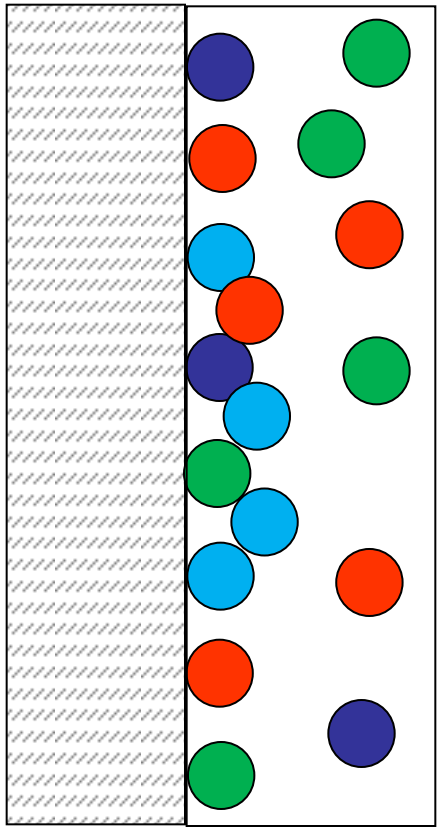
ADSORPTION

Briefly, *adsorption* is the surface accumulation of material.



Solid phase

Liquid phase

Adsorption is a unit operation in which dissolved constituents are removed from the solvent (water) by transfer to the surfaces of an adsorbent particle.

ADSORPTION cont'd

Sorption is a general term which refers to the action of absorption or adsorption.

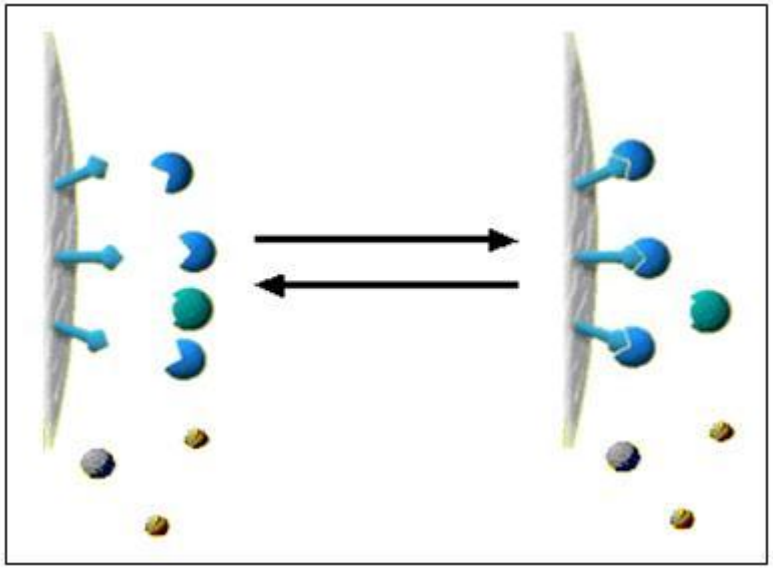
Adsorption – chemicals adhere to surface of solid (dominant mechanism)
Absorption – chemicals penetrate into solid, forming solid solution

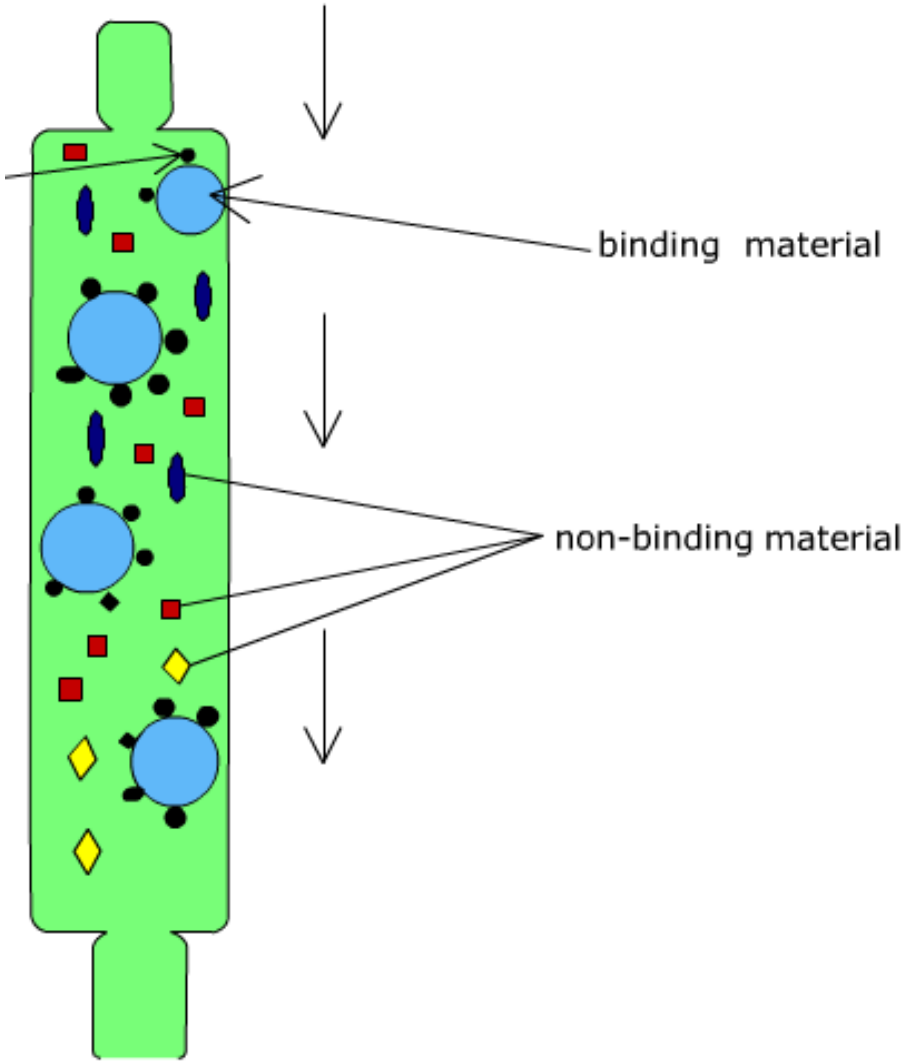
Adsorbent – adsorbing phase
Adsorbate – chemical being adsorbed

