Activated Carbons

For Wastewater Odor Control

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Presentation Overview

- Review of odor control basics.
- Review of activated carbon basics.
- Activated carbons and odor control.

Review of Odor Control Basics

- Odors are produced primarily in two areas:

- Wastewater Treatment Plants (WWTP)
  - Headworks
  - Clarification Systems
  - Biological Systems
  - Solids Processing

- Collection System Facilities
  - Force Main Discharges
  - Pump / Lift Stations
  - Transition Structures

Nature of Odors

- Odorous compounds in wastewater include both inorganic and organic gases.
  - Primary inorganic odorous compounds:
    - Hydrogen Sulfide (H_2S)
    - Ammonia (NH_3)
  - Common organic odorous compounds:
    - Methyl Mercaptan (CH_3SH)
    - Dimethyl Sulfide ($(CH_3)_2S$)
    - Indole ($C_6H_4(CH)_2NH$)

Odor Generation

- Odors are ordinarily generated when turbulence in the wastewater stream volatilizes the odorous compounds from the liquid.
- Odors from inorganic compounds (primarily H_2S) dominate the Collection System.
- Odors at the WWTP generally originate from a mixture of inorganic and organic compounds. **However, even here, H_2S tends to be the major odor contributor.**

Importance of Odor Control

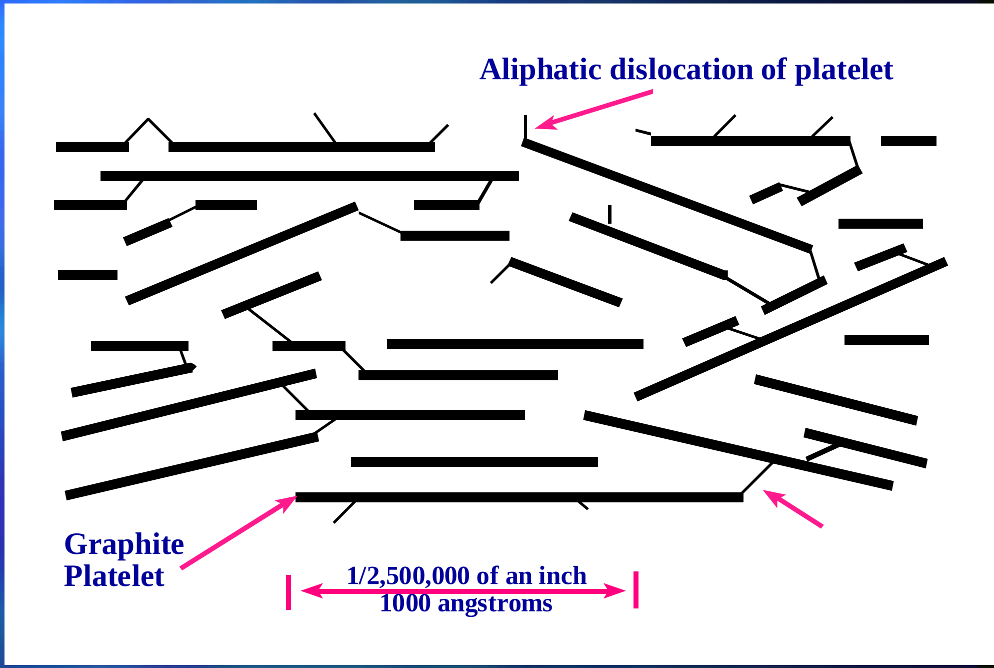
- Factors influencing growing importance of controlling odors include:
  - Encroachment of new residential and commercial development near once isolated wastewater facilities.
    - New neighbors do not want to smell odors!
  - Increased waste loadings being carried by collection systems and treated by WWTPs fueling expansion of plants.
    - Another result of population growth and encroachment!

Review of Activated Carbon

- Definition of Activated Carbon:
  - Activated carbon is a crude form of graphite with a random or amorphous platelet structure, which is highly porous over a broad range of pore sizes, from visible cracks and crevices to cracks and crevices of molecular dimensions.

