Clearwash™ Whitepaper

Enabling a carbon negative future by repurposing discarded agriculture residues into useful aggregates & fibers.

Abstract

There is an estimated one billion tons of dry weight biomass produced from agriculture in the United States every year. That number increases to 140 billion metric tons of biomass generated annually when calculated on a global scale. The majority of this tonnage is either burned for energy, or requires paid removal to a composting site. Both options are a money, energy, and GhG intensive burden - a burden that Clearwash ™ was designed to alleviate. A number of existing biorefinery operations are looking to put this biomass to use by converting it to biofuels and macromolecules derived from the cellulose, lignin, and hemicellulose. Enterprises around these types of processes have their role in developing a sustainable economy; however, these methods have very low conversion rates and require nontrivial amounts of energy. Our Clearwash™ process takes a different approach in that instead of breaking down the biomass, we leave it largely in its existing form to serve other uses (plastics, composites, construction, textiles). By doing this we avoid expensive chemicals and energy intensive processes like high heats and pressures. Our flagship implementation of this process is to convert discarded stalks from CBD producing hemp operations into aggregates for construction materials.

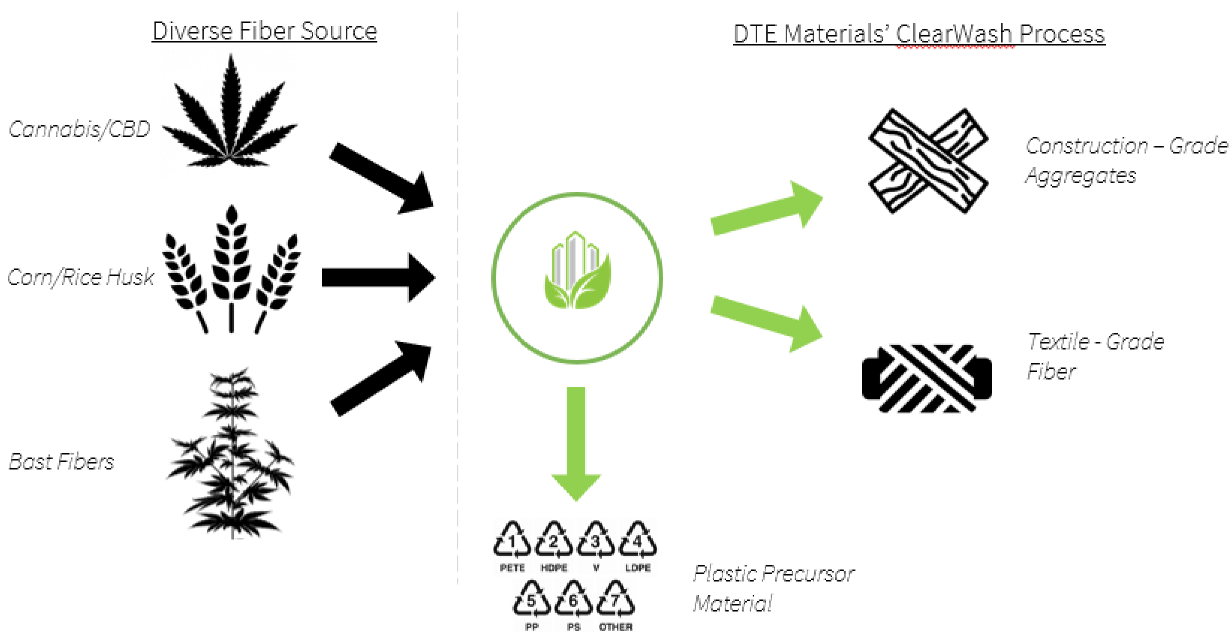

Figure 1. Infographic of the ClearWash process.

Letting Nature do the Work

The DTE in DTE Materials stands for Down to Earth, a phrase we took to heart when designing our business and manufacturing methods by staying out of nature's way. The thesis behind the Clearwash process was that the much of the discarded agriculture biomass comes in a form that is only a slight modification away from being highly valuable inputs to multiple products. Our process handles these minor modifications such as size reduction, dust & sugar removal, sterilization of mold and fungus, increases in porosity, and adjustments to the surface chemistry of the fibers. Choosing to leave the fibers primarily in their natural form allows the manufacturing design to be automated, low energy input, and have minimal-to-zero waste – a significant contrast to biofuel and pyrolysis operations.