ADSORPTION cont'd

Adsorption occurs due to the

- hydrophobicity of the material
- specific affinity




binding material
non-binding material

Solute-Solid Interactions

Most bonding is physical, occurring by various mechanisms such as van der Waals forces.

Van der Waals interactions result in relatively weak, reversible adsorption. The adsorbate is free to move on the surface. This interaction corresponds to energies of about 2 to 20 kj/mol.

Some bondings between adsorbate and adsorbent are chemical as characterized by strong attractiveness. Adsorbed molecules are not free to move on the surface. The process is generally irreversible.

Applications

If we have to remove soluble material from the solution phase, but the material is neither volatile nor biodegradable, we often employ adsorption processes.

Applications

a) Drinking water treatment, removal of taste and odor causing chemicals, halogenated organics and their precursors, natural and synthetic organic substances.

b) Groundwater remediation, restoration of contaminated groundwater (pump and treat)

c) Industrial wastewater treatment (removal of toxic organic compounds)

d) Polishing of treated municipal waste (advanced wastewater treatment)

Types

I. Activated carbon (PAC or GAC)
   a) GAC Size: 0.5-1.0 mm;
      surface area up to 1500 m^2/gram.
   a) PAC Size: 50-75 μ;
      surface area up to 2500 m^2/gram (basically internal surface)

II. Synthetic adsorbents, used to a lesser extend, useful for certain purposes

Activated Carbon is widely used in water and wastewater treatment because

- it has very large internal pores
- can adsorb a wide variety of organic compounds, not selective
- economically feasible

Activated carbon is prepared in two steps

Carbonization step: Carbonaceous material (wood, coal, coconut, shells) is heated in oxygen-starved environment to liberate carbon. At about 600 ^{o}C volatiles are driven off and carbon content is increased.

Activation step: Carbonized material is exposed to steam or hot CO_2 to cause pores and fissures to form. At 200-1000 ^{o}C in an oxidizing atmosphere non-carbon impurities are burned. The product is a highly porous material with high surface area.

This procedure increases

- the carbon content of the material to which organic chemicals will sorp
- the surface area available for sorption