The Structure of Activated Carbon

- This is a conceptual view of the structure of activated carbon, magnified 10,000,000 times.
- The carbon shown is a standard, unimpregnated, bituminous coal based material.



How is Activated Carbon Made?

- Activated carbon is made in one of two ways:
  - Direct Activation
  - Reagglomeration

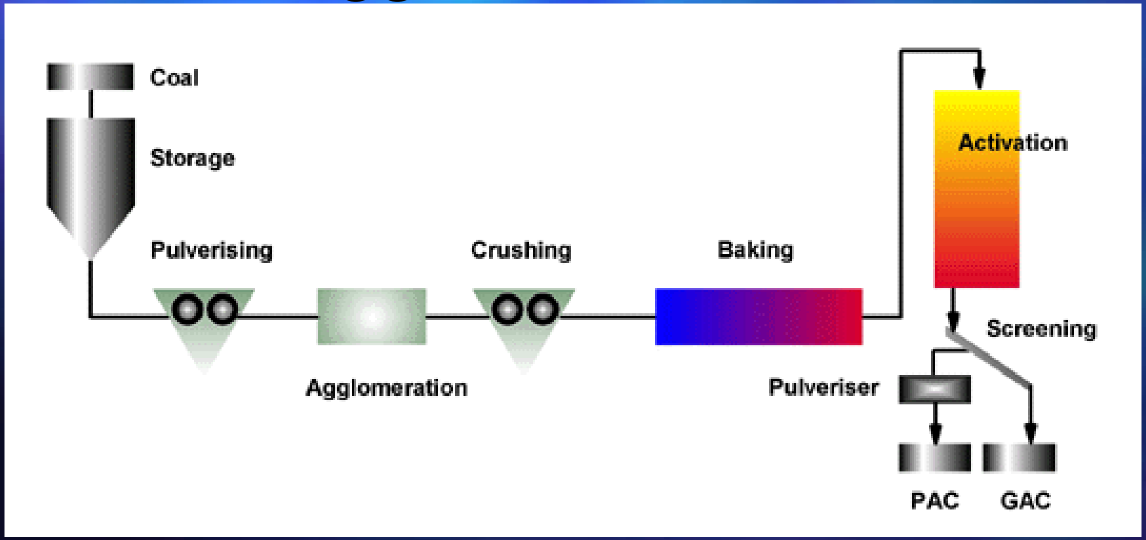


Diagram showing reagglomerated carbon manufacturing process.

Direct Activated Carbon

- Direct Activation:
  - Starting material is crushed to desired final size and fed into activation furnace.
  - Virtually all carbons are made this way, as it is easier, requires less capital equipment, and is therefore less expensive.

Reagglomerated Carbon

- Reagglomeration:
  - Starting material is crushed to a powder. It is then recombined (reagglomerated) with a binder into a briquette. The briquette is then crushed to the final desired size and fed into the activation furnace.
  - This method provides much greater surface area than direct activation. Resultant adsorption capacity is greater.

What is Activated Carbon made of ?

- Any carbonaceous material can be a starting material for activated carbon:
  - Coal (typically bituminous)
  - Coconut shell
  - Wood
  - Even blood and animal bones !

How does Activated Carbon Work?

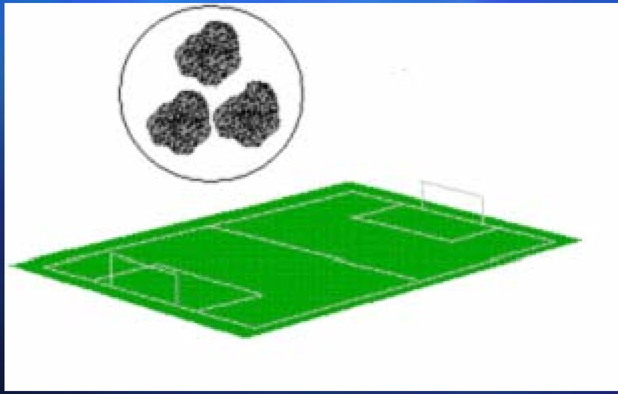
- Most activated carbons work primarily through the mechanism of *Physical Adsorption*.
- Some activated carbons used in odor control work primarily through other means:
  - *Chemisorption*
  - *Catalytic Adsorption*

Physical Adsorption

- Based on "London Dispersion Forces":
  - An intermolecular interaction that exists between all molecules.
  - Responsible for condensation of most gases to liquids as well as physical adsorption on carbon.
  - Essentially, this force traps and holds incoming molecules (odorous and otherwise) between carbon particle platelets!

