

Adsorbants, Types and Applications

By Dr. Rafi Jamal Algawi

Adsorbents: Basic types

- **Activated Carbon (AC)**

Removal of all of the adsorbates mentioned above (to varying degrees) by the far most popular adsorbent

- **Activated Alumina**

- **Molecular Sieves (zeolite)**

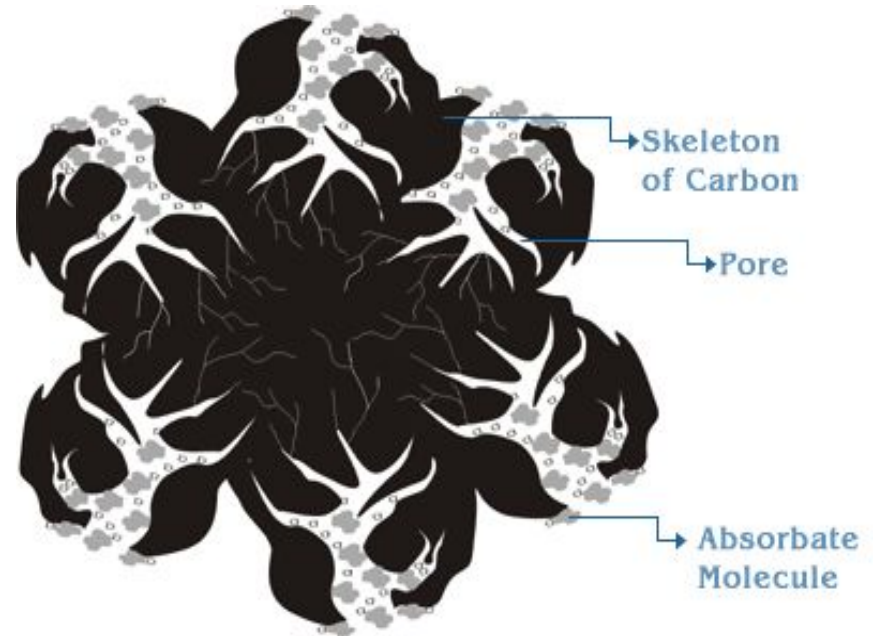
Clays with adsorptive properties

Adsorbents: Preparation of **activated carbon**

AC can be prepared from any carbonaceous material

e.g.

- Wood
- Lignite
- Coal
- Nutshells
- Bones



[Kan-Carbon,
2018]

Adsorbents: Preparation of **activated carbon**

Production process: Two steps

- **Pyrolysis:**

The carbonaceous material has to be **pyrolyzed** (heated in a low oxygen environment). This forms a “char”.

- **Activation:**

The char is then **activated** by heating to 800-1000 °C in the presence of steam, oxygen or CO₂ to form gaseous products.

Adsorbents: Preparation of **activated carbon**

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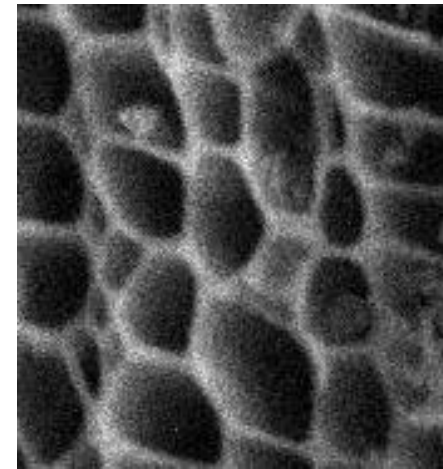
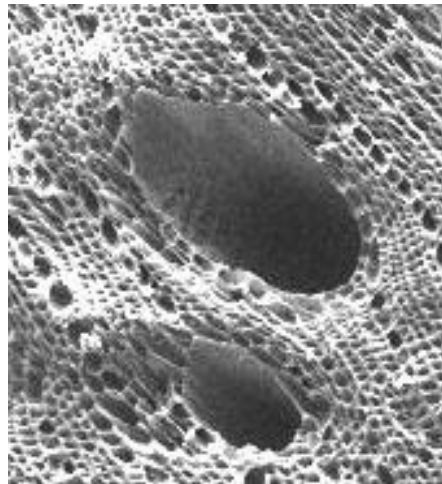
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Adsorbents: Properties of **activated carbon**

