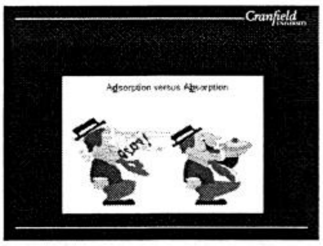
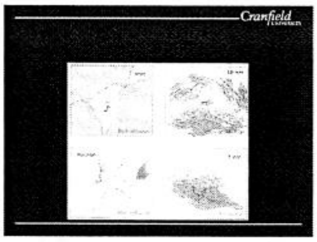
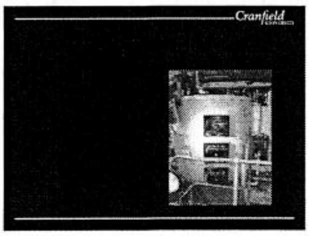
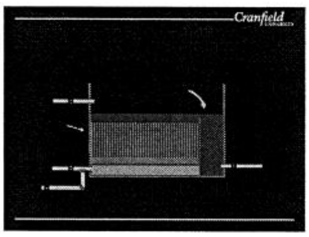
# Adsorption Theory and Application

Simon Parsons



## What is covered in this lecture?



## Adsorption

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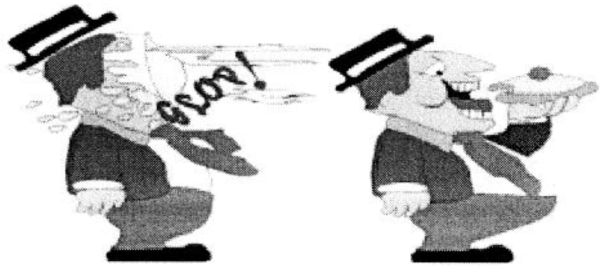
Adsorption versus Absorption



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## Adsorption

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- Tells us about fate and transport in the environment
  - also tells us how to remove them
- **Sorption**
  - Concentration or movement of contaminants from one phase to another
- **Adsorption**
  - Process where ion/molecules in one phase concentrate on the surface of another phase

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## Common Adsorbents

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| Adsorbent | Mean particle size (mm) | Surface area ($m^2\ g^{-1}$) | Density ($g\ cm^{-3}$) | PZC | Application |
|---|---|---|---|---|---|
| GAC PICACARB | 1 | 500-2000 | 0.5 | 4 | T&O, pesticides, NOM removal |
| PAC | 0.1 | 500-2000 | 0.5 | 4 | Taste and odour, pesticides, |
| Activated Alumina | 11 | 220 | 0.91 | 7.3 | Arsenic and fluoride removal |
| β-FeOOH | 0.03 | 142 | 0.45 | 8.3 | Arsenic Removal |

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## Potable Water Applications

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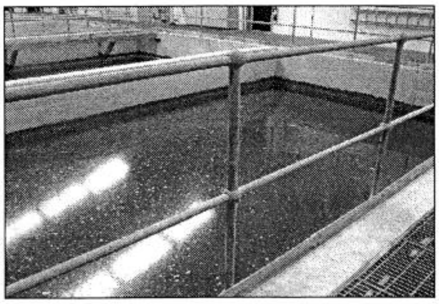

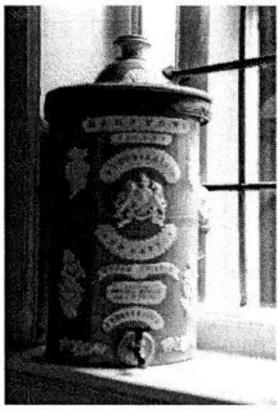

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## Adsorption Theory

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## Theory

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- What is adsorption
- Introduce isotherms
- What do isotherms tell us for design?
- Carbon activation and regeneration

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## Adsorption – What?