Physical Adsorption

- Activated carbon has the strongest physical adsorption forces or the highest volume of adsorbing porosity of any material known to mankind.



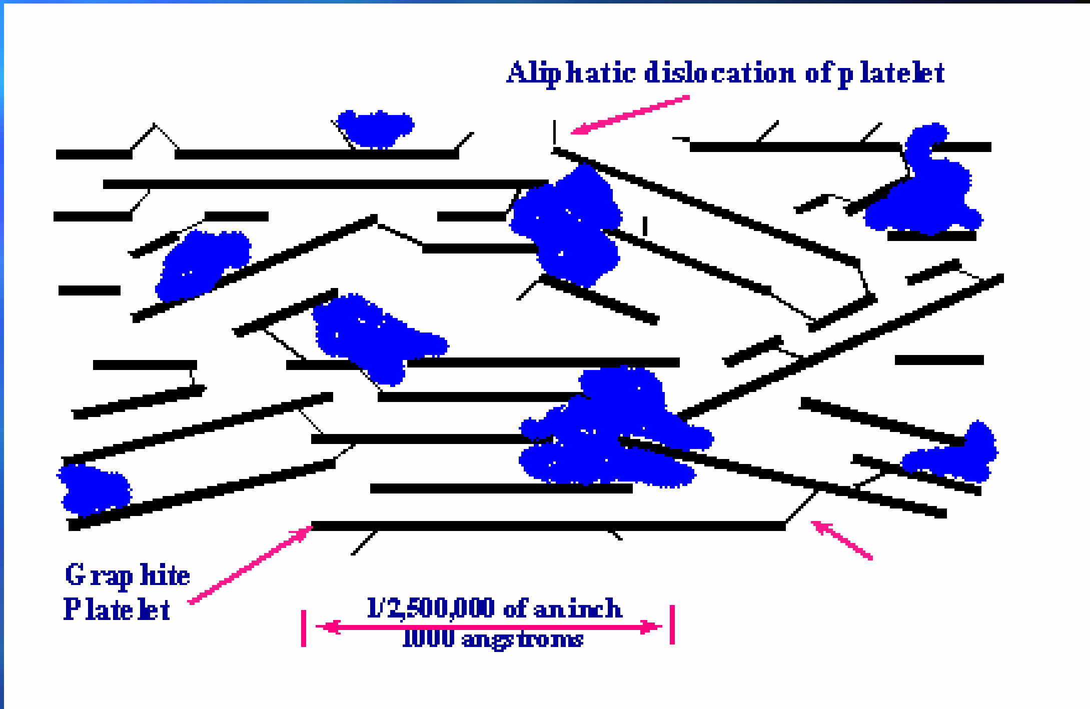
A 4.0 mm diameter granule of reagglomerated activated carbon has as much internal surface area as a football field !

Chemisorption

- Activated carbons can be impregnated with various chemical compounds.
- After incoming molecules are initially physically adsorbed, they react with the chemical impregnant to form a new compound more readily adsorbed onto the carbon.
- This approach can result in higher removal capacity for specific compounds.

Chemisorption

- This is a conceptual view of a chemically impregnated activated carbon at 10,000,000 magnification.
- Compare this to the earlier slide of the standard, unimpregnated carbon. The blue splotches are the chemical impregnants.