AC has a heterogeneous pore structure:

Increasing magnification

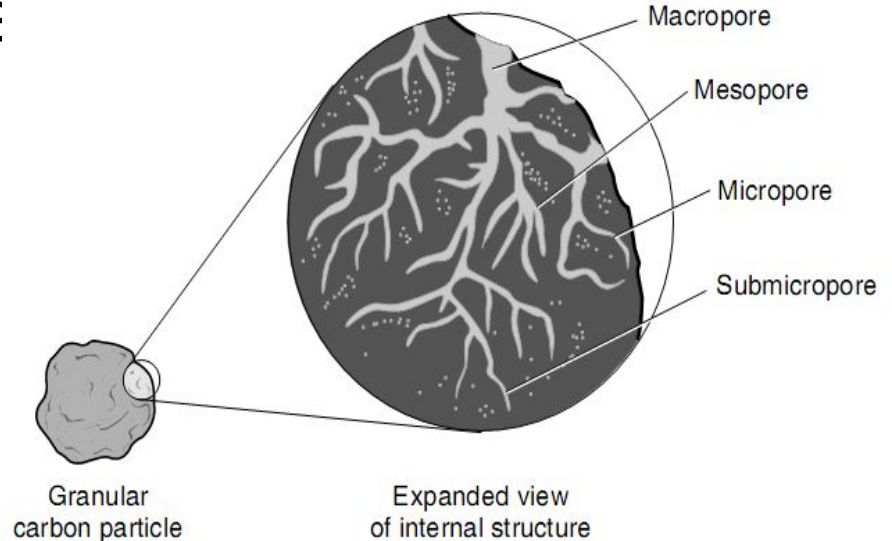


Photos of Activated Carbon [Zhang, 2015]

Adsorbents: Properties of **activated carbon**

Definition of AC pore size

- Micropores: $d < 2 \text{ nm}$
- Mesopores: $d = 2\text{-}20 \text{ nm}$
- Macropores: $d > 20 \text{ nm}$



Distribution:

Pore size	% pore volume	% surface area
Micro	30 - 60	> 95
Meso	< 10	< 5
Macro	25 - 30	negligible

Adsorbents: Types of **activated carbon**

PAC: Powdered activated carbon

- Fine powder, $d < 0.05$ mm
- Surface area as much as 100 acres/lb (≈ 1000 m²/g)
- Pore sizes (radii) down to 10^{-9} m

