Engineered Coal: A New Green Product for the Coal Industry

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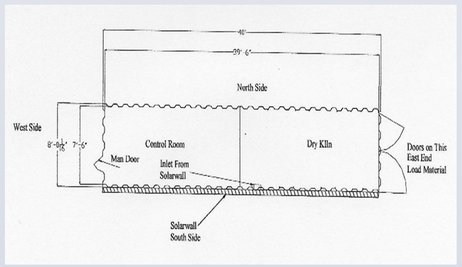
Introduction

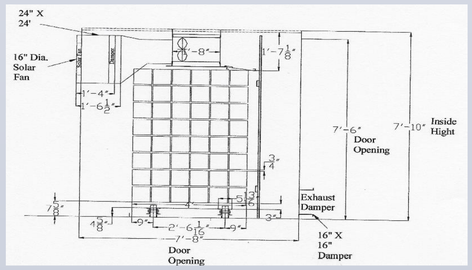
This paper presents an overview of a joint research effort by teams from The George Washington University and the Mississippi State University to develop green technologies for the US coal industry. The methodology consists of a combination of the design of a solar hybrid kiln, systems engineering and chemistry. The developed process provides a route for low cost and low waste production of the engineered coal leading to green value-added products that supports the coal industry.

The Solar Hybrid Kiln

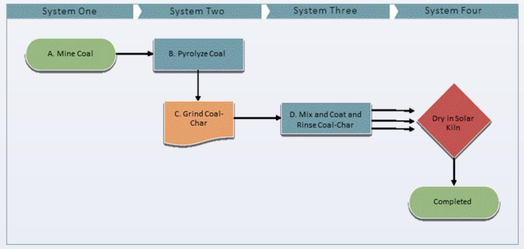
This solar hybrid kiln utilizes a novel solar energy collector previously used to pre-heat air for ventilation and crop drying. The solar hybrid kiln was designed using the SolarWall™ on a standard shipping container. Half of the container is used as the drying chamber, and the other half is designated as the control room. The SolarWall takes heat out of the air and redistributes it throughout the kiln, producing the heat needed for the drying process for the kiln. Ambient air is drawn through the metal skin of the solar panels by a variable speed fan to adsorb the solar heat. The fan speed is controlled to maintain a generally constant supply temperature. This system eliminates the need for natural gas or other sources of energy.



On site, the solar panels are oriented facing due south with no physical obstruction, maximizing sunlight adsorption by the specially coated perforated metal skin. Hot air from the SolarWall™ is ducted to the chamber above the load and enters the drying chamber through vents in the south side of the chamber. The central distribution duct is penetrated by three passages with reversible fans that circulate the dryer atmosphere through the load, such that the air entering from the SolarWall™ passes at least twice through the load before exhausting through the gravity damper low on the northern wall.



The Process



After the coal is mined, depending on the coal grade, it may be pyrolyzed in a continuous reactor (400 to 900°C with a residence time of a few seconds to a few minutes) or engineered directly. The coal is ground and then moved to the mixer and mixed while spraying with a salt solution until slurried. The salted coal-char is then transported to the to solar hybrid kiln for drying. This process is repeated two more times to produce and fix metal oxides to the coal surface.

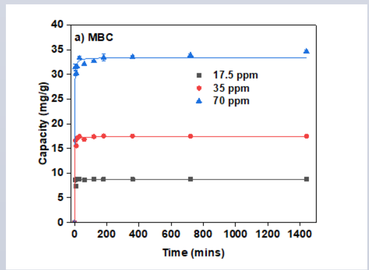
A layout of the conceptualized production process is displayed below

The Chemistry

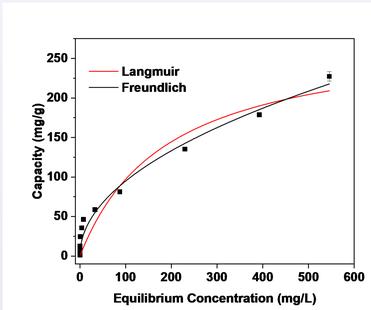
The following experiments were conducted for each coal char to determine optimal absorption:

- Kinetics (contact time ranged from 5 minutes to 24 hours)
- pH Level (ranged from 2 to 12)
- Initial Concentration (100 ppm to 500 ppm)
- Temperature (25°C, 35°C, 45°C)

For the experiment, mass of 0.05 g of engineered coal and 25 mL of a working solution were measured into a vial, prior to being placed in the industrial shaker. After each experiment, the vials were filtered and a color test was performed to acquire the absorbance data using a UV-Vis Spectrophotometer.