Chemisorption

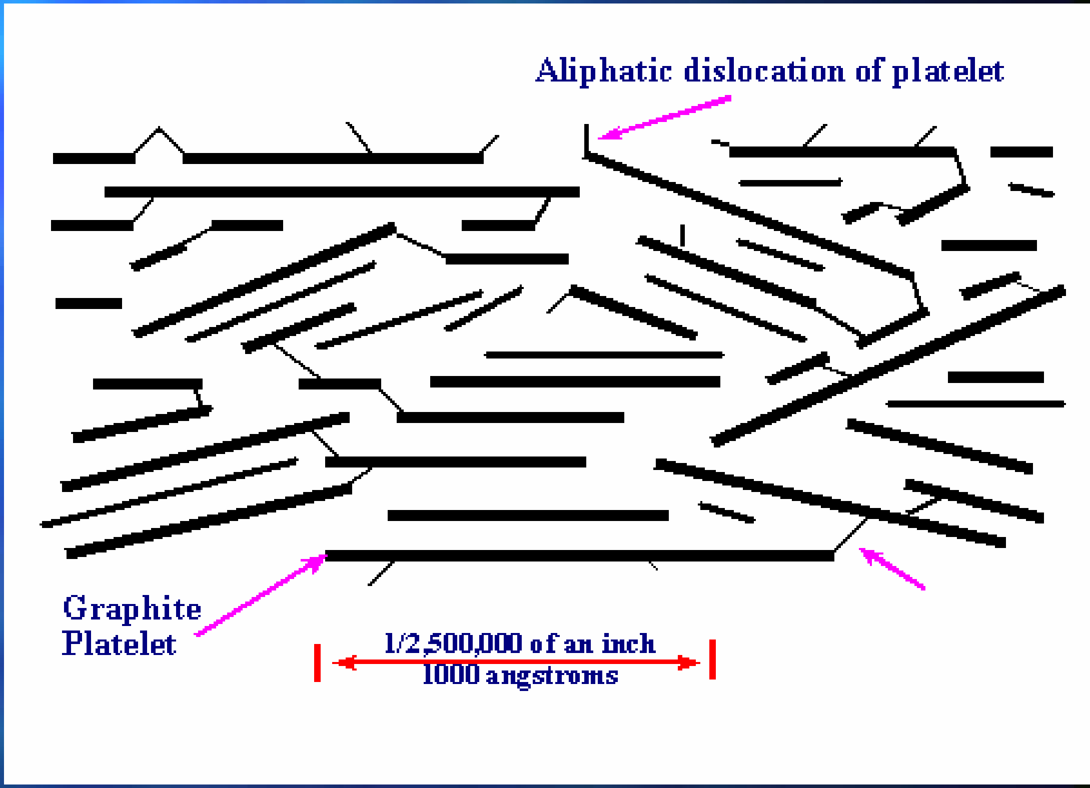
- In municipal odor control, the most common impregnant is caustic soda:
  - Sodium hydroxide
  - Potassium hydroxide
- The caustic chemical oxidizes the H_2S to form elemental sulfur. This greatly increases the carbon's capacity for H_2S removal.
- Caustically impregnated carbons can theoretically be regenerated in-place with more caustic.

Catalytic Adsorption

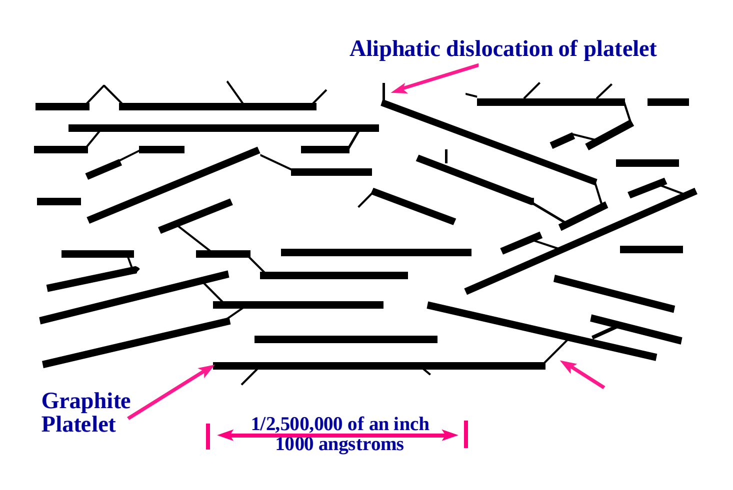
- The *newest* type of activated carbon.
- All activated carbons exhibit some degree of catalytic activity.
- Calgon Carbon Corp. has discovered how to modify the surface of the carbon granule to greatly enhance the carbon's catalytic nature.
  - CCC's catalytic carbon is *Centaur HSV*.

