kg/y and from 135kg/y to 87kg/y by remove high mercury component of coal seams used as feed coal. Most of reduced mercury is from gaseous elemental mercury fraction

Factors influencing the reduction of mercury from Alberta power plants burning Sub-bituminous coal

- Coal Geology, depositional environment of coal
- Variation in organic matter and natural char content of coal



Variation of boron (mg/kg) content versus percent ash for western Canadian Sub-bituminous coals.

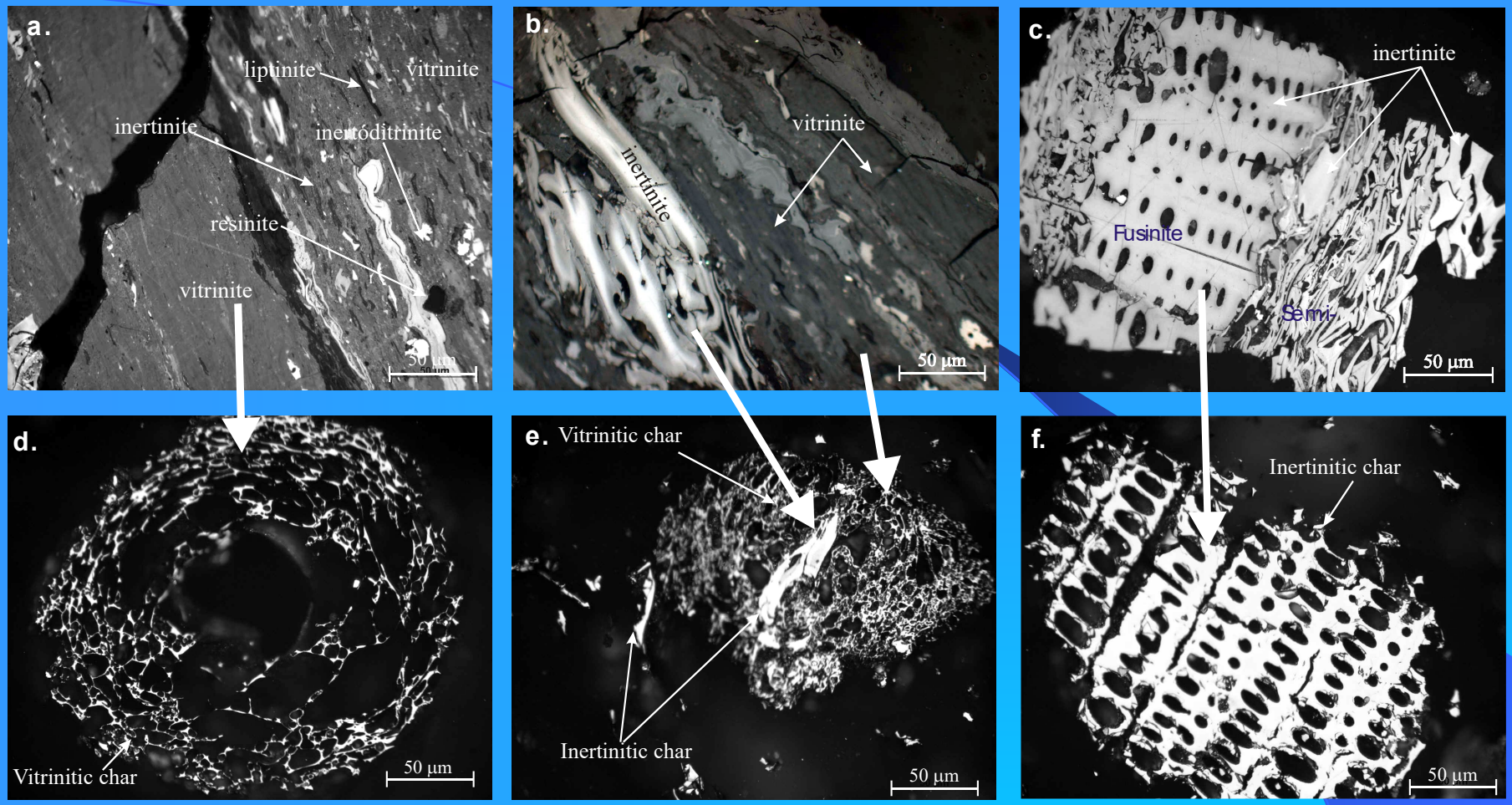
Variation of organic matter in sub-bituminous feed coals used in Alberta power plants.

Depositional Environment	Brackish		Freshwater		
Reactive					
Vitrinites (%)	76.2	75	54.2	46	48.5
Liptinites (%)	2.4	4.0	4.5	3.4	3.0
Less Reactive					
Inertinites (%)	14.2	14.0	35.4	37.6	43.8
Mineral Matter (%)	7.2	7.0	5.9	13.0	4.7

Comparison of boron (mg/kg), inertinite (%), and Hg (mg/kg) content of milled coal with carbon (%), and Hg content (mg/kg) of feed coal and ESP fly ash.

Depositional Environment		Station	Boron content of milled coal (mg/kg, dry basis)	Percent inertinite in milled coal	Hg content of milled-coal (mg/kg, dry basis)	Percent carbon in fly ash	Hg content in fly ash (mg/kg, dry basis)	Hg in flue Gas (%) (normalized to 100%)
Brackish**	Group A	1	217	14.0	0.066	0.13	0.094	94
		2	266	14.2	0.053	0.26	0.061	86
Fresh Water*	Group B	3	75	35.4	0.058	0.52	0.131	60
		4	69	43.8	0.075	2.72	0.157	58
		5	49	43.6	0.074	1.32	0.24	42
	Group C	6***	51	37.6	0.051	1.27	0.005	97

