Addressing Commercialization Issues for an Ex-Situ Oil Shale Process by Addressing Critical Operational Issues

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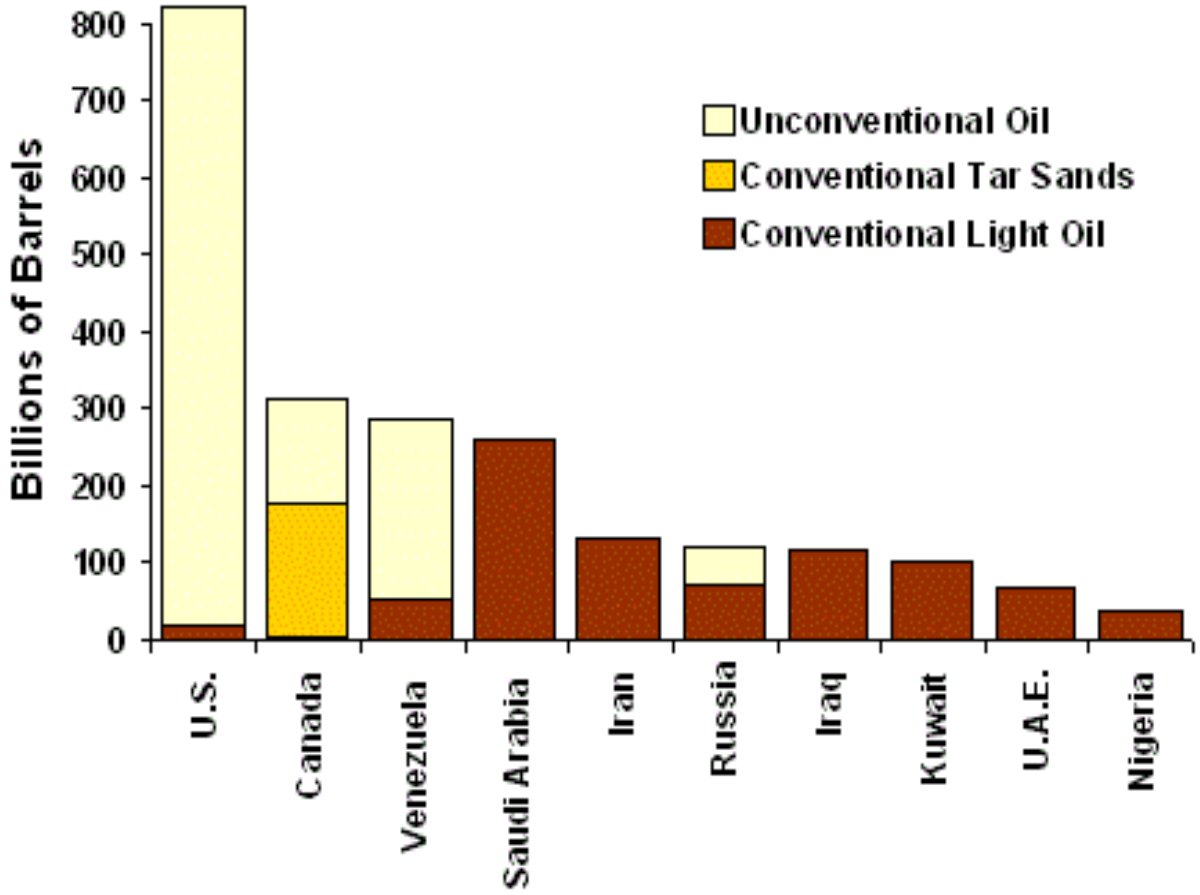
Outline

- Introduction
- Spent Oil Shale Leaching Background
- Leaching Methodology
- Test results
- Future Work
- Conclusion