GAC: Granular activated carbon

- Diameter: 0.5 - 4 mm
- Surface area equal or a bit less than PAC

Adsorbents: Types of **activated carbon**

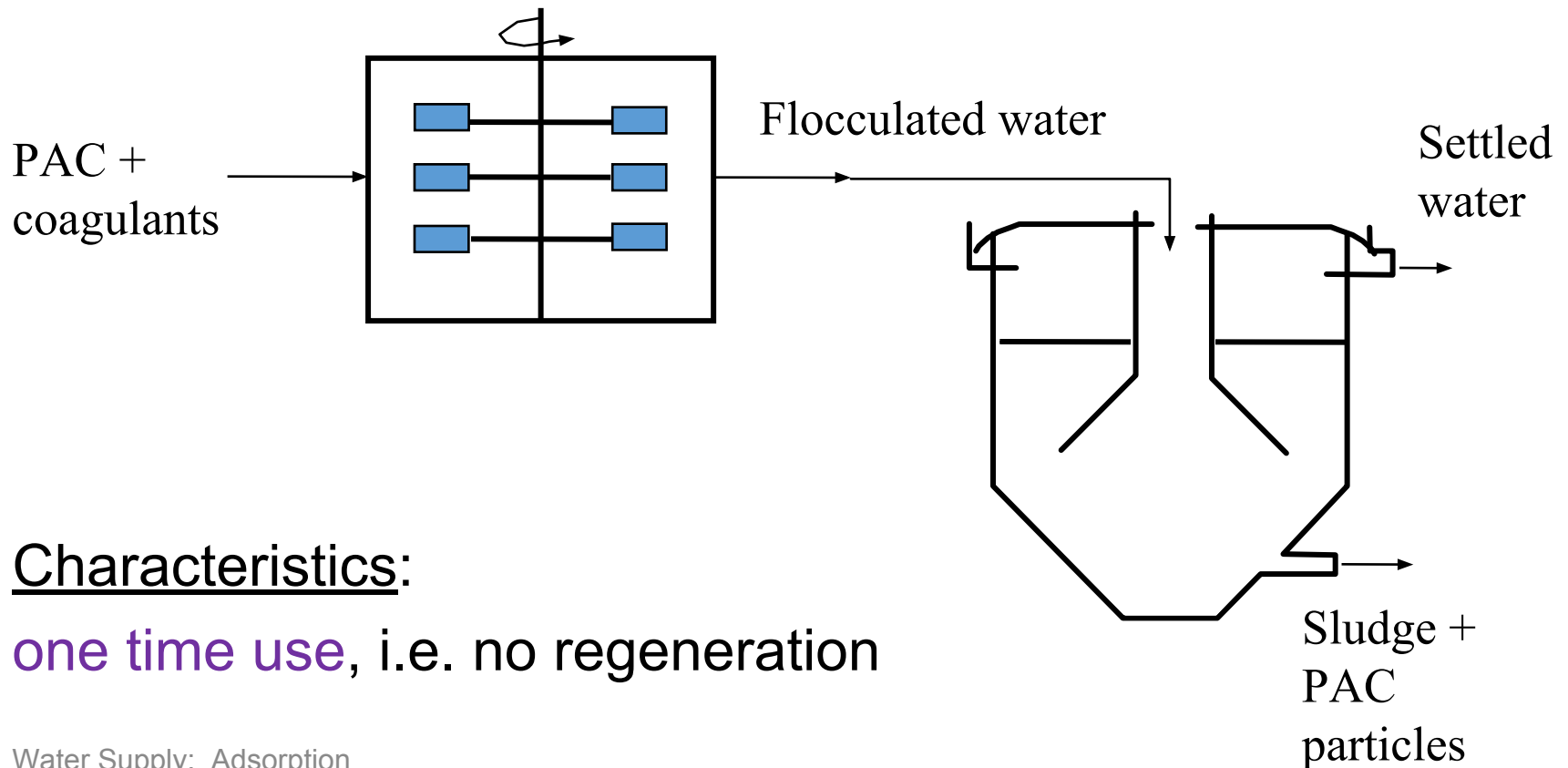
Comparison of GAC and PAC [Zhang, 2015]:

Parameter	Unit	Type of activated carbon ^a	
		GAC	PAC
Total surface area	m ² /g	700–1300	800–1800
Bulk density	kg/m ³	400–500	360–740
Particle density, wetted in water	kg/L	1.0–1.5	1.3–1.4
Particle size range	mm (μm)	0.1–2.36	(5–50)
Effective size	mm	0.6–0.9	na
Uniformity coefficient	UC	≤1.9	na
Mean pore radius	Å	16–30	20–40
Iodine number		600–1100	800–1200
Abrasion number	minimum	75–85	70–80
Ash	%	≤8	≤6
Moisture as packed	%	2–8	3–10

Adsorbents: Types of **activated carbon**

How to use PAC (typically for taste and odor removal):

Mixing with raw water + removal by sedimentation or filtration



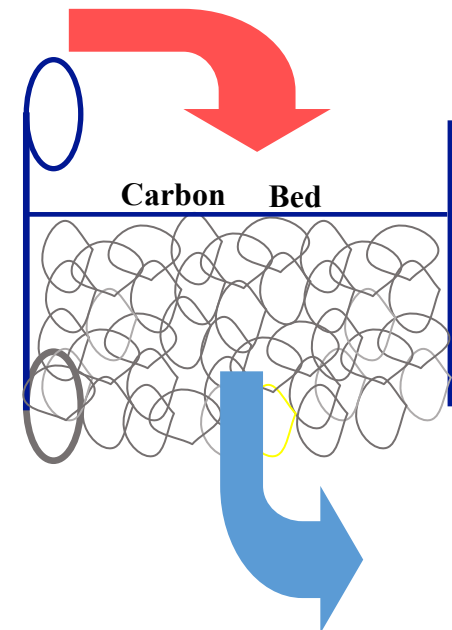
Characteristics:

one time use, i.e. no regeneration

Adsorbents: Types of **activated carbon**

How to use GAC (typically for treatment of groundwater and riverbank filtrate in order to remove taste, odor, and micropollutants):