*Scollard Formation; **Horseshoe Formation; ***Hot side ESP

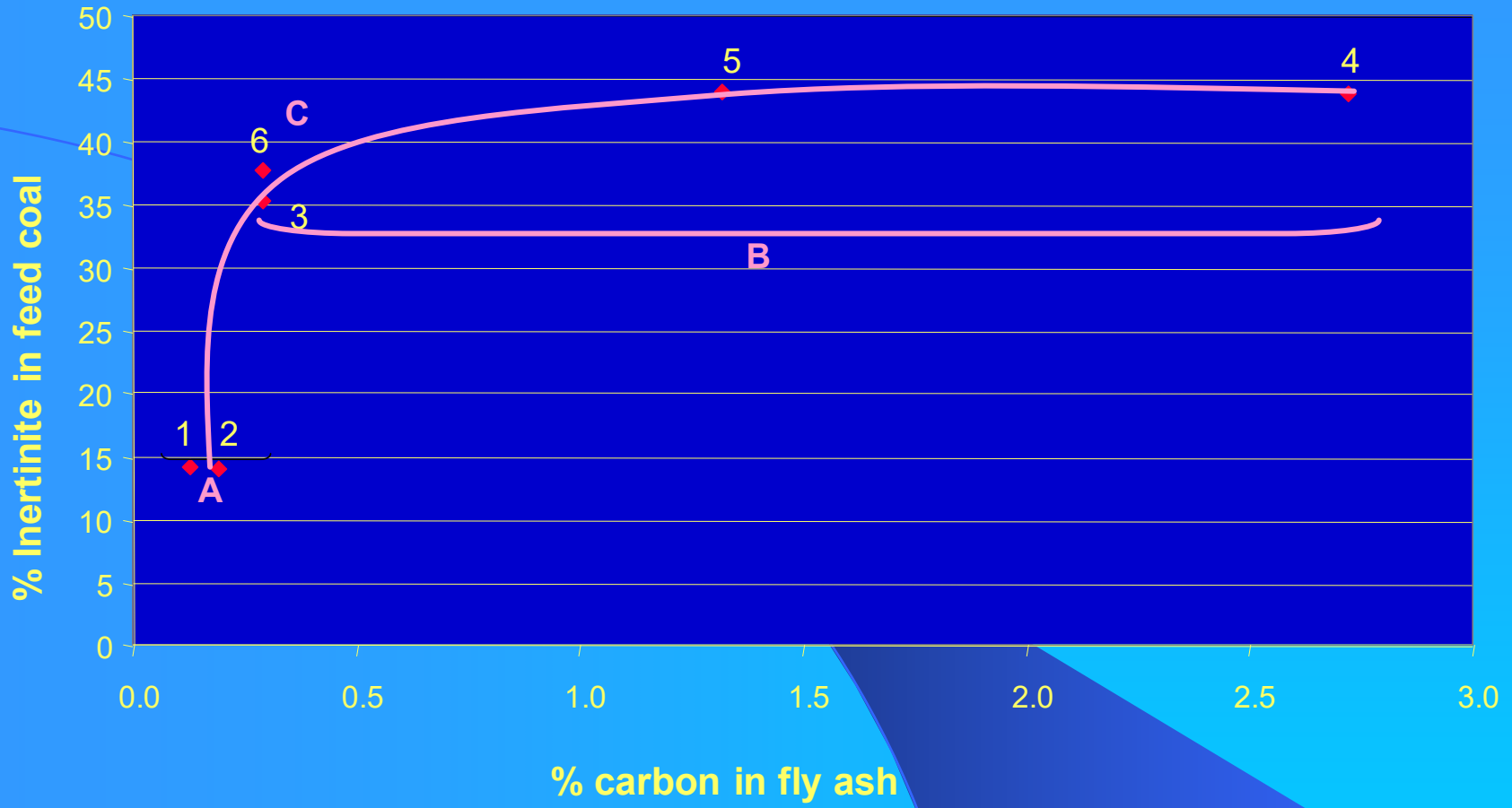


Transformation of Organic matter from feed-coal to char in fly ash.

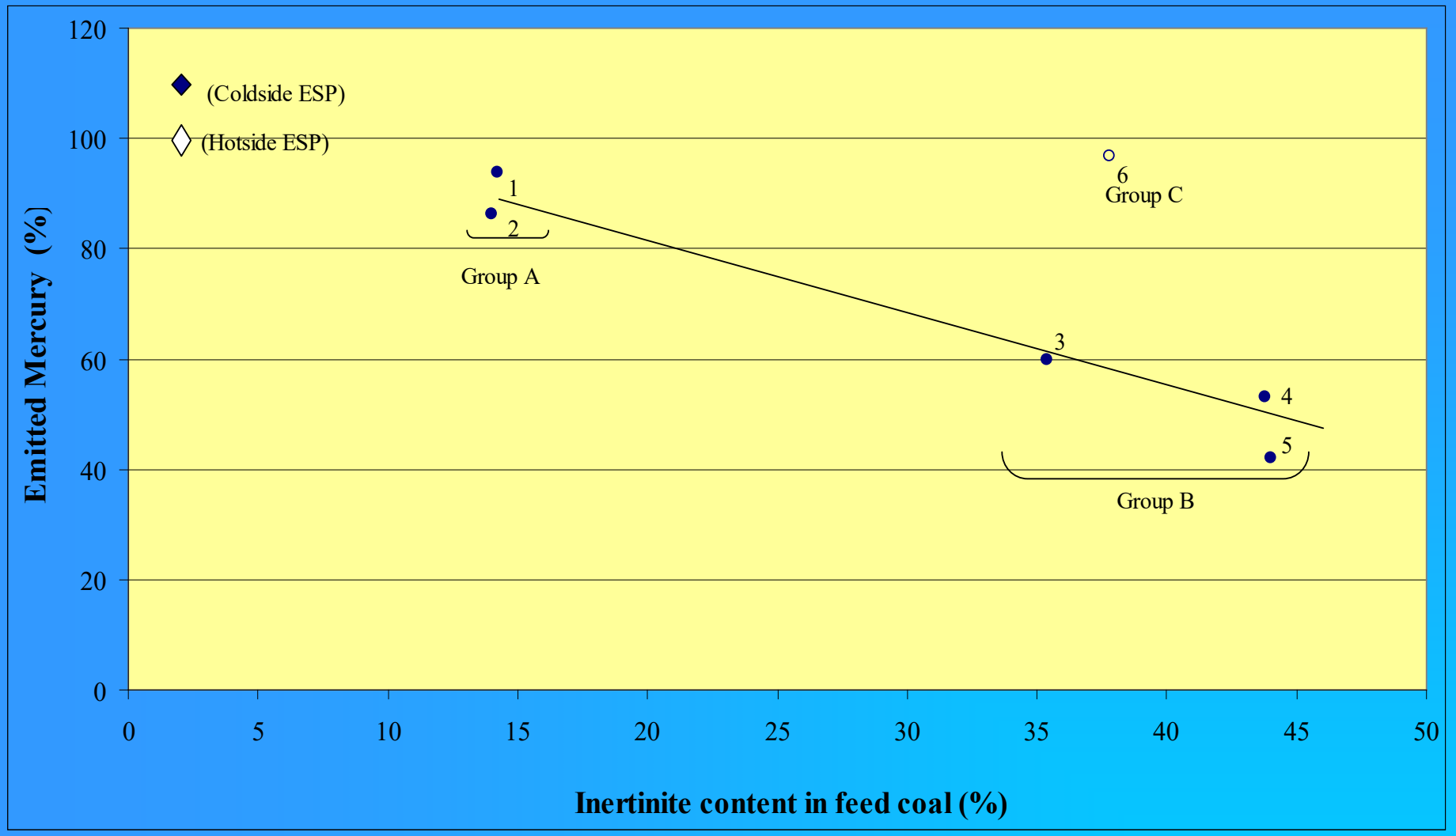
a. The reactive organic matter produce a spongy char with large surface area coal