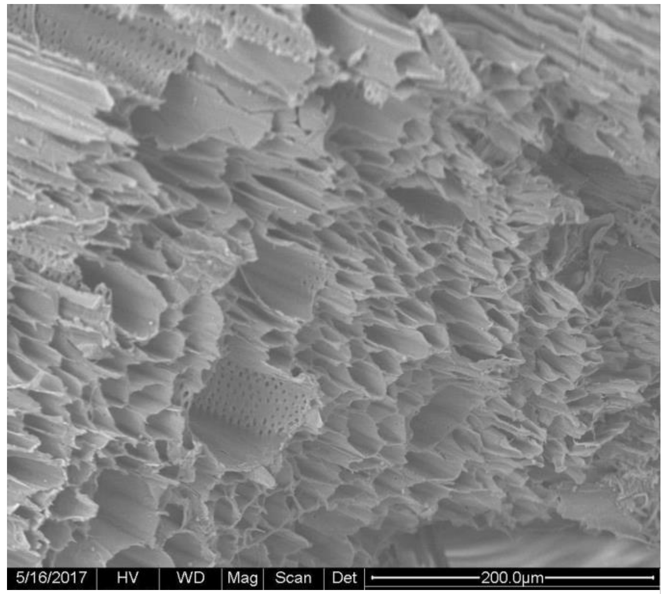

Figure 2. Scanning electron microscope image of Industrial Hemp after Clearwash treatment. The results were an increase in porosity of 17% and increased surface roughness[3].

Construction Applications

Our primary R&D focus and product deployment are insulating aggregates for the construction industry. We are able to take stalky material of differing shapes, sizes, densities, and porosities modify them into standardized aggregates for insulating applications. Ultimately, like sand aggregates, there will need to be a level of standardization for bioaggregates in accordance to the American Society for Testing and Materials. In order to achieve this level of standardization, we have designed ClearWash to handle a variety of biomass inputs while repeatably producing aggregates in accordance to ASTM standards based on these outcomes:

- Comminution of differing sizes, ~1/4" for concrete & micronized for plasters and stuccos
- Dust & Carbohydrate removal for superior bonding interface with cementitious binders
- Increase in available surface area and surface roughness superior bonding
- Sterilization of any residual mold/fungus from field retting or extended storage
- Standardization of intra-fiber porosity to increase insulating properties (Figure 2)

Stonefiber Bioaggregate Concrete Panels

The first implementation of ClearWash bioaggregates will be hemp hurd (shiv) derived from CBD-yielding industrial hemp crops. CBD derived hemp aggregates provide a unique opportunity to source discarded hemp stalks and convert them into fiber grade hemp shiv aggregates. This helps the farmer maintain a more closed loop and sustainable operation, while also providing DTE Materials a favorable supply chain which we describe later within this whitepaper. We are uniquely equipped to handle CBD derived hemp stalks because we can address its three main shortcomings as an aggregate: inherent mold from field retting/prolonged storage, removal of carbohydrates that inhibit binding with cementitious binders, and standardization of the porosity for consistent mechanical and thermal performance.

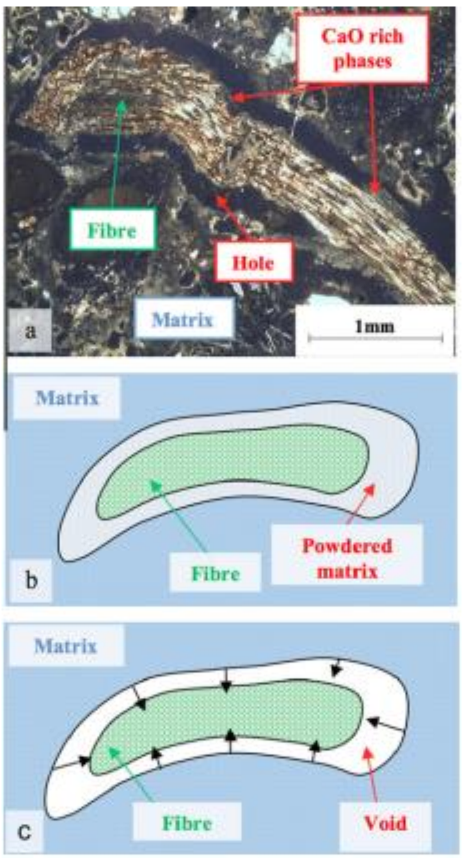

Figure 3. Microscopic and illustrated view of the void created between the fiber and cementitious binder interface as a result of sugar interference.[4]