- Use of a fixed-bed column
- Downward flow through the column
- After exhaustion of the carbon capacity regeneration in a furnace by oxidizing the adsorbed organic matter



Applications

- Removal of refractory organic compounds
- Removal of inorganic compounds such as nitrogen, sulfides, and heavy metals
- Chemical reduction of oxidants
- Removal of taste and odor compounds



Process configurations

Column flow system: Fixed-bed

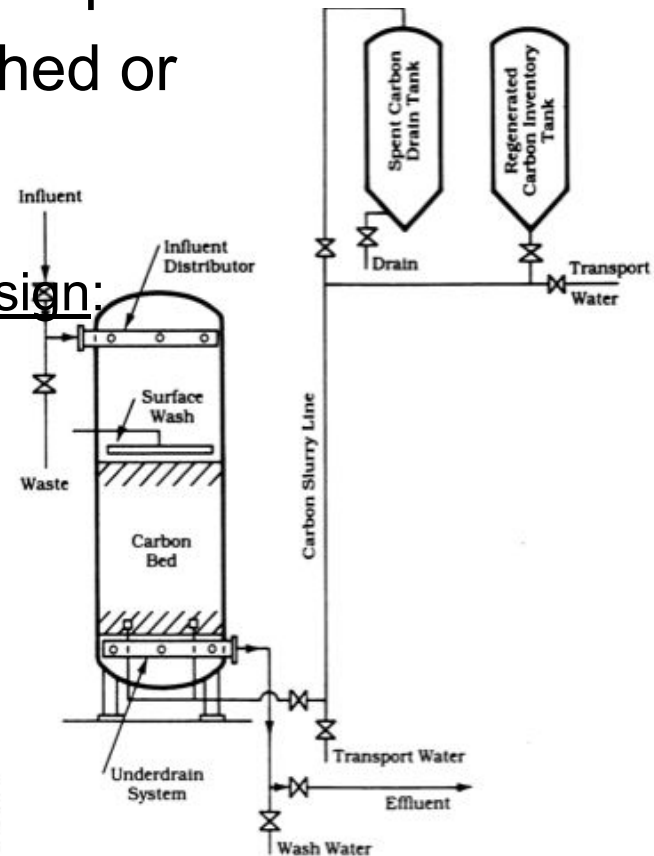
- Provides filtration as well as adsorption
- Has to be periodically backwashed or cleaned

Principle:



Practical design:

[Gao, 2016]