b. A combination of reactive and natural char produces a char with less spongy appearance that contains inertinitic particles.

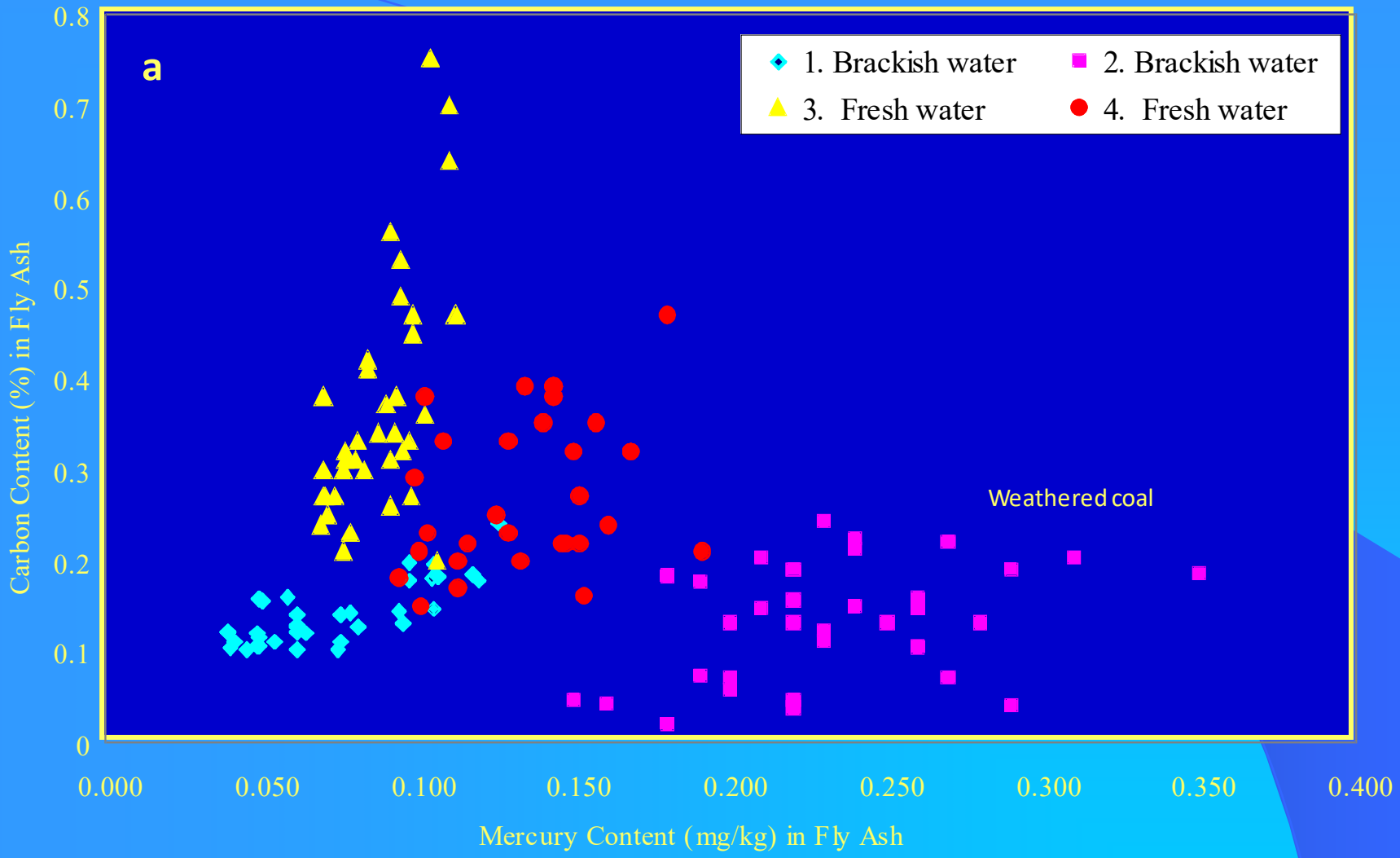
c. Natural char (inertinite) remains almost unchanged after combustion.



Variation of inertinite in feed coal (%) with carbon content in fly ash (%) for Alberta power plants



Variation of mercury content in emitted from stack with inertinite content in feed coal for Alberta power plants.



Variation of mercury content (mg/kg) with carbon content (%) of fly ashes for feed coals from two different depositional environments (1 and 4).

The mitigation strategies for reduction of Hg prior to combustion

Role of carbon (char) in capture of Hg.