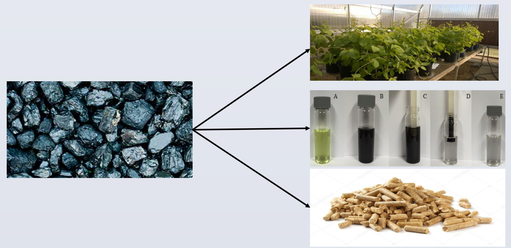


The Engineered Coal adsorbs agricultural pollutants quickly. Figure below shows that adsorption happens within the first few minutes of exposure.



The product has an impressive adsorption capacity of near 200 mg/g.

The Products

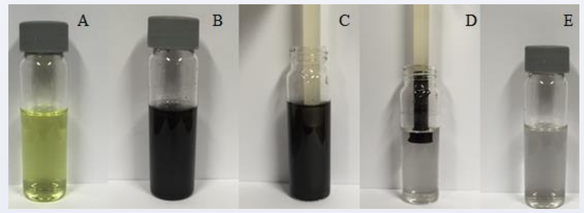


Low-cost adsorbents for nitrate and phosphate nutrients for application in agriculture and urban landscape architecture. Phosphate is a major cause of eutrophication since it is often the limiting nutrient for explosive algal growth. Cyanobacterial blooms can release soluble neurotoxins and hepatotoxins, killing fish or livestock when ingested and causing severe hazardous health effects in humans. The proposed engineered coal currently being developed can be used to rebuild lost and depleted topsoil in agriculture and urban settings.

The engineered coal can be used to amend depleted soils. Greenhouse studies are underway.

Economics

Applications also exist in water remediation. Below contaminated water is cleaned using the engineered coal.



When the engineered coal is combined with cornstarch, coal pellets can be made for a clean and efficient energy source compared to the current wood pellet products. The engineered coal will burn with reduced emissions because that added salts will scrub sulfur. The reduced sulfur emissions will help combat acid rain.

The markets for these products are large. For engineered coal, early adopters include the lawn and garden soil conditioners (~$7B); Mid-level adopters includes agriculture row crop and forest crop conditioners (~$8B) and late adopters include applications in environmental remediation (~$123B) and municipal waste water treatment (~$28.5B).

- Early Adopters
  - Lawn and Garden - Soil Conditioner $6.9B by 2023
- Mid
  - Agricultural Product
  - US Cannabis industry projection $32B by 2020
  - Row crops $7.8B by 2022
- Later
  - Environmental Remediation $123B by 2022
  - Municipal Waste Water Treatment
    - $28.5B industry
    - 54,000 Providers in the US.

In addition to the engineered coal, the coal pellet alternative for heating is very financially attractive. The cost of wood pellet fuel is typically around $250 per ton and The average home uses about 7.3 tons of pellet fuel per season. Cost to produce pellets depends on the cost of the raw material but the average price is $55 -$65 per ton. The average sale price of coal at the mine $33.72 per short ton.

References

S. Warren, R. Millar, T. Mazzuchi, T. Mlsna, Hybrid dryer for drying biochar, lumber, coffee, coco, and agricultural products, US Patent Pending, 2018.

S. Warren, R. Millar, T. Mazzuchi, T. Mlsna, M. Parkhue, J. Soffer, C. Navarathna, J. Williams, A. Sharp, and H.. Samaraweera, Solar hybrid kiln operations manual, Technical Report, 2019.