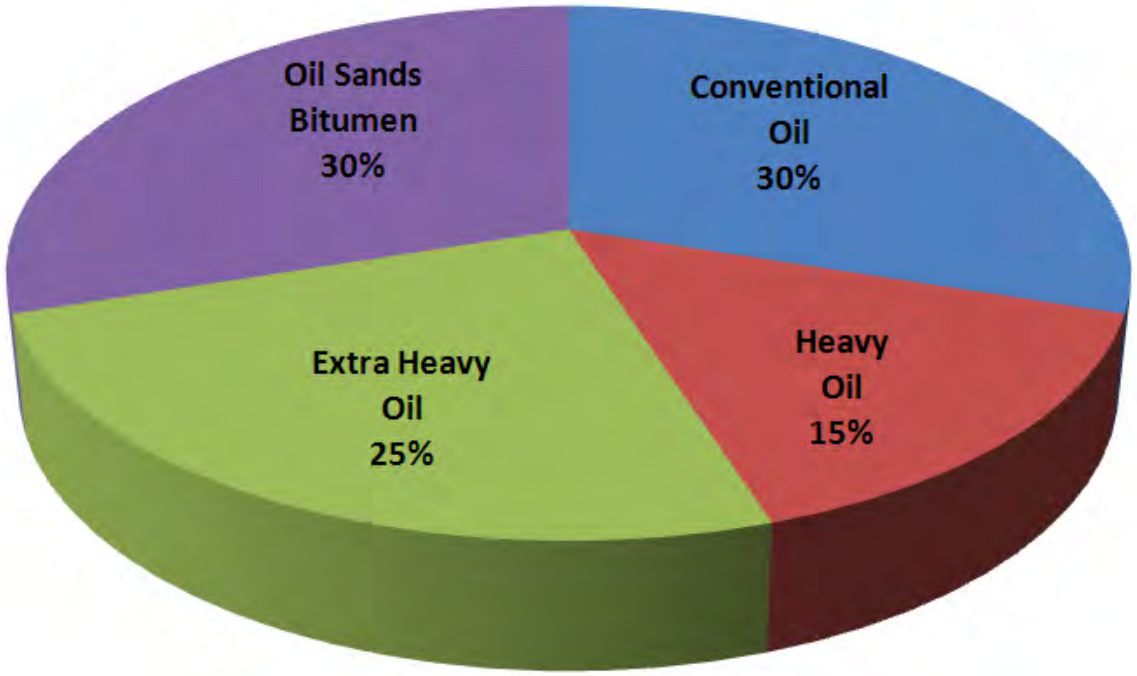
Total world oil reserves

Unconventional Vs. Conventional



Taken from: "Conventional light oil reserves", *World Oil*, Vol. 227, No. 9 September (2006)

Total world oil reserves



Ref. Alboudwarej, H., Felix, J., Badry, R., et.al., “Highlighting Heavy Oil”, *Oilfield Review*, Summer (2006).

Oil Shale Ex-Situ & In-Situ Methods

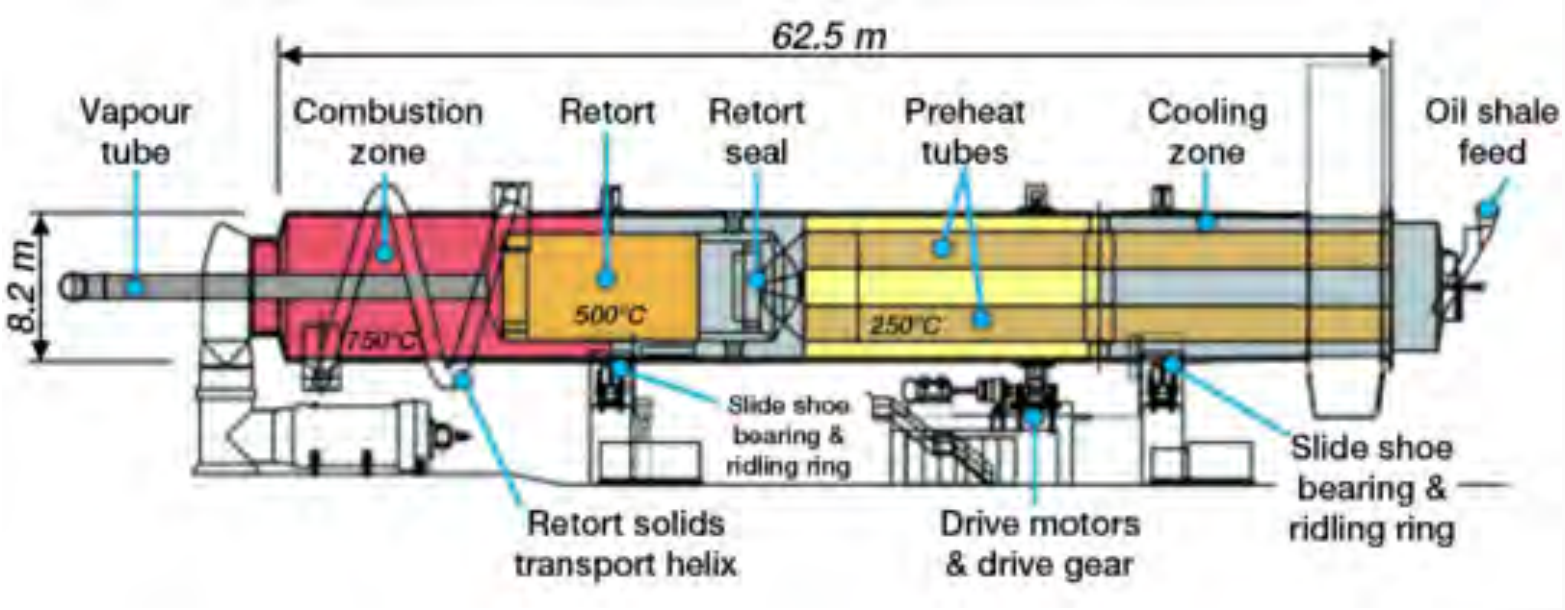
In-situ Process:

- Shell's In-Situ conversion process (ICP)
- ExxonMobil's Electrofrac process
- Petro Probe superheated air method and
- IEP Geothermal Fuel Cell (GFC)

Ex-situ Process:

- Hot Water Extraction
- External Hot Gas
- Indirect Heating and
- Internal Combustion

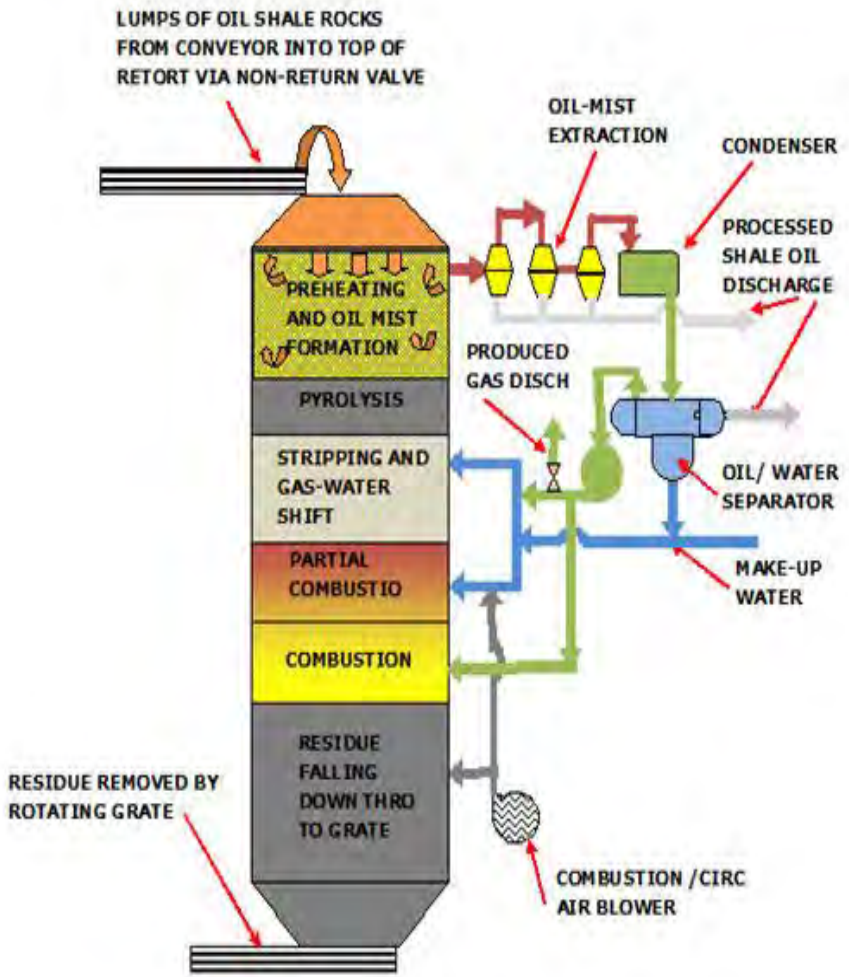
Horizontal Retort



Alberta Taciuk process (ATP), Horizontal oil-shale retorting

From: Qian, J., Wang, J. "Recent Trends In Oil Shale", RTOS-A118, *International Conference on Oil Shale*, Amman, Jordan, 7 -9 November (2006).

Vertical Retort