- A solute is retained on the surface of an adsorbent by the forces associated with the internal surface and structure of a porous solid
    - van der Waals forces
    - London forces
    - Hydrogen bonding and hydrophobic interactions
- Once adsorbed, it is termed the adsorbate



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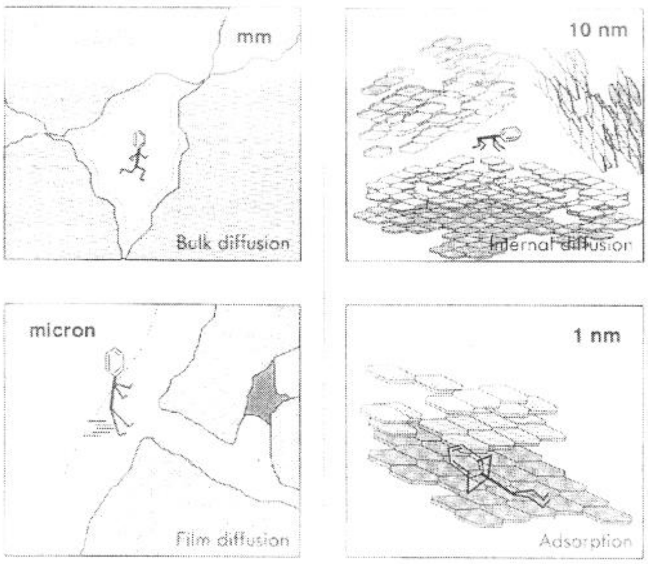
## Adsorption



## Isotherms

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- An Isotherm is a simple method to determine feasibility of using an adsorbent for a particular application.
- Allows you to work out capacity of a adsorbent for a impurity
- Allows you to compare different adsorbents

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## Isotherms

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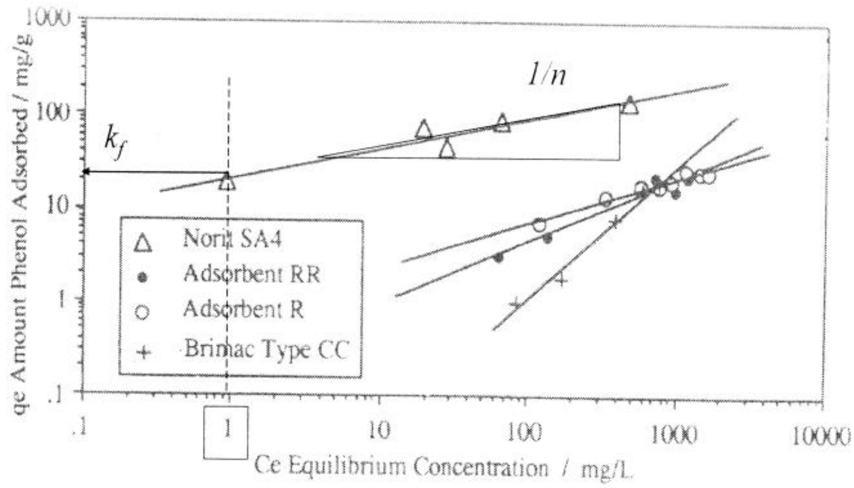


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## Activated Carbon (Pg 118)

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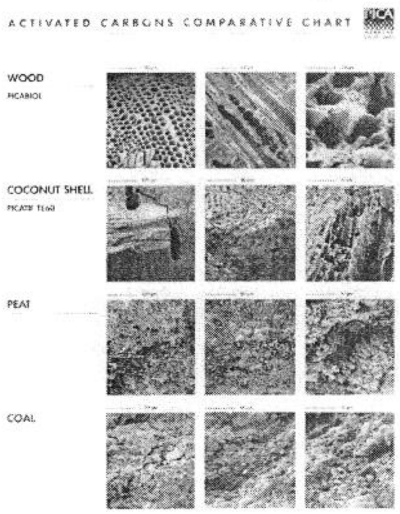


- Most common adsorbent used
- Developed during 1st World War for gas masks
- Why is carbon activated
  - one gram of ground coal has an internal surface area of only 10 $m^2$
  - the process of activation increases this internal surface area is increased up to 1000 $m^2$

