

OHD: RETHINKING THE COAL-TO-LIQUIDS PROCESS

INTRODUCTION

What We Have



Macromolecular Solid (coal)

What We'd Like To Have



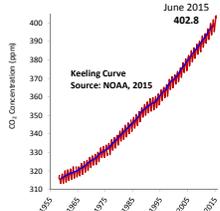
Pumpable liquid (not necessarily crude) that can be refined into useful high-value products, including liquid fuels and chemical feedstocks

Conventional Approach

- Pyrolysis/Retorting
- Direct liquefaction
- Indirect Liquefaction
 - Gasification/Fischer-Tropsch
- Others

All the above processes occur via **Reductive Bond Cleavage with Rejection of Carbon.**

In a carbon-constrained future, conversion technologies that assume rejected carbon are unlikely to be acceptable in the market



CO₂ Concentration (ppm)
 Keeling Curve
 Source: NOAA, 2015
 June 2015: 402.8

Oxidative Processes are Favorable



- Overall thermodynamics are disfavored.
- Cannot achieve complete carbon conversion (except by gasification).
- Residues contain residual carbon (often contaminated with PAHs).

- Thermodynamics are favored: downhill after overcoming initial barrier.
- All carbon can be utilized.
- Residues stable and basically consist of unaltered rock.

TECHNOLOGY

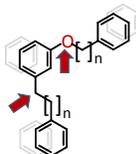
Oxidative Hydrothermal Dissolution (OHD)

Thermaquatica's OHD process is a novel, **environmentally friendly** technology, for the conversion of coal and other solid organic materials, into low molecular weight, water soluble products, by a direct, (non-gasification) process based on **oxidative** bond scission.

OHD takes advantage of, rather than runs counter to, the coal's inherent properties.

Both benzylic structures and ethers are prone to oxidation.

Neither of these structures is particularly reactive towards reduction.



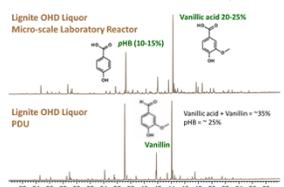
The OHD Process readily achieves **complete conversion** of coal, with high recovery (typically 70-90+%) of the products as solubilized, low molecular weight compounds.

OHD is inherently environmentally friendly:

- Uses only water and oxygen. Requires no exotic solvents or catalysts.
- Produces no or very little CO₂.
- Minor gaseous product is mainly CO.
- No NO_x, SO_x, or other problematic emissions.
- Unaffected by initial water content of feed.

Successfully demonstrated at laboratory and small engineering scale (5 kg/h).

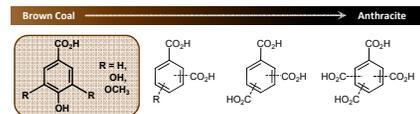
Process Design Unit (PDU, 5 kg/h)
 A 20 ton/day pilot plant, processing Australian Lignite, will be built in 2016 in collaboration with our commercial partner.



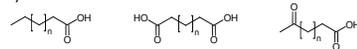

PRODUCTS

Coal-derived OHD products are dominated by:

Aromatic acids and phenols (dominate from humic components)

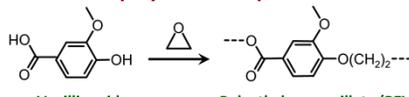


Aliphatic acids, diacids & keto acids (dominate from sapropellic components)

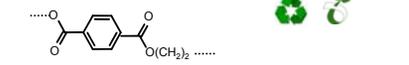


Most products are di- or poly-functionalized

Vanillate and pHB can be used for production of aromatic polyesters comparable to PET



Vanillic acid → Polyethylene vanillate (PEV) Biodegradable



Polyethylene terephthalate (PET)
 Obtained from crude oil, NOT readily biodegradable

CONCLUSIONS

- The OHD Process is an **industrially feasible, environmentally friendly** approach to convert organic solids to solubilized, low molecular weight compounds.
- The process produces no or very little CO₂, and OHD is proven for coal, biomass, oil sands, and shales.
- Distribution of the products will be unique to the feed, but the nature of the product suite stays consistent.
- An economic analysis and independent engineering evaluation were completed and results were found to be very favorable.
- Current focus is on engineering scale-up and integration of the downstream process steps.
- Our current commercialization partner is based in Australia; however **Thermaquatica is actively seeking development partners in the US.**