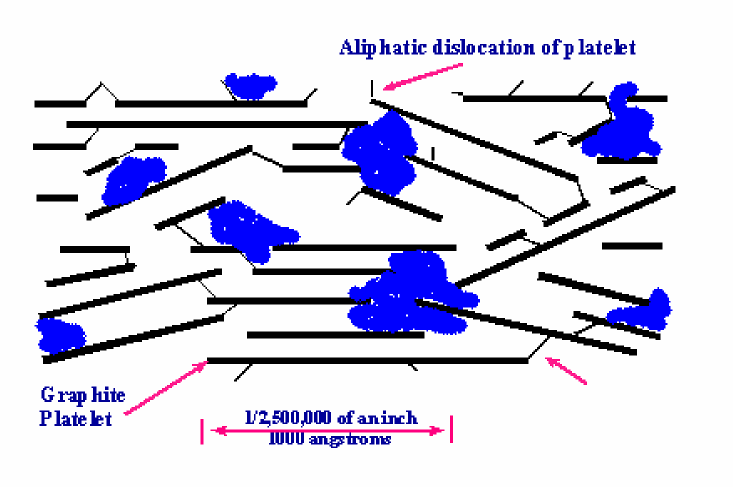
Catalytic Adsorption

- This is a view of Centaur HSV at 10,000,000 magnification.
- Note that the carbon has more platelets than standard carbon.

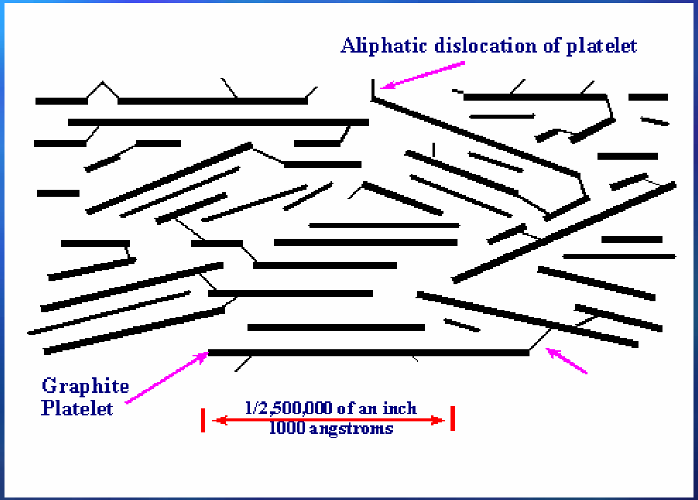


Comparison of Activated Carbon Structures





- Standard Carbon
- Impregnated Carbon



- Catalytic Carbon
- Centaur HSV

Catalytic Adsorption

- The greater number of platelets results in the carbon having more “high energy” (i.e. catalytic) adsorption sites than standard activated carbon.

- Other than this, *Centaur HSV* is very similar to standard, unimpregnated, bituminous coal based carbon:
  - Shape, size, color, texture is the same.

How does Catalytic Adsorption Work ?

- After the initial physical adsorption step, catalytic carbon promotes an oxidation reaction.
- In odor control applications, this primarily means conversion of H_2S to sulfuric acid (H_2SO_4).
- This differs from conventional carbon in that:
  - Standard (virgin or reactivated) carbon only physically adsorbs the H_2S.
  - Impregnated carbons chemically react with H_2S to form sulfur (S).