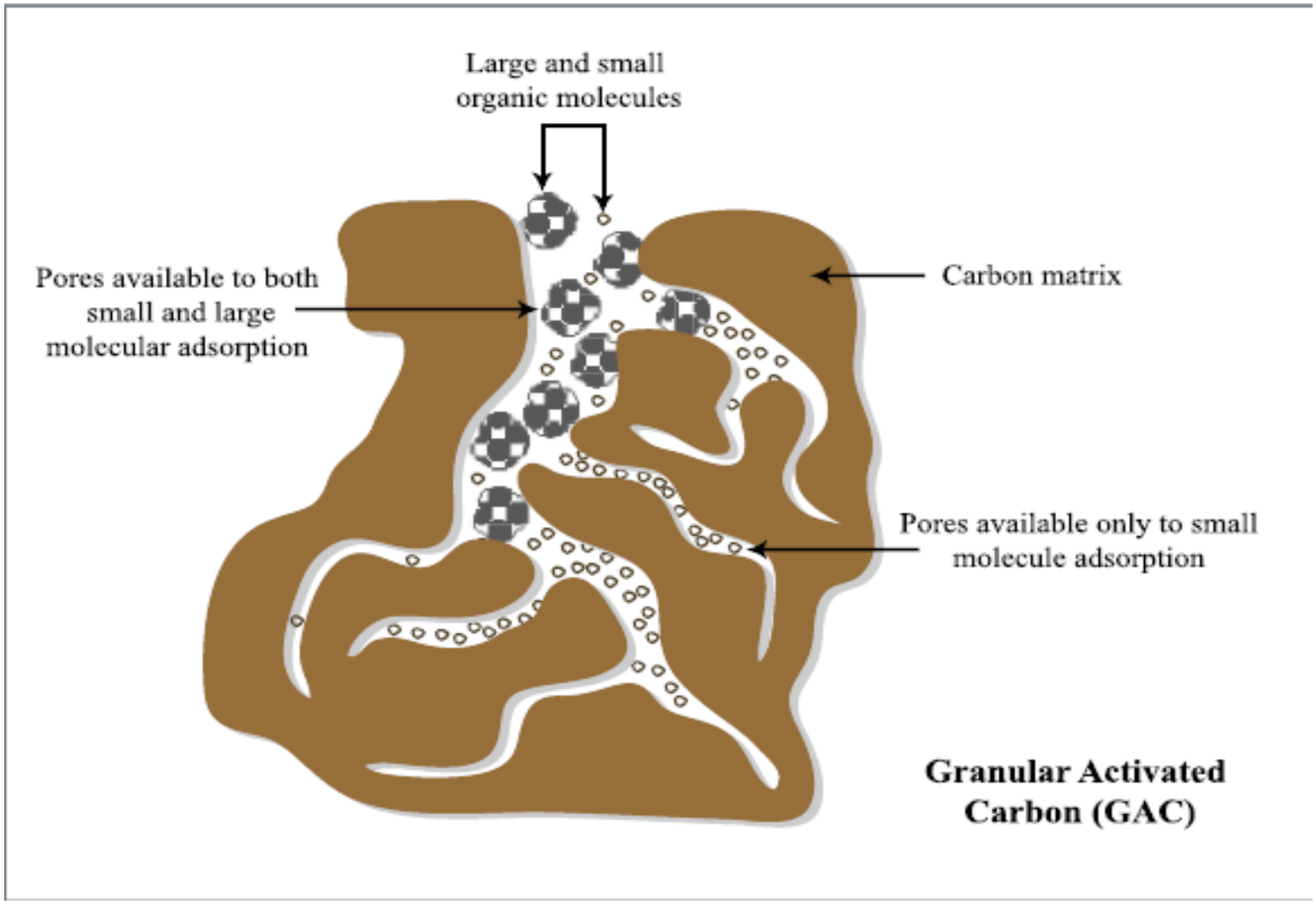
The nature of the surface and the porous structure are determined by the conditions of activation (time, temperature, air composition) and by the characteristics of the base material.

Factors Affecting Activated Carbon Properties

- Starting materials (e.g., coal vs. wood based) and activation
- Pores and pore size distributions
- Internal surface area
- Surface chemistry (esp. polarity)
- Apparent density
- Particle Size: Granular vs. Powdered (GAC vs. PAC)

Characteristics of Some Granular Activated Carbons

Characteristics of Activated Carbons (Zimmer, 1988)			
Activated Carbon	**F 300**	**H 71**	**C25**
Raw Material	**Bituminous Coal**	**Lignite**	**Coconut Shell**
Bed Density, ρ_F (kg/m^3)	**500**	**380**	**500**
Particle Density, ρ_P (kg/m^3)	**868**	**685**	**778**
Particle Radius (mm)	**0.81**	**0.90**	**0.79**
Surface Area BET (m^2/g)	**875**	**670**	**930**
Pore Volume (cm^3/g)			
Micro- (radius < 1nm)	**0.33**	**0.21**	**0.35**
Meso- (1nm < r < 25nm)	**----**	**0.38**	**0.14**
Macro- (radius > 25nm)	**----**	**0.58**	**0.16**
Total	**----**	**1.17**	**0.65**


Large and small
organic molecules
Pores available to both
small and large
molecular adsorption
Carbon matrix
Pores available only to small
molecule adsorption
Granular Activated
Carbon (GAC)

Adsorption depends on

- Properties of activated carbon
- Chemistry of adsorbate
- pH and temperature of water

Modes of application

- Generally used in granular form (GAC)
  - batch,
  - column;

    i) fixed bed, ii) counter current bed

- fluidized bed operations

*** fixed bed mode is the most common.

EBCT for fixed bed mode is

10-15 min. in water treatment,

10-50 min. in waste water treatment

at flow rates of 1.5-3.5 L/s.m^2.

- PAC is applied in mixed contactors, usually in batch operation.

Advantages of GAC

- Beds provide better contact, therefore GAC requires less carbon.
- No subsequent separation is needed.
- Beds are easier to monitor with respect to performance.
- Can be regenerated.

Advantages of PAC

- Can be readily applied as needed, little or no capital cost.
- Flexible, it can be added at different points during treatment. However, points of addition should provide sufficient contact time, good mixing, subsequent settling and no interference by coagulants, chlorine, etc.

Disadvantages of PAC

- Requires subsequent separation by coagulation/sedimentation/filtration.
- Regeneration is difficult.