Vertical Gas Combustion Retort

From: DOE Office of Petroleum Reserves – Strategic Unconventional Fuels – Fact Sheet

What does Leaching mean?

Spent oil shale leaching?

Why is it so important?

Two-Step Analytical Methodology
1. Extraction
2. Leaching

Queensland oil shale mine

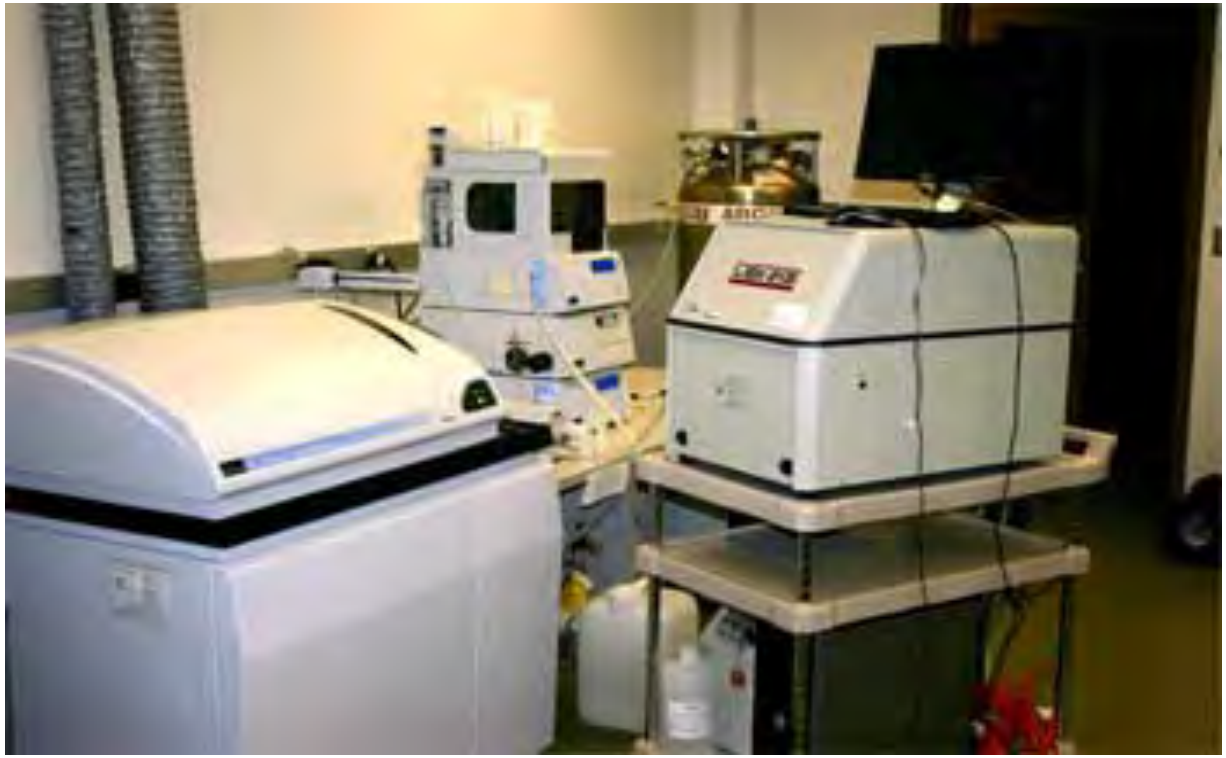
Ash disposal area of Eesti Power Plant

Environmental Issues

EPA Extraction & ASTM leaching methods

Leaching Methodology

- Increasing the leachate pH
- Changing ratio of solid to liquid



Inductively Coupled Plasma Mass Spectrometry (ICP-MS)