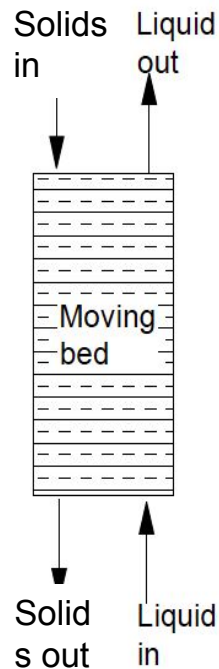


Process configurations

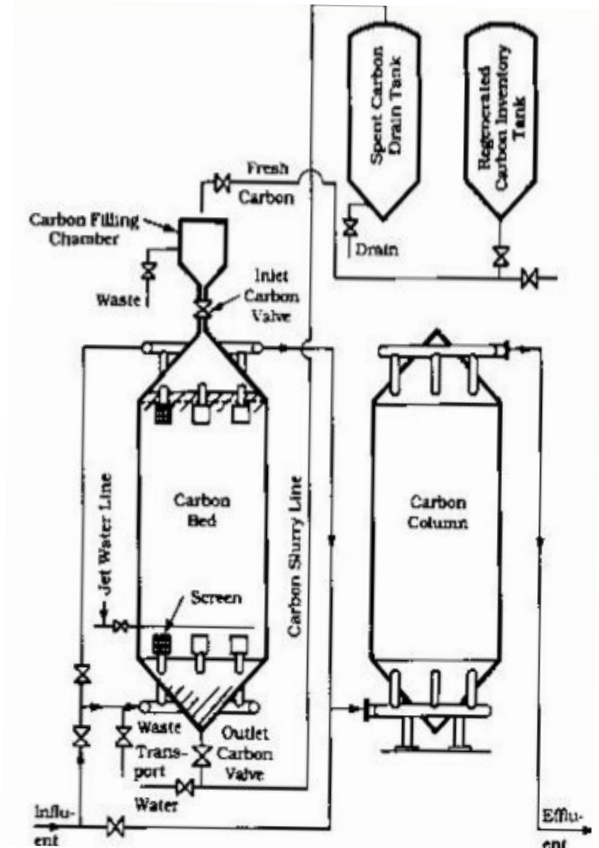
Column flow system: Fluidized-bed

- Continuous supply of fresh + removal of spent carbon
- Not effective as a filter

Principle:



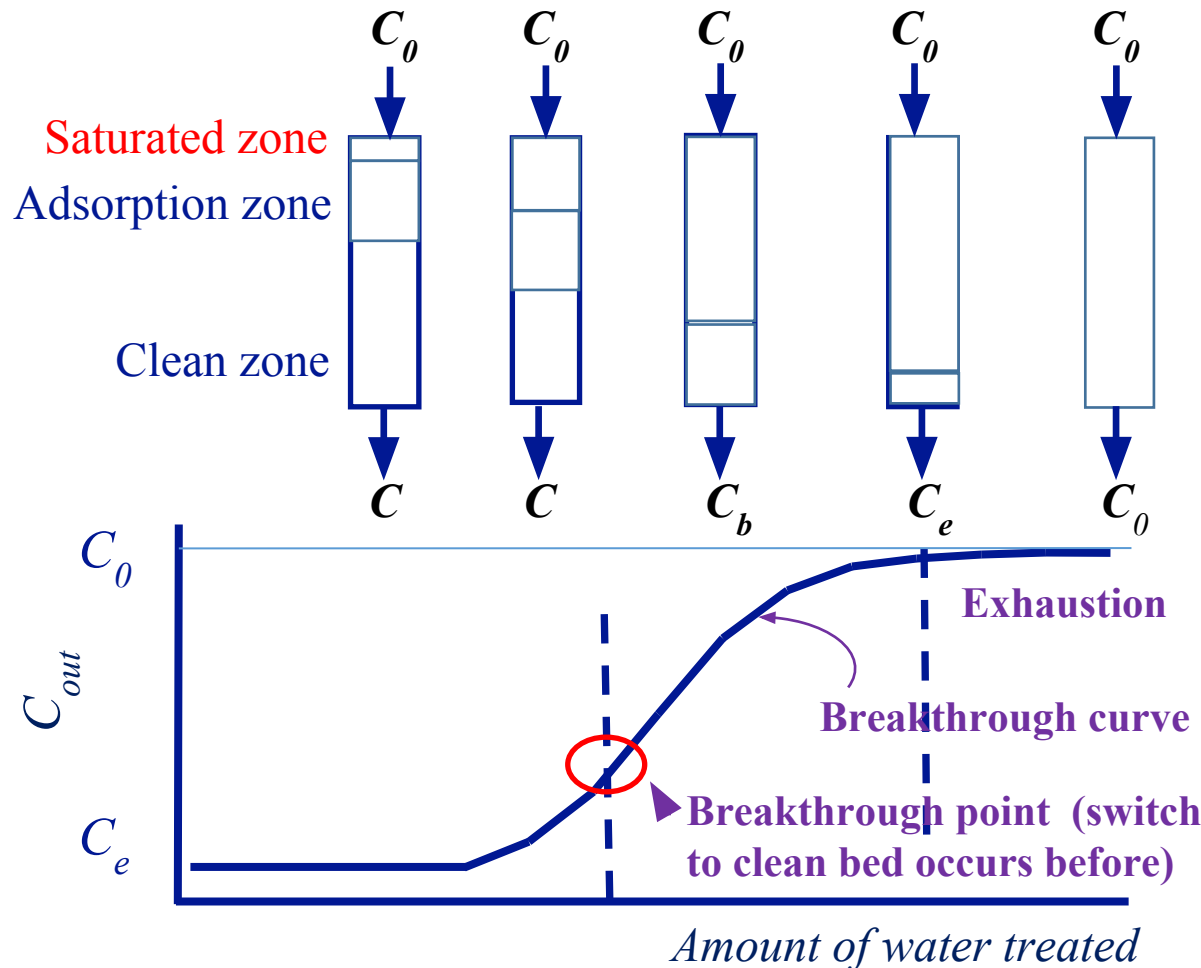
Practical design:



[Gao, 2016]

Process configurations

Fixed-bed system: Breakthrough development

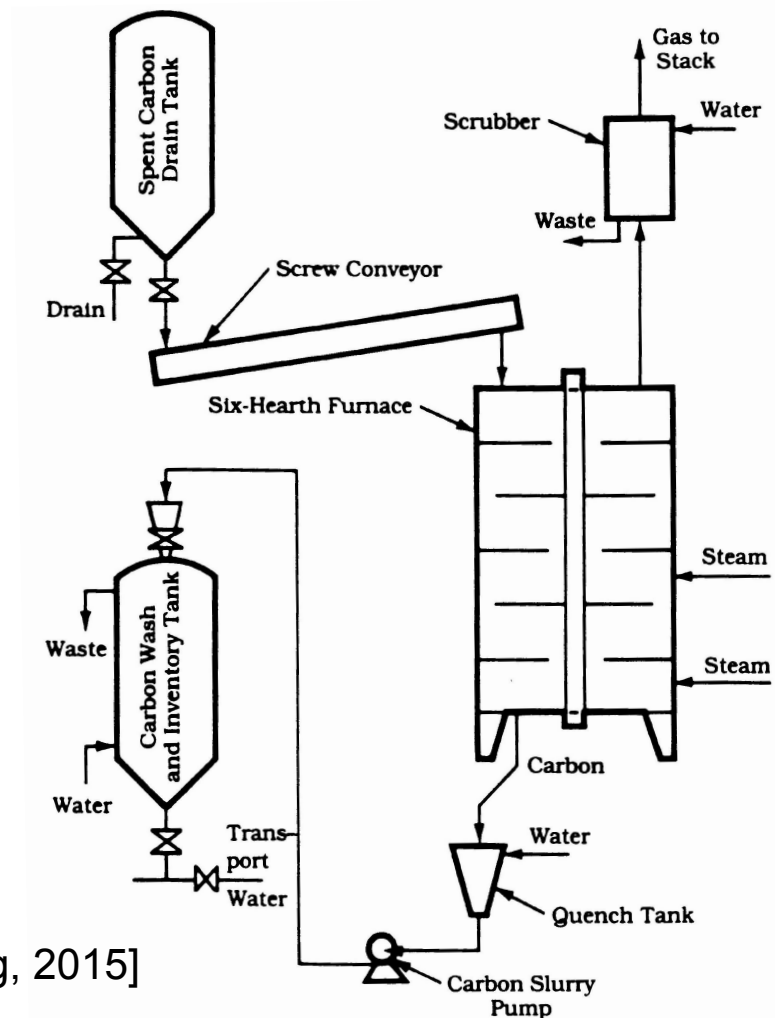


The time to breakthrough is decreased by:

- ✓ Increased particle size of carbon
- ✓ Higher concentration in the influent
- ✓ Increased pH of the water
- ✓ Increased flow rate
- ✓ Lower bed depth

Carbon Regeneration

- Spent carbon is usually regenerated at 500 °C under low oxygen conditions in the presence of steam.
- Activated carbon loss is about 5-15% for each regeneration.
- Adsorbed organics are volatilized and oxidized during the regeneration process.



[Zhang, 2015]