<u>Surface Chemistry Modifications</u>

Removing residual mold from the long-term storage and field retting (rotting) process is key because although the lime binder is naturally antimicrobial, existing mold within the fibers micropores themselves can eat away at the aggregates from within. The solvent used in ClearWash is able to penetrate even nanopores to sterilize all potential regions of future decay. Additionally, cannabinoids, fats, and sugars need to be removed as they inhibit binding at the interface between the binder and the fiber as demonstrated in Figure 3. Pectin and hemicellulose, sugars found in all lignocellulosic agriculture residues, disrupt CSH hydration of lime binders by trapping Ca^{2+} ions, forming CaO rich gel. CaO (calcium oxide) is left unhydrated leading to a dislocation boundary around the fiber. This void between the structurally sound CSH hydrates and the fibers themselves results in a weaker compressive strength and flaking. The high pH of lime and Portland cement binders act as a positive feedback loop for this detrimental mechanism as more of these sugar molecules depolymerize out of their complex carbohydrate molecule structure. Although already demonstrated in open-source literature, we were recently able to confirm this again with MasterBuilders' chemists using our exact blend of hemp hurd within a lime and pumice-based binder.

Standardization of Porosity

Cell wall structure and porosity within the fibers can vary dramatically between agriculture residues. This is especially true with CBD variants compared to fiber or dual crop industrial hemp species. Utilizing Mercury Intrusion Porosimetry we were able to graphically model the differing pore structures between the fiber bioaggregate (Figure 4) and the denser CBD crop bioaggregate

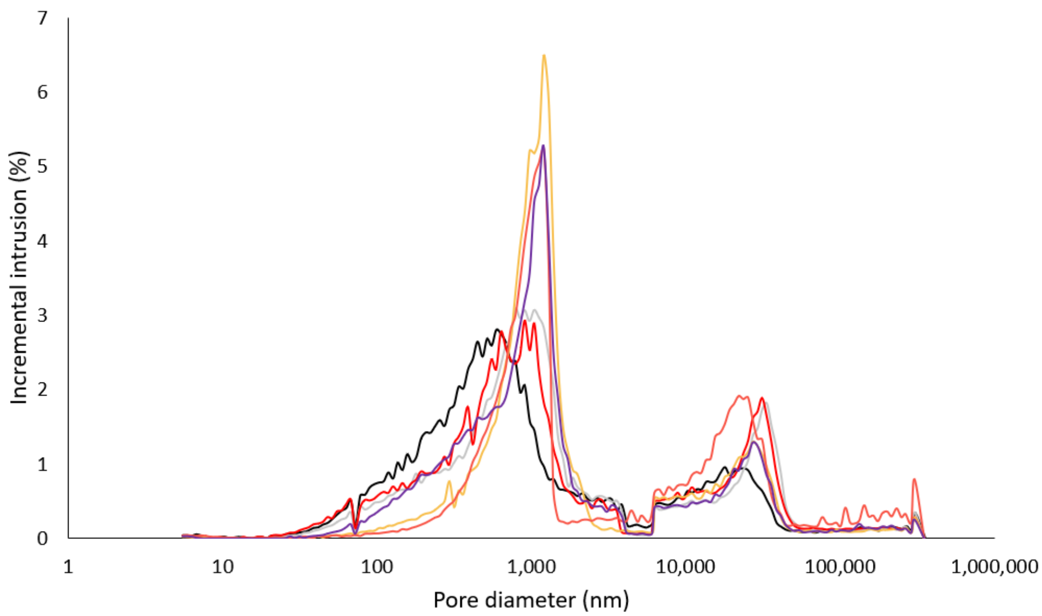

Figure 4. MIP chart illustrating pore size distribution for multiple ClearWash samples. The majority of pores are distributed around 1 micron.

(Figure 5). Fiber variety hurd having undergone differing ClearWash methods, had total porosity percentages between 76 and 82%. CBD variety hurd without ClearWash processing had a total porosity percentage of 63%. When evaluating and translating the relationship between thermal conductivity and pore dynamics, it's important to not only consider the total amount of porosity, but also the relative sizes of the pores that make up the total porosity as contrasted between