Metals concentration in blanks

Sample ID	Concentrations in (ppb)											
	Be	Cr	Ni	Cu	Zn	As	Se	Cd	Sb	Ba	Pb	Ti
Blank pH 5	<DL	<DL	1.98	0.27	<DL	<DL	<DL	<DL	<DL	0.23	<DL	<DL
Blank pH 4	<DL	<DL	1.13	0.61	1.95	<DL	<DL	<DL	<DL	0.62	0.09	<DL
Detection Limit	0.02	1.5	1.00	0.2	1.00	0.2	1.00	0.02	0.2	0.05	0.05	0.05

Case 1, pH=4 and Solid to Liquid ratio=1/10

Sample ID	Concentration (ppb)					
	Be	Cr	Ni	Cu	Zn	As
1/10 & pH 4	0.04	<DL	2.00	0.85	<DL	32
Spike 20ppb	14.87	17.34	17.38	16.32	17.77	55.04
Spike recovery%	74.35	81.66	77.12	77.33	86.26	105.01

Sample ID	Concentration (ppb)					
	Se	Cd	Sb	Ba	Pb	Tl
1/10 & pH 4	9.6	1.57	12.78	123	0.08	0.05
Spike 20ppb	31.68	22.01	33.80		18.32	25.24
Spike recovery%	118.55	103.08	108.01		91.52	126.00

Case 2, pH=4 and Solid to Liquid ratio=1/20

Sample ID	Concentration (ppb)					
	Be	Cr	Ni	Cu	Zn	As
1/20 & pH 4	0.03	<DL	1.15	0.68	<DL	35
Spike 20ppb	16.64	16.19	16.34	15.42	17.65	56.14
Spike recovery%	83.19	77.48	74.86	73.65	86.49	93.73

Sample ID	Concentration (ppb)					
	Se	Cd	Sb	Ba	Pb	Tl
1/20 & pH 4	6.9	0.82	7.61	103.7	<DL	<DL
Spike 20ppb	30.15	21.12	27.61		16.45	22.05
Spike recovery%	114.92	101.63	102.35		82.08	110.12

Case 3, pH=5 and Solid to Liquid ratio=1/10

Sample ID	Concentration (ppb)					
	Be	Cr	Ni	Cu	Zn	As
Spike 20ppb	13.72	16.52	16.77	15.60	16.72	48.07
Spike recovery%	68.56	79.22	74.82	73.98	81.82	103.63
1/10 & pH 5	<DL	<DL	1.76	0.85	<DL	29