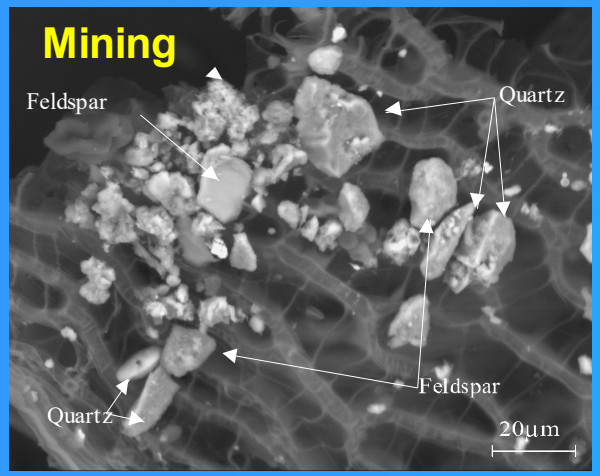
Char in fly ash can capture up to 60% of input of mercury

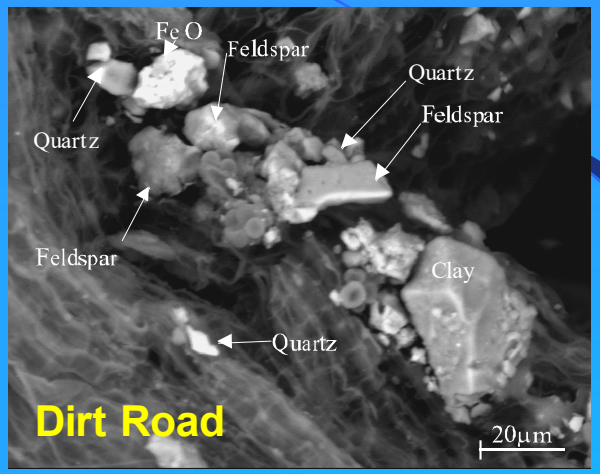
Particles/elements emitted from coal fired power plants

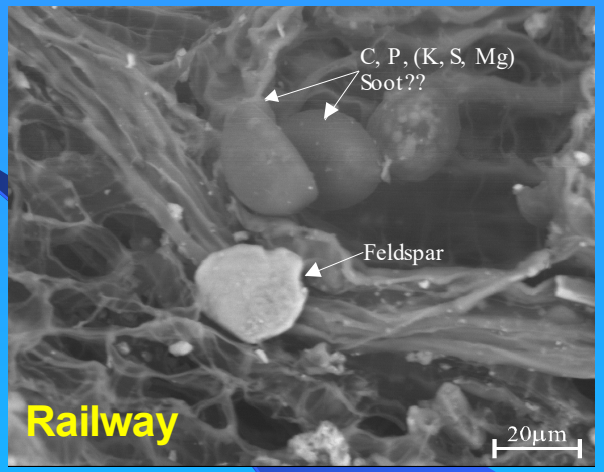
Particles emitted from Canadian power plants and smelters

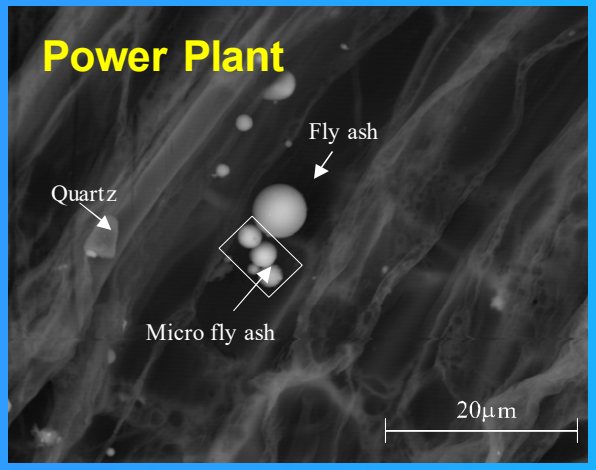
- Total particles
- $PM^{2.5}$
- PM^{10}
- $PM^{>10}$
- Contaminations
- Malfunction
- Compliances with guideline