Reactions on Catalytic Carbon

$H_2S + 2O_2$	H_2SO_4	90%
$H_2S + 3/2\ O_2$	H_2SO_3	~5%
$H_2S + ½\ O_2$	$H_2O + S$	~5%

- Note that 90% of the reaction product is sulfuric acid. This material is water soluble. This is what makes catalytic adsorption advantageous for H_2S removal … *the catalytic carbon can be washed with water to remove the acid and allow further H_2S removal*.

Use of Activated Carbon in Odor Control

- Factors to consider when selecting an activated carbon for odor control:
  - Capacity for hydrogen sulfide removal.
    - This means total capacity, not just initial cycle capacity.
  - Capacity for odorous organic compound removal.
    - Organic sulfides can be present in odor streams.
  - Economics:
    - Initial Cost of Media versus Lifespan of the Media.
  - Frequency and ease of regeneration and replacement:
    - Both from an economic and operational nuisance standpoint.

Comparison of Activated Carbons for Odor Control

- The following slides compare the three most common types of activated carbons relative to their odor control capabilities.
  - Physical Adsorptive (also known Standard Carbon or Unimpregnated Carbon)
  - Chemisorptive (Caustically Impregnated)
  - Catalytic (Centaur HSV)

Standard (Physical Adsorptive) Carbon

- Benefits:
  - Simple, passive systems with few moving parts.
  - Effective capacity to remove low ppm levels of organics.
  - Safe operation with no hazardous materials.
  - Can provide an effective second stage polishing treatment for other technologies.
  - Flexible ("off-on").
- Limitations:
  - Very limited H_2S capacity leads to frequent change-outs and resultantly poor economics for H_2S removal.
  - Media change-out is time consuming, labor intensive, and dirty.
  - Spent media must be either land-filled or thermally reactivated off-site – no in-place regeneration is possible.