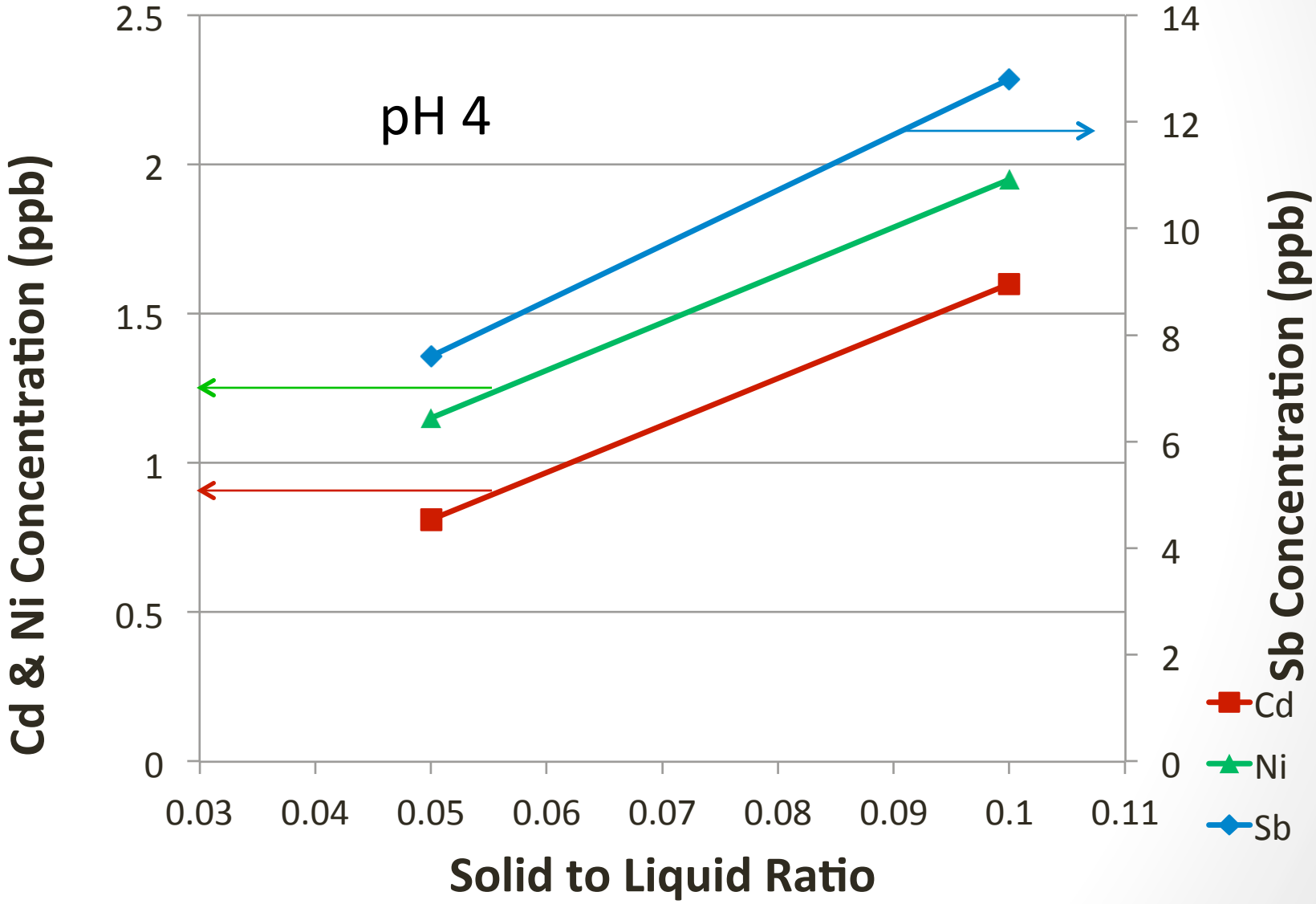
Sample ID	Concentration (ppb)					
	Se	Cd	Sb	Ba	Pb	Tl
1-10 pH 5 A	10.5	1.55	14.11	125.18	0.08	0.07
Spike 20ppb	33.60	21.85	34.33		17.58	24.22
Spike recovery%	117.20	100.58	104.19		87.74	120.90

