Alternatives to Organic Liquids for use during Coal Exploration

Producing Clean Coal from Western Canadian Coal Fields using the Water-based Boner Jig Process

Canadian Carbonization Research Association and Geoscience BC

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Traditional method for washing small scale exploration samples is the Float/Sink Method – ASTM D4371

- Depends on different sample types: type of cores, reverse circulation
- Screened into specific sizes according to the needs of the client.

Traditional Liquids Used:

- Heavy Liquids: Methylene Bromide (SG 2.47) or Bromoform (SG 2.89)
- Medium Liquid: Tetrachloroethylene / Perchloroethylene (SG 1.62)
- Light Liquid: VMP Naptha (SG 0.75)
- Mix together to produce a spectrum of specific gravities, for example from 1.30 to 1.90 SG
- Alternate Liquid: Halocarbon (SG 1.70)





Traditional Organic Liquids Method PROS and CONS

PROS:

- Easy to manipulate organic liquids into precise Specific Gravity fractions
- Liquids are low viscosity and coal readily wets with organic liquids
- Inert towards shales
- Efficient and repeatable results
- Finer sizes can be float sank if care is taken
- Drying times reduced as trace liquids left on floats and sinks are volatile





Traditional Organic Liquids Method PROS and CONS

CONS:

- Health hazard due to harsh chemicals
- Heavy loads and repetition for large scale samples
- Physical strain from prolonged wearing of a chemical mask
- <u>Costs:</u>
 - VMP Naptha (\$4.6 per Kg) 2017 price (Carbon tax included)
 - Perchloroethylene (\$5.2 per Kg) 2017 price
 - Methylene Bromide (\$27 per Kg) 2016 price
 - Bromoform (\$83 per Kg) 2016 price
 - Halocarbon (\$240 per Kg) 2017 price





WHAT IS TETRACHLOROETHYLENE – PERCHLOROETHYLENE?

Tetrachloroethylene, also known as perchloroethylene, PCE, or "perc," is a commonly used solvent (a substance, usually a liquid, capable of dissolving another substance). It has been in commercial use since the early 1900s.

Chemical Formula:

C_2CI_4

Tetrachloroethylene is a colorless, volatile, non-flammable, liquid, chlorinated hydrocarbon with an ether-like odor that may emit toxic fumes of phosgene when exposed to sunlight or flames.





Exposure to this substance can cause the following:

- 1. Irritation of the upper respiratory tract and eyes
- 2. Causes neurological effects
- 3. Causes kidney and liver damage
- 4. Reasonably considered a human carcinogen (increased risk of skin, colon, lung, lymphosarcoma, leukemia, esophageal and urogenital tract cancer).

As such engineering controls and personal protection equipment (organic vapor mask, gloves, goggles, apron) must be used with these types of chemicals.





FLOAT/SINK ROOM DESIGN

- Strong ventilation required to capture fumes from chemicals while samples are being float sank
- Ventilation required to be mostly horizontal ventilation as VMP Naptha is heavier than air and could present a fire hazard, and as well, horizontal ventilation keeps the fumes off the technicians face
- Air drying oven for float sink samples must be separate from air drying of wet coal samples so as not to introduce trace amounts of organic liquids onto them
- Ventilation materials required to be inert to all organic liquids





THE USE OF PERCHLOROETHYLENE

- 1. Adverse human health risks
- 2. Increased lab design cost
- 3. Added cost of the liquid
- 4. Unpredictable effects on coking properties of metallurgical coal
 - Anecdotal claims of no effect on coking properties
 - ACARP studies showing negative effects on AUS coals
 - CCRA study on western Canadian coals





CCRA "Organic Liquids" research group published a paper:

Holuzko, M., Leeder, R., Mackay, M., Giroux, L., MacPhee, T., Ng, K., and H. Dexter. Effect of organic liquids on coking properties of a higher-inert Western Canadian Coal. Fuel Processing Technology. Volume 155, pgs 225 – 231.

Looked at effects on coal quality when exposed to perchloroethylene vs. control sample:

Changes in Thermal Rheology

- Decrease in Gieseler Fluidity 27 ddpm to 5 ddpm (80% decrease)
- Similar decrease in Dilatation and Caking Index G
- No detectable change in Free-Swelling Index or Sapozhnikov





Effects on Carbonization & Coke Quality

- Longer Coking Time for treated sample, 20 hr, vs untreated sample, 18.25 hr.
- Lower Coke Yield for treated sample, 71%, vs untreated sample, 78%.
- Much MORE fine coke, <12.5 mm, in treated vs untreated sample: 21-26% vs 4% and SMALLER Mean Coke Size, 41-46 mm vs 53 mm







Fine Coke ~21%





• LOWER Hot coke strength for treated sample,









PERCHLOROETHYLENE:

- ADVERSE HEALTH EFFECTS
- UNPREDICTABLE EFFECTS ON COAL AND COKE QUALITY

The industry needs an alternative to float/sink in organic liquids in order to more accurately determine if their coal is hard coking coal.