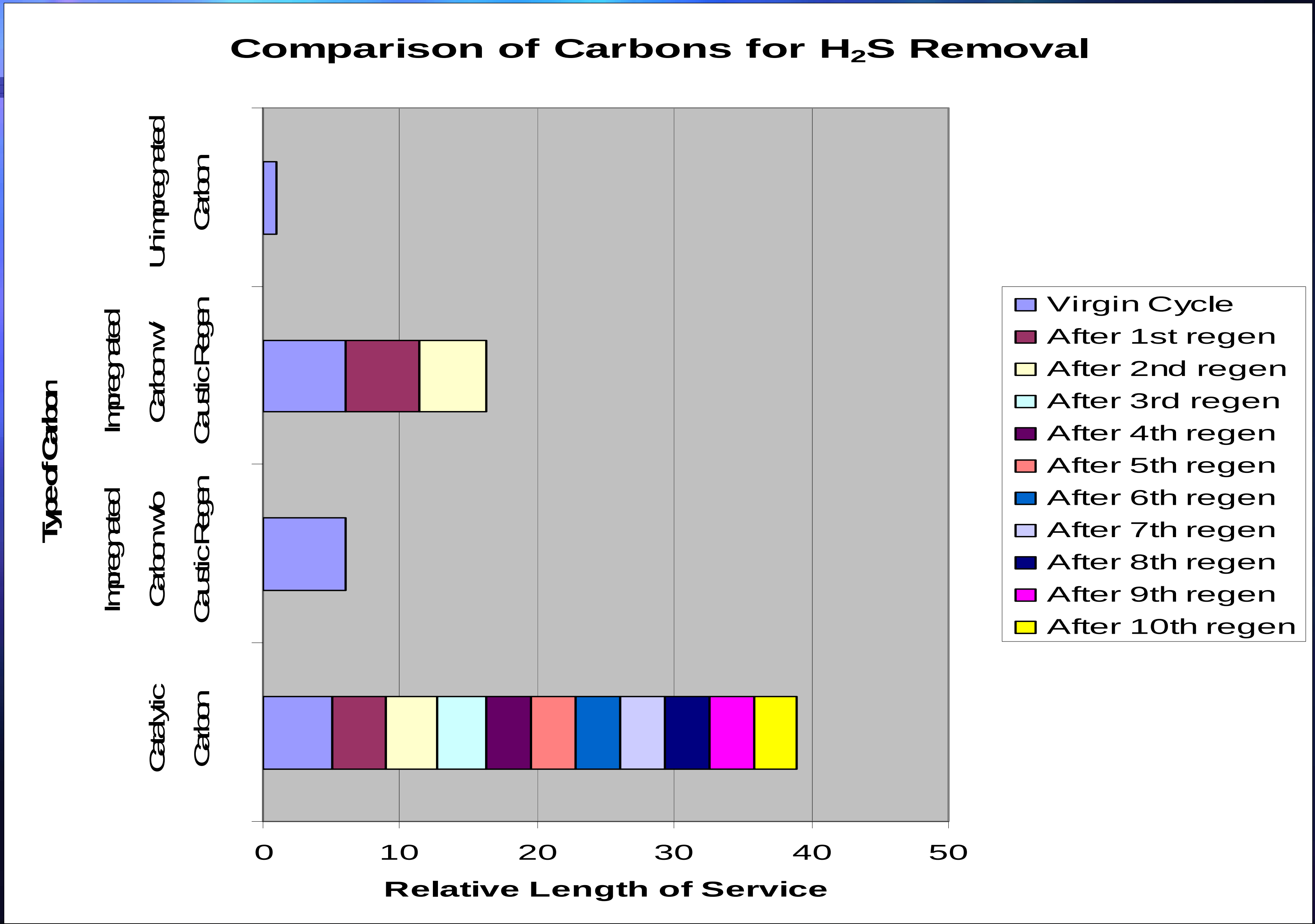
Impregnated (Chemisorptive) Carbon

- Benefits:
  - Simple, passive system with few moving parts.
  - Effective removal capacity for H_2S levels up to ~ 20 ppm.
  - Flexible ("off-on").
- Limitations:
  - Reduced capacity to remove organic compounds due to impregnant.
  - System must go off-line for regeneration (6 to 7 days).
  - Caustic regeneration is costly and hazardous (use of 50% caustic). Generally only two regenerations are possible.
  - Improper system operation can lead to fires (relatively low ignition temperature).
  - Media change-out is time consuming, labor intensive, and dirty.
  - Spent media must be land-filled.

Catalytic Carbon (Centaur HSV)

- Benefits:
  - With water washing, total H_2S capacity is far in excess to that provided by other carbons.
  - Effective treatment of H_2S levels up to ~ 20 ppm.
  - Provides organic compound removal capacity equal to standard carbon and greater than impregnated carbon.
  - Vastly reduces bed fire potential present with impregnated carbon.
  - Flexible (“on-off”).
  - Replacement operation is far less frequent than with the other carbons.
  - Can be returned to the factory for reactivation, thereby avoiding land-filling.
- Limitations:
  - System must go off-line for water washing (2 days maximum).
  - After 10 water washes, carbon usually must be replaced:
    - Replacement operation is time consuming, labor intensive, and dirty.

Relative Total H_2S Removal Capacities of Activated Carbon



Relative H_2S Capacities

- Catalytic carbon (Centaur HSV) has up to *35 times* the capacity to removal H_2S as standard / unimpregnated carbon!
- Catalytic carbon has up to *6 times* the capacity for H_2S as impregnated carbon which is not regenerated in place!
- Catalytic carbon has up to *2.5 times* the capacity for H_2S as impregnated carbon which is caustically regenerated twice!

Conclusions

- Use of Activated Carbon Will Continue To Be An Effective Method of Treating Wastewater Odors.
- Centaur HSV Makes Activated Carbon Better.
  - Risk of Bed Fires Virtually Eliminated.
  - Caustic Regeneration Problems Eliminated.
  - Spent Carbon Disposal Potentially Eliminated with Ability to Return Centaur HSV to CCC for Reactivation.
  - Long Term Costs of Using Granular Carbon for H_2S Are Greatly Reduced.