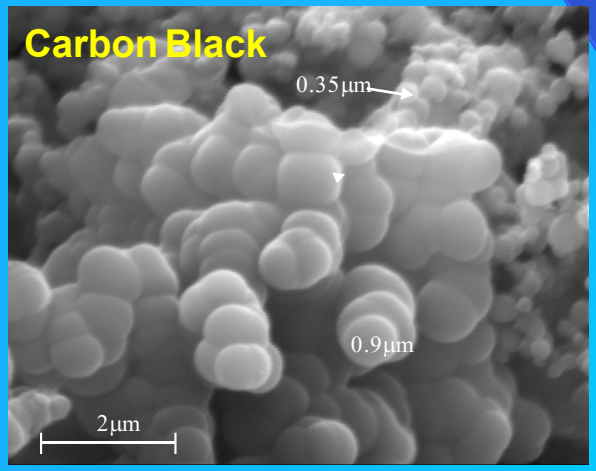
Particle In Nature



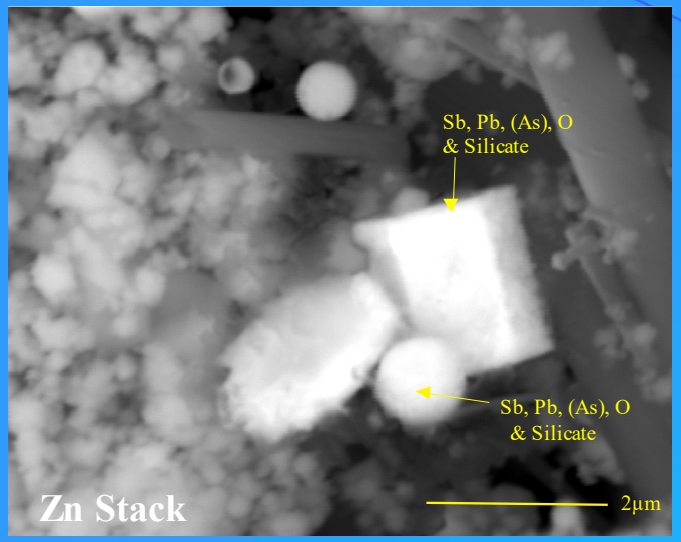


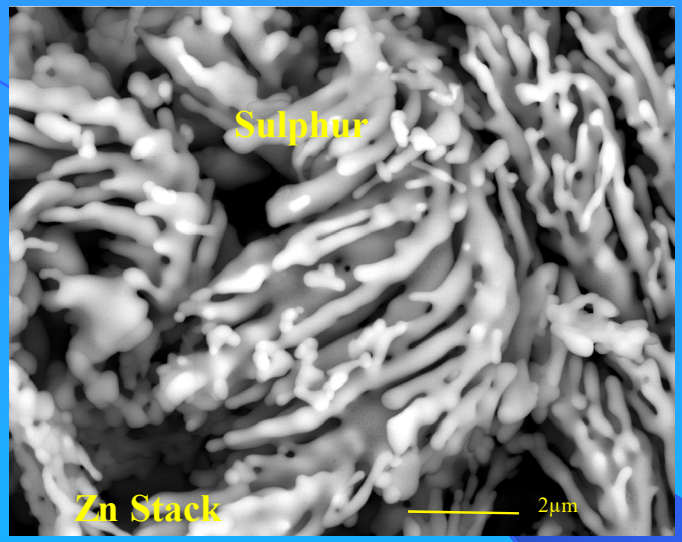


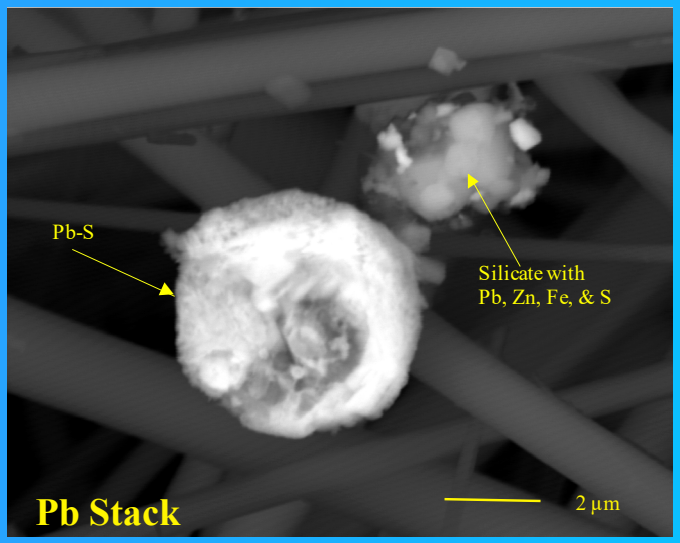


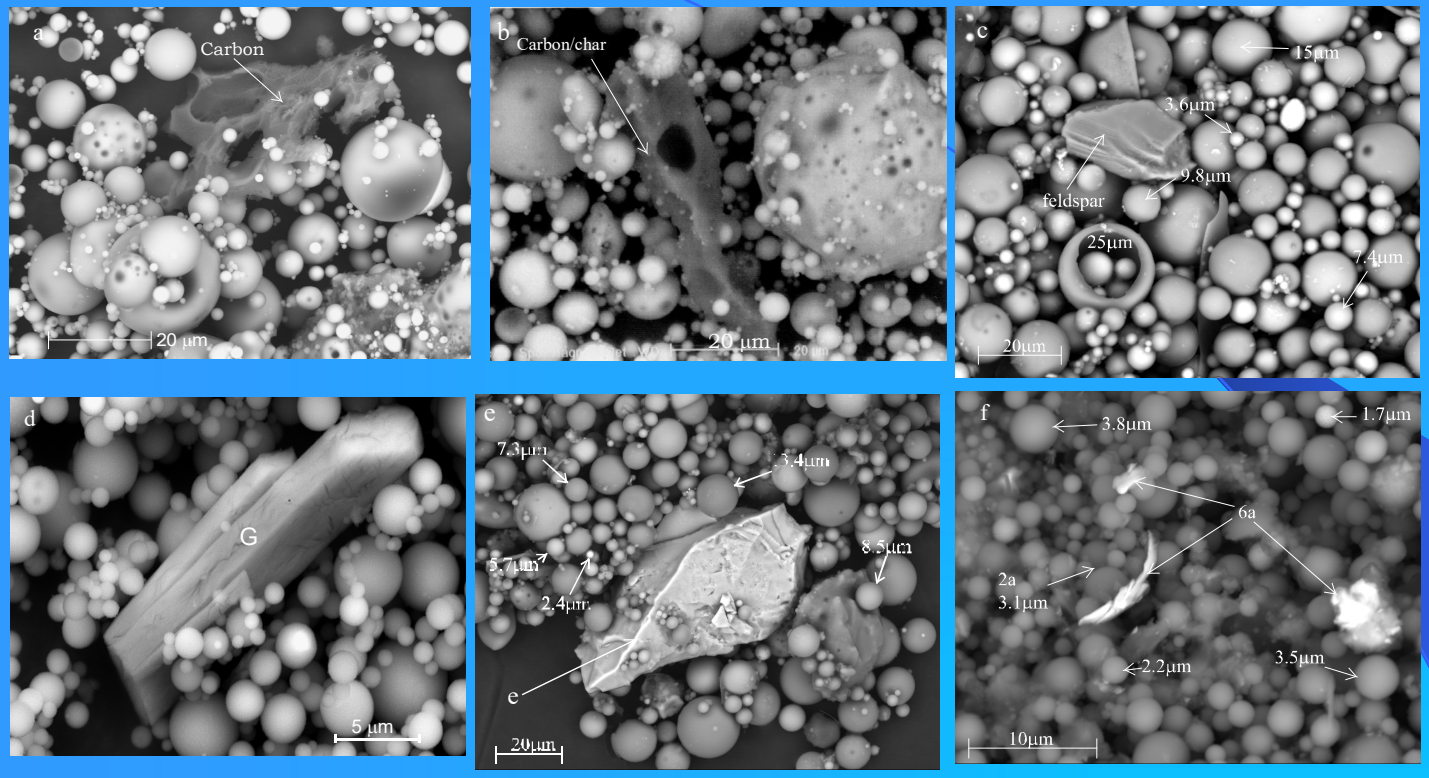


Particle Emitted from Pb-ZN Smelter

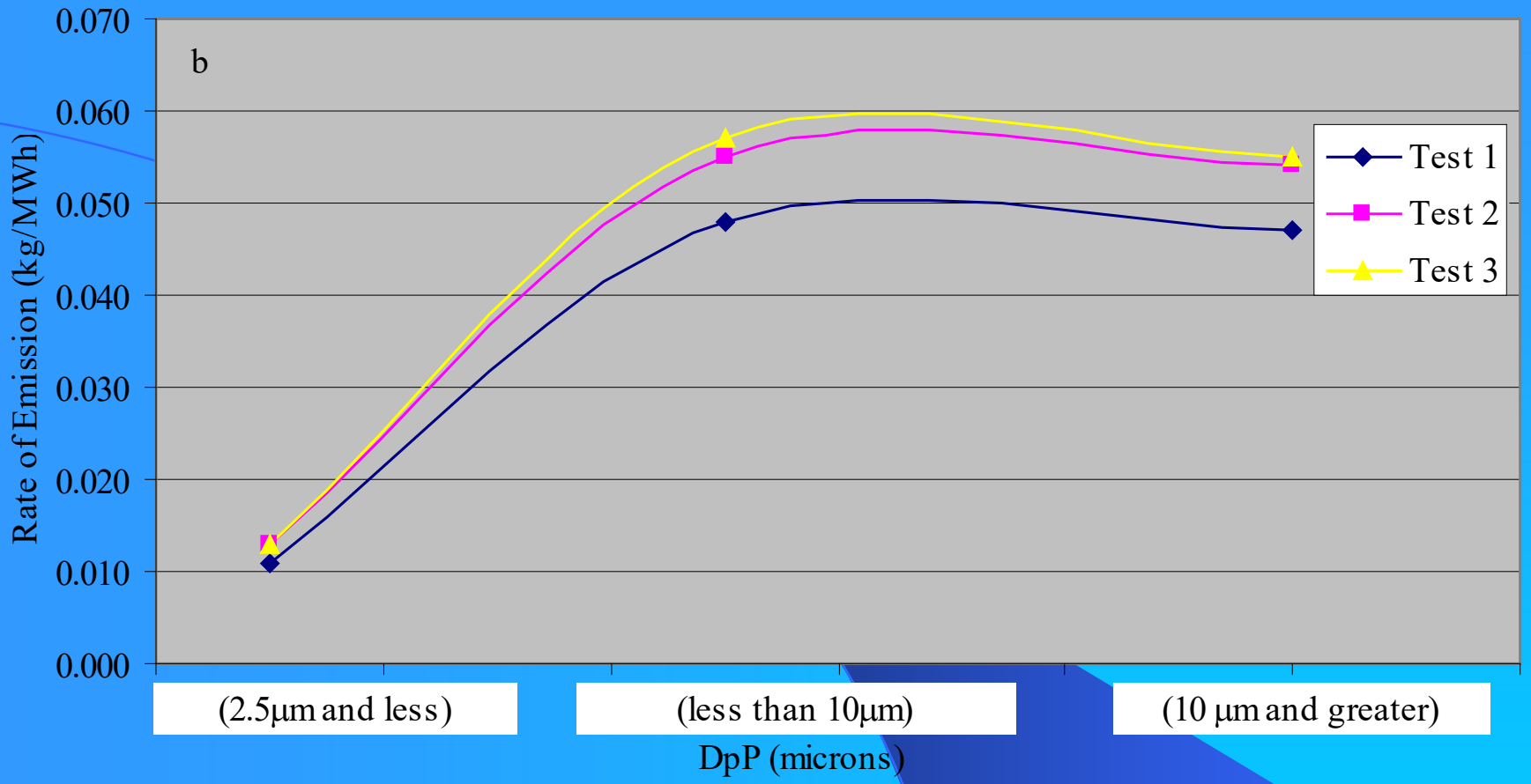


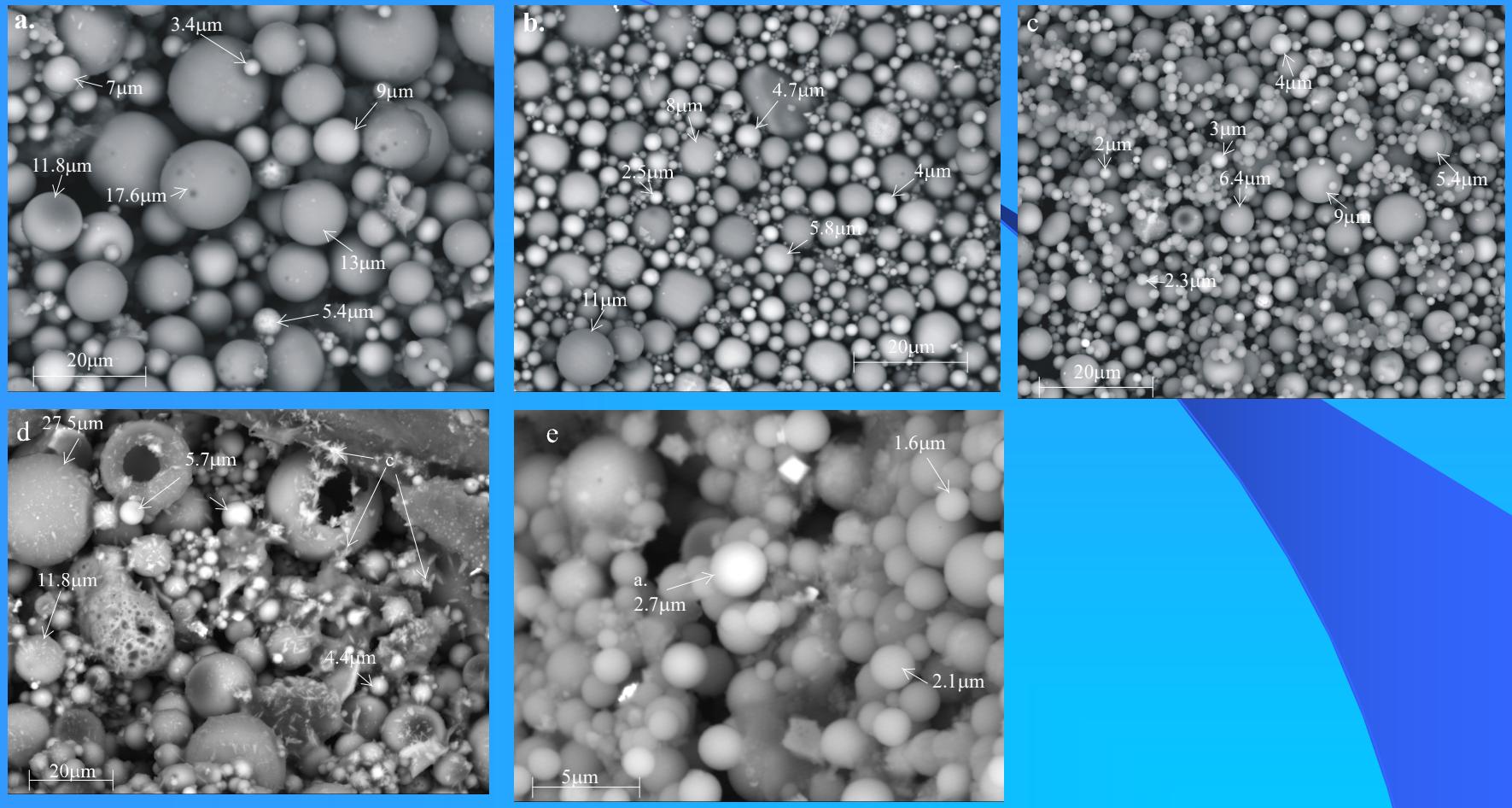






Typical particles emitted from the a coal-fired power plants. SEM/EDX, carbon coated, natural surface.


b
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
Rate of Emission (kg/MWh)
Test 1
Test 2
Test 3
(2.5µm and less)
(less than 10µm)
(10 µm and greater)
DpP (microns)