Case 4, pH=5 and Solid to Liquid ratio=1/20

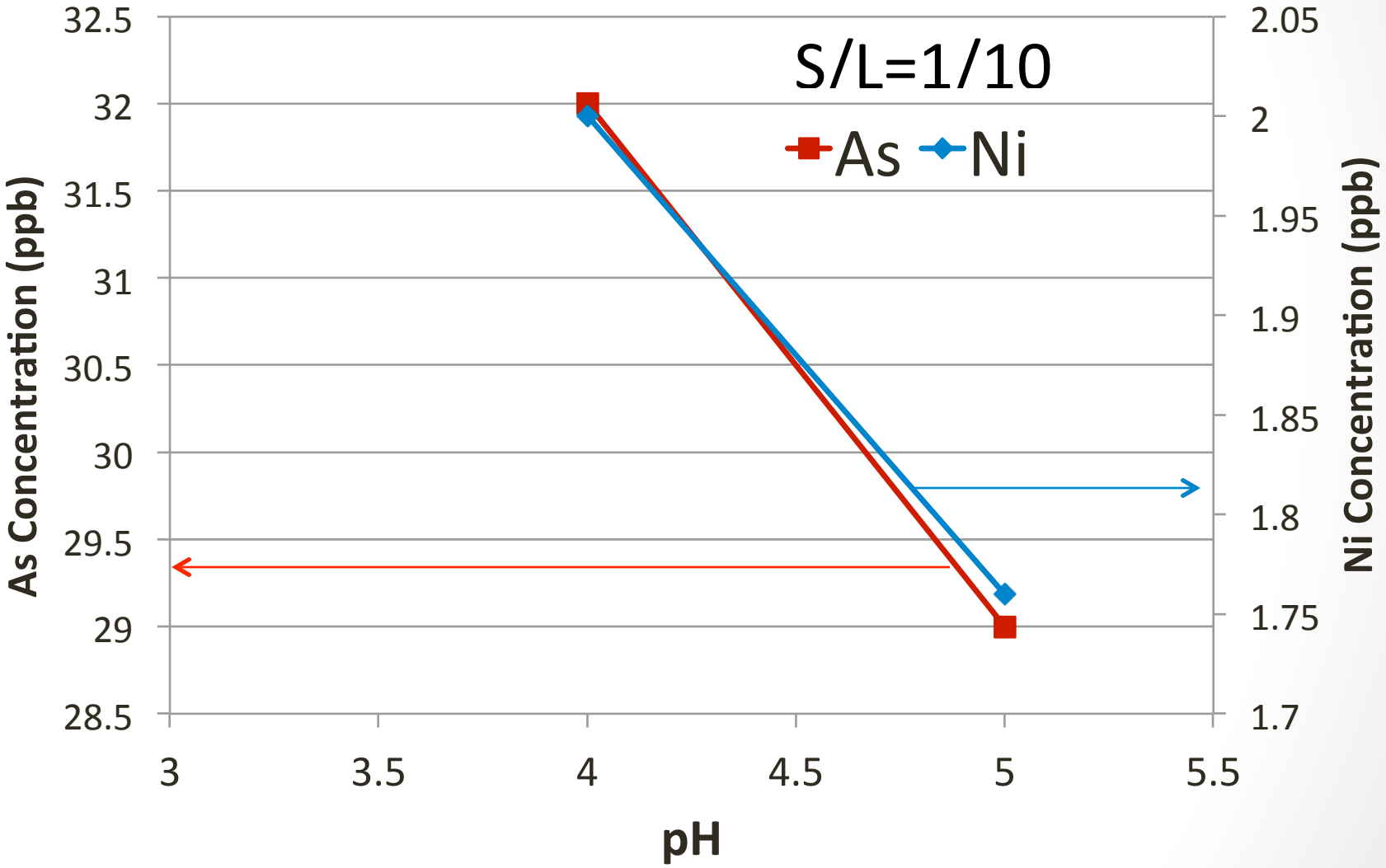
Sample ID	Concentration (ppb)					
	Be	Cr	Ni	Cu	Zn	As
1/20 & pH 5	<DL	<DL	1.08	0.57	<DL	34.2
Spike 20ppb	15.63		16.30	15.47	17.16	58.24
Spike recovery%	78.17		76.26	74.01	84.32	110.19

Sample ID	Concentration (ppb)					
	Se	Cd	Sb	Ba	Pb	Tl
1-20 pH 5 A	6.46	0.83	7.81	112.2	0.05	<DL
Spike 20ppb	32.50	21.56	29.99		15.87	21.91
Spike recovery%	125.07	103.55	106.40		79.06	109.39