New study in 2015 to test a Jig for use to clean small mass exploration samples.





"The Jig Study (2015)"

- Jig (Coal Doctor, Lindsay Bone AUS)
- Traditional float/sink method

The coal was a low ash (A low-ash, ~6%, medium-volatile, 24-25% VM (db), and medium - high-inert, 23- 26%, Western Canadian coal.





Organic Liquids – Float/Sink

Treated with organic liquids (perchloroethylene, bromoform and white spirits depending on specific gravity) and flotation using the following methods:

- Raw coal drop shattered and sized to minus 50mm -
- 50mm X 0.15 mm washed in organic liquid at multiple specific gravities.
- 0.15mm X 0 raw coal was cleaned by flotation

Flotation concentrate was combined with coarser coal that floated at 1.50 SG.





Jig – Coal Doctor - Lindsay Bone - Australia

Washed with H_2O in Jig at Coal Doctor Lab Australia the following procedure (specific to the Boner Jig) was used:

- Raw coal sized to pass -4mm
- 0.5mm X 0 fines were screen out and removed from the coal washed in the Boner Jig
- Following the jigging action, sequential samples from each coal layer within the jig representing a "cut" at a specific gravity.





Jig – Coal Doctor - Lindsay Bone – Australia

- Each float was analysed for SG, Ash and FSI
- Given the measured SG and ash, a simple washability table was produced
- Based on these results, selected what to composite to make a Clean Coal Composite, targeting the same ash and FSI as organic liquid washed samples.







Insert pusher







Fit pusher mechanism







Insert coal and Density tracers on top of coal





Jig tube inverted after jig cycle, showing density tracers have migrated to the bottom







SG 1.4 tracers found within the jigged column of coal during fraction collection









Sample Collection Tray Submitted







Sorted coal bed fraction







Carefully scrape fraction







Scrape Fraction into ARD basket







Coal Fraction in ARD Basket







Determine ARD mass in water





Results:

Description		100% CCRA-ORGCCC	100% CCRA-JIGCCC
Chemical Analysis			
Proximate Analysis (db)			
Ash	%	5.8	5.8
Volatile Matter	%	24.7	24.9
Fixed Carbon	%	69.4	69.2
Ultimate Analysis (db)			
Carbon	%	84.2	84.4
Hydrogen	%	4.6	4.4
Nitrogen	%	1.3	1.3
Sulphur	%	0.6	0.5
Oxygen by difference	%	3.5	3.5
Ash Analysis (adb)			
SiO2	%	52.0	54.4
A12O3	%	24.6	24.6
Fe2O3	%	5.1	4.3
P2O5	%	2.4	2.0
CaO	%	5.3	4.6
MgO	%	1.1	1.0
Na2O	%	0.6	0.6
K2O	%	1.0	1.3
Basicity Index		0.171	0.150
Thermal Rheology			
Gieseler Plasticity			
Max Fluidity	ddpm	152	153
log10 Max Fluidity		2.18	2.18
Dilatation			
Contraction	%	25	26
Dilatation	%	39	44
FSI		8	8
CSR		67.9	67.9
CRI		23.7	22.1





Results:

Why no decrease in Fluidity or CSR?

• Perchloroethylene unpredictable effects on coking properties

More research needed

2017 Study

Producing Clean Coal from Western Canadian Coal Fields using the Water-based Boner Jig Process





Canadian Carbonization Research Association and Geoscience BC collaboration on coal research

- 1. We are bringing the Jig to Canada
- 2. Testing 4 coals from British Columbia (SEBC & NEBC)
- Each coal traditional float/sink and Jig washed
- Full suite of coal analyses
- Carbonization in sole-heated oven at Canmet
- Coke quality





Canadian Carbonization Research Association and Geoscience BC collaboration on coal research

GOALS OF 2017 STUDY

- 1. Confirm the applicability of the Jig for use in cleaning small mass exploration samples
- 2. Finalize Jig methodology
- 3. Spread the word! (publish)





Canadian Carbonization Research Association and Geoscience BC collaboration on coal research

Further Research (funding dependent)

- 1. Test the jig with more coals from BC
- 2. Test a larger capacity jig
- 3. Test other liquids
- 4. Determine what is happening chemically when coal and perchloroethylene come into contact





Questions?