Particle size (PM) distribution in stack gas emitted from Station A as determined using EPA Method 201A sample train (modified to include $PM_{2.5}$) and SEM/EDX, carbon coated, natural surface. a. $PM_{>10}$ fractions contain particles 17.6µm and less. b. PM_{10} fraction contains particles 11µm and less. d. $PM_{2.5}$ fraction contains particles 9µm and less. e. Hollow sphere (cenospheres). e. $PM_{2.5}$ fraction consists mostly of spherical particles of 3.1µm and less.

Calculated emissions of elements from the stack in grams/hour (g/h) with enrichment indices

Elements	$PM_{>10}$ g/h	RE**	PM_{10} g/h	RE	$PM_{2.5}$ g/h	RE	Sum g/h
Elements of Prime Environmental Concern							
As[1]	0.18	0.57	0.37	1.18	1.27	4.04	1.82
Cd[1]	BD[a]	NA[b]	BD	NA	0.07	1.32	0.07
Cr[2]	0.75	0.33	2.3	1.01	3.11	1.35	6.2
Cu[1]	BD	NA	BD	NA	0.91	0.46	0.91
Mo[1]	BD	NA	BD	NA	1.97	0.74	1.97
Ni[1]	0.23	0.19	2.8	2.2	10.4	8.4	13.4
Pb[1]	0.49	0.21	0.98	0.42	1.11	0.47	2.6
V[2]	0.2	0.06	0.9	0.26	5.28	1.51	6.4
Zn[1]	101.7	23.5	8.4	1.9	4.3	1	114

Results

The total particles emitted from coal-fired power in this studies are:

0.041, 0.044 kg/MWh for the modern power plants which is below guideline of 0.095 kg/MWh.

However, older power plant emits 0.118kg/MWh.

New direction

Pathway and Impact of Toxic Substances from Anthropogenic and Geogenic Sources on Canadian Land (*water and soil*) and Their Health Implication