Ni, Cd & Sb Concentration vs. Solid to Liquid Ratio in Constant pH 4



Ni and As concentration vs. pH in constant S/L

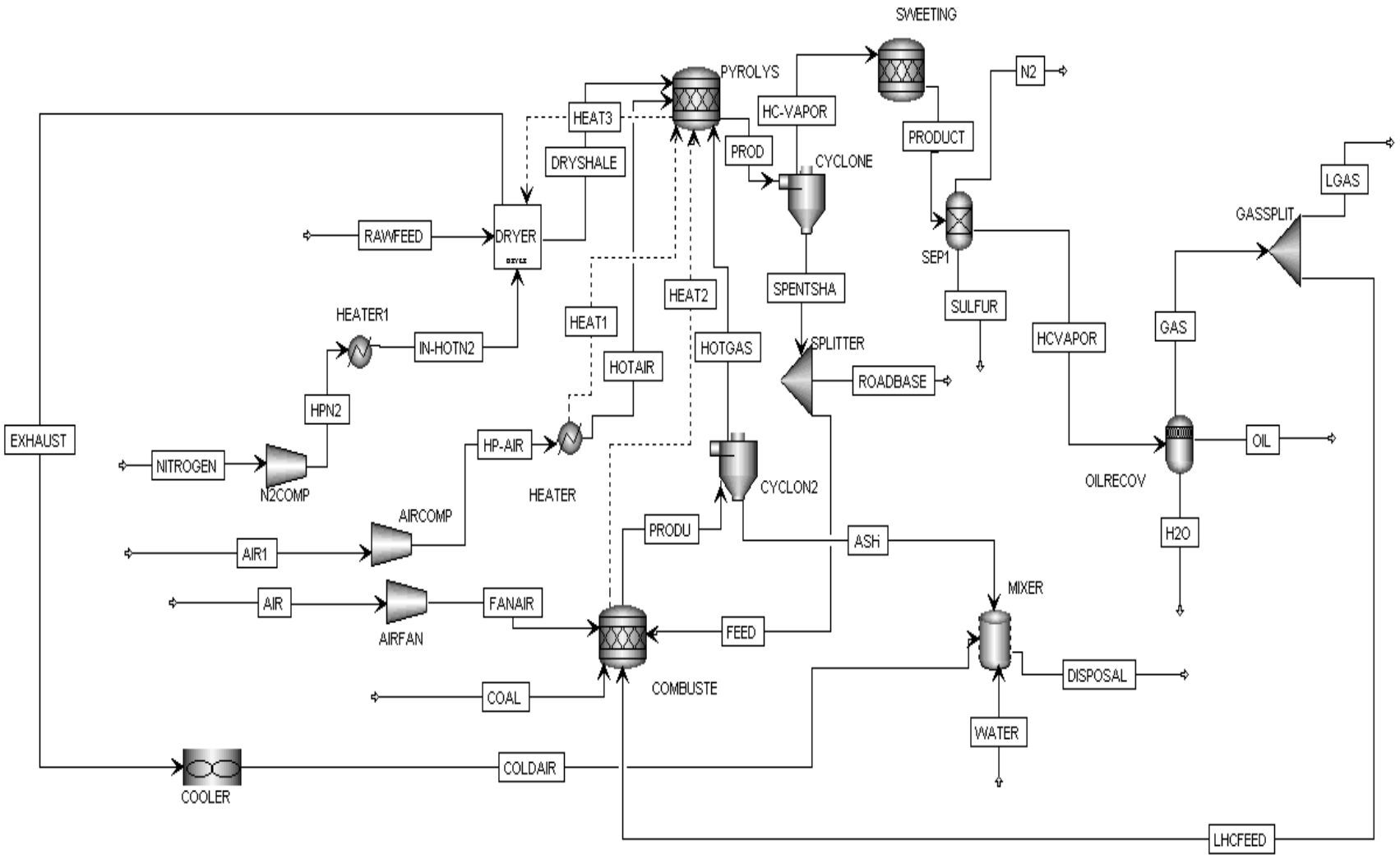


Commercializing the Oil Shale Process

Develop ASPEN Process Model to:

- Establish general process description and block flow diagram.
- Provide a summary of the process with energy efficiency
- Estimate Process cost per unit of product
  - cost of water,
  - electricity, and
  - other utilities per unit of product.

Future Work: Overall Oil Shale Vertical Retort Using Aspen Plus



Conclusion

Mechanical Issues:

Key issues that affect online reliability and process efficiency include:

- 1) particle size effect on extraction efficiency
- 2) control of kiln bed temperature (i.e., bed heat transfer)
- 3) solids/gas mixing efficiency
- 4) Particle size effect on extraction efficiency

Conclusion

Environmental Issues:

- The leachability of heavy metals in spent oil shale was studied and its importance as an environmental issue.
- The results of leaching tests illustrated the impacts of solid-to-liquid ratio and increasing pH on the leachability of heavy metals and their concentration in the leachate.
- Future work will include further development of an Aspen process model.

Thank you

Questions or Comments?