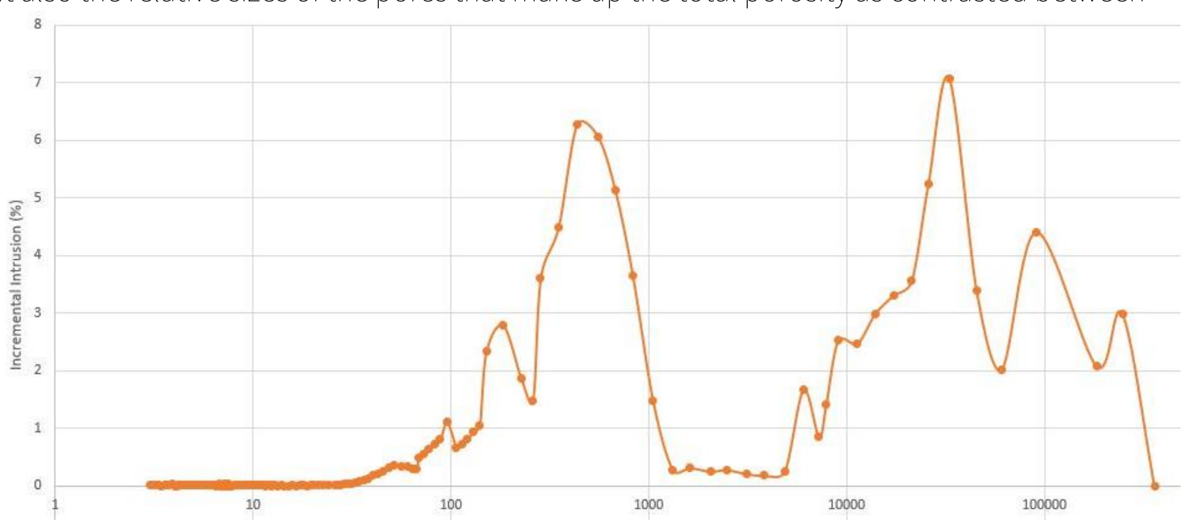

Figure 5. MIP chart of CBD derived hurd without ClearWash processing. The majority of pores are 50 microns and larger.

Figure 4 and 5. The plots in Figure 4, fiber varietal hurd w/ ClearWash, illustrate that the majority of the pores are roughly 1000nm or 1 micron. Compare this with Figure 5, CBD hurd without ClearWash, where the majority of pores are actually closer to 50,000 nm or 50 microns. This is an important concept in the implementation of our technology as larger pores are less effective at mitigating convection heat transfer across their boundaries. In summary, a higher percent porosity aggregate will undergo more convection modes of heat transfer over conduction because of less free pathways for phonon transfer. Convection across air results in a much lower thermal conductivity relative to conduction across physical boundaries. Similarly, controlling the size of the pores to 1 micron and smaller further reduces the ability of phonons to traverse the air convection boundaries (Figure 6). These differences in porosity between ag residues result in a wide range of thermal conductivities and water absorption rates (important for vapor regulation and thermal inertia). The official results of ASTM C518 show our thermal conductivity to be .057 W/m*k for our Stonefiber block with ClearWash treated aggregates with average porosity of 79%. Online journal publication results for the thermal conductivity of standard hempcrete range between .07-.2 W/m*k. A copy of our C518 results conducted at Radco Laboratories is available on our website or by request. Bulk density and mix design of the concrete play a significant role in thermal conductivity as well, but pore structure of the aggregates themselves ultimately determine the theoretically maximums for these metrics. Other ag residues that we have considered and their average porosity: wood species (35-65%), wheat straw (51%), corn stalk (58%), soybean stalk (68%), coffee husk (64%), cotton stalk (74%).

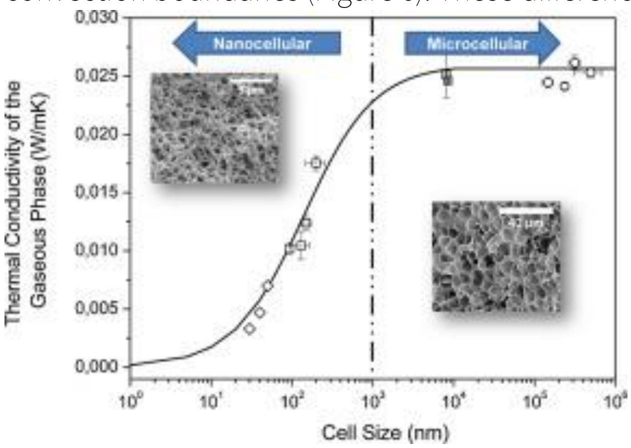

Figure 6. Graphical relationship of the thermal conductivity across gasses within differing cell sizes.