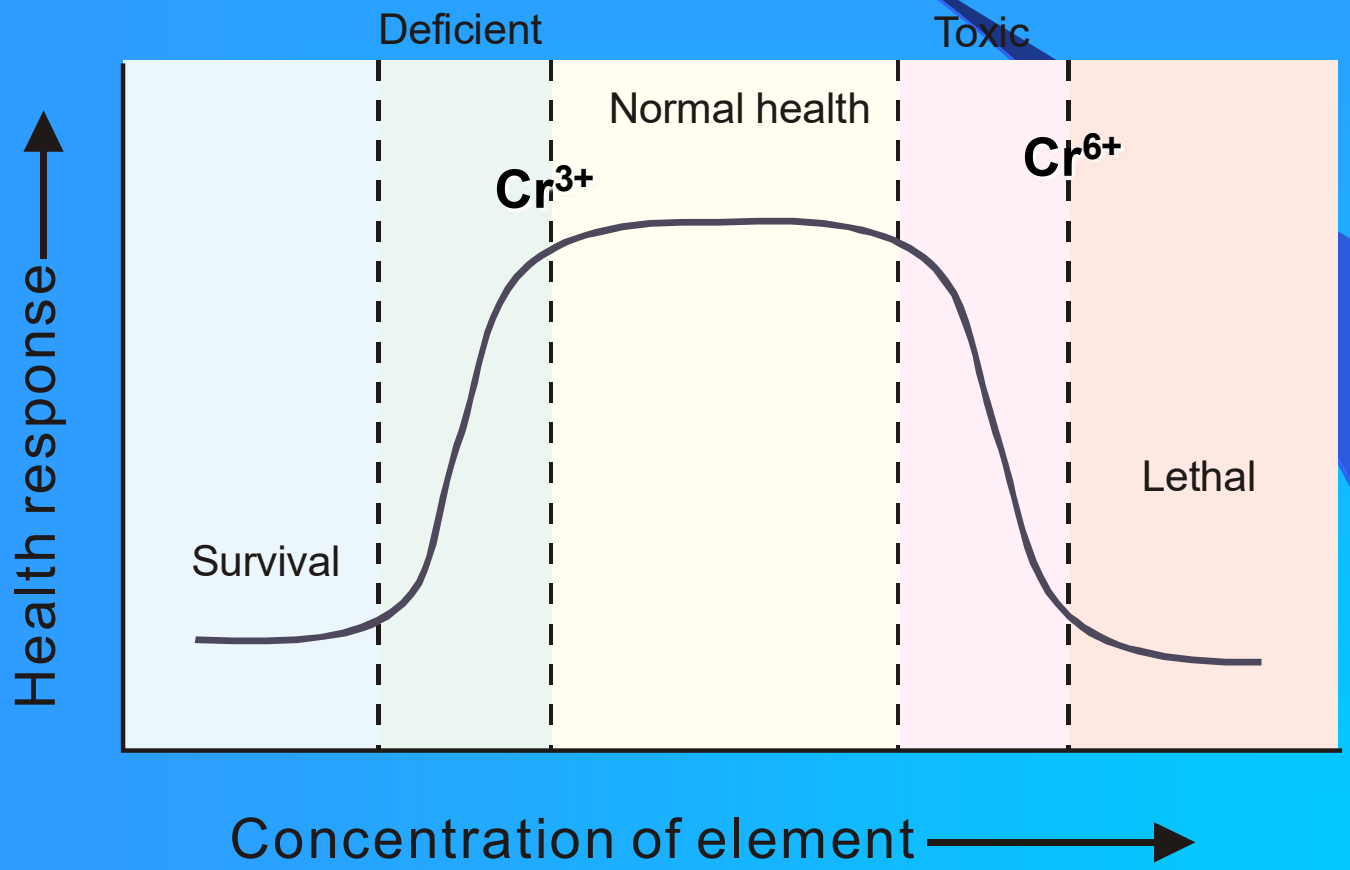
What Next

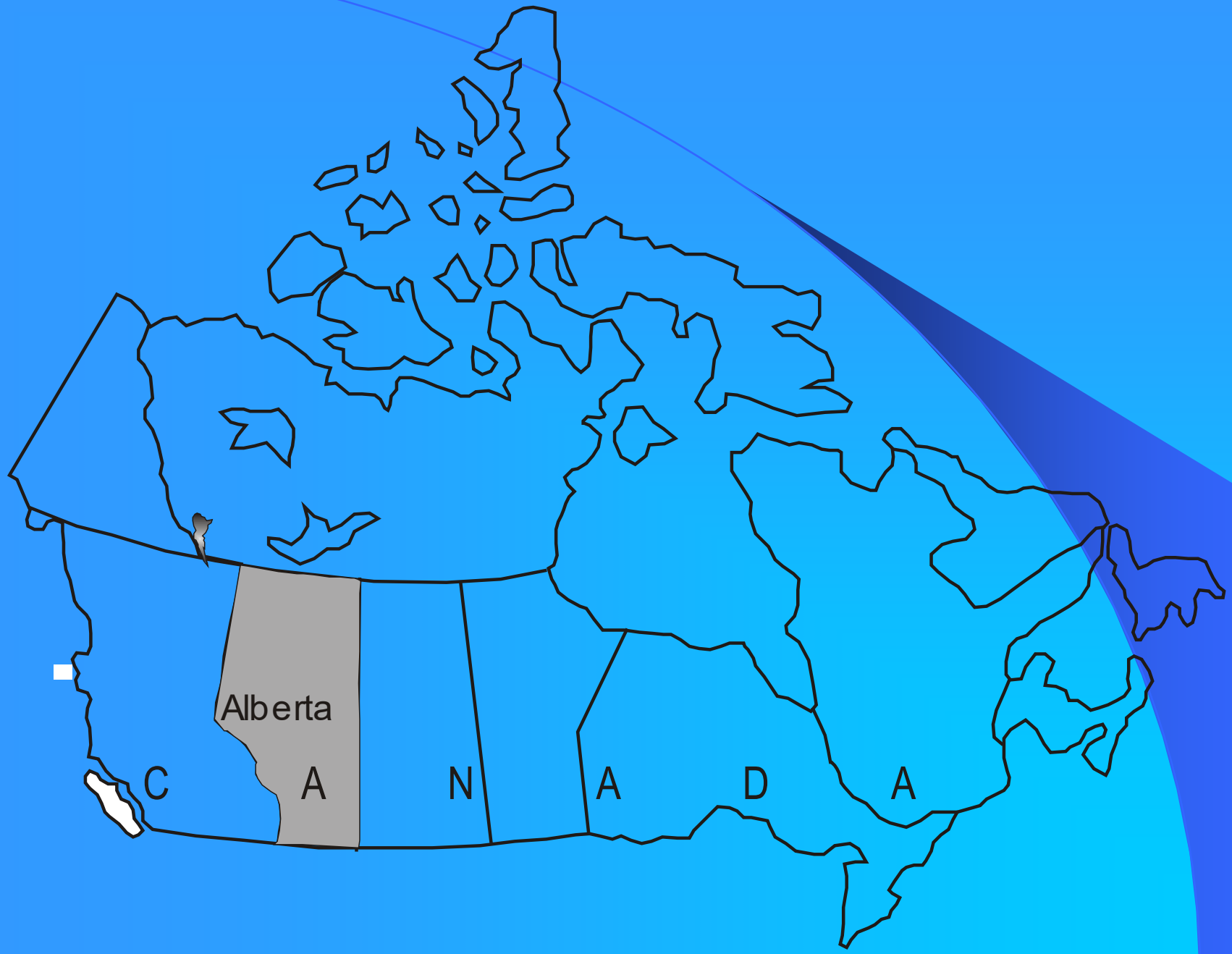
The Health and Environment Program

Moving forward towards what we thought could and should be done in second phase of MITE

- Determination of the anthropogenic and geogenic flux of elements and particles on Canadian land (soil) and water (lakes and stream), their health implication, and including, a transact from Alberta to Yukon, Arctic and Ice-cores study.
- Participation in the second phase of Canada-wide study of mercury emitted from coal fired power plant-reduction.
- Health impact study (elements & PAHs) of produced water from CBM and Tight Gas exploration and self burning coal seams
- Participation in Environmental Assessments studies
- International activities and transfer of knowledge as related to health hazard elements (Hg As, Cr) in China , India, Greece, The Netherlands and USA.

Health effects of elements (Swaine and Goodarzi 1995)




Alberta
C A N A D A