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## Chemical Functionality

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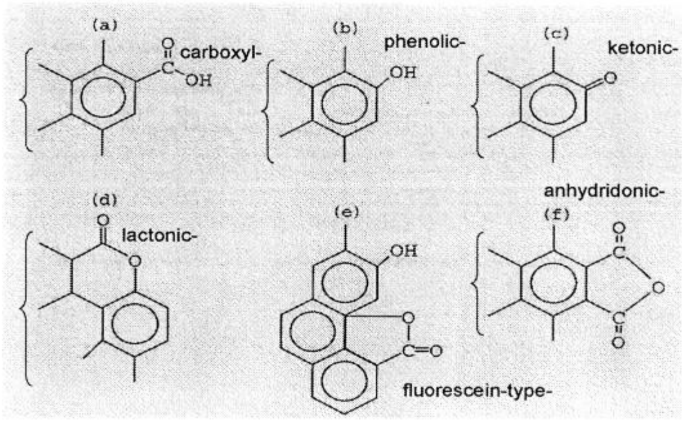


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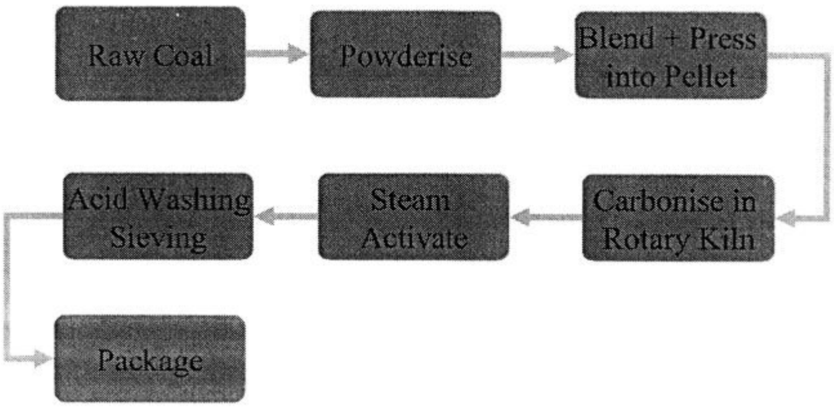
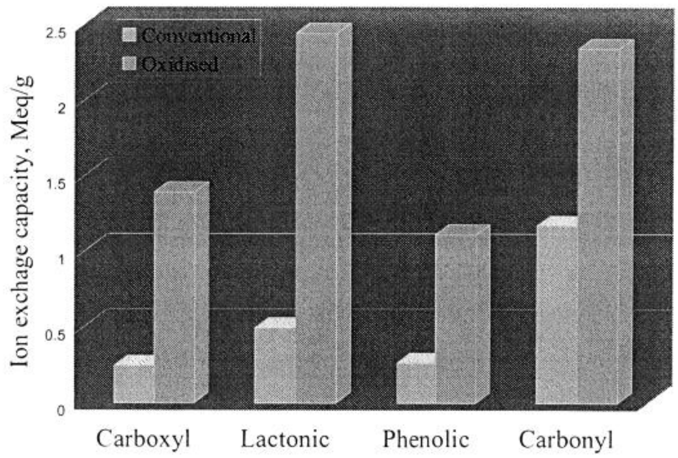
## Activating Carbon




## Activation – Functionality



## Dynamic Process

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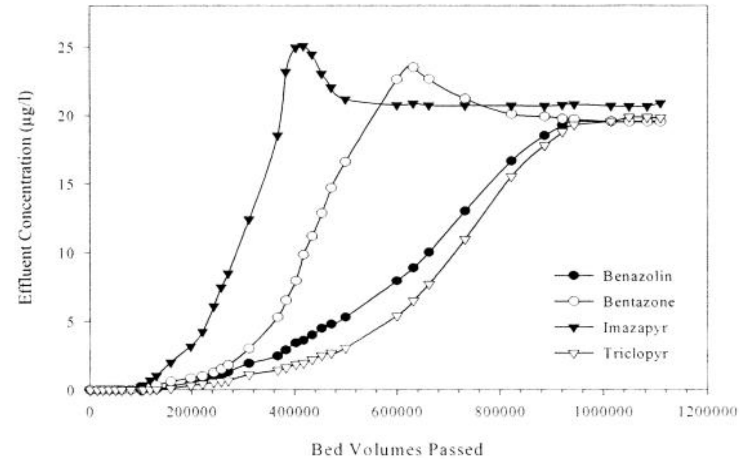


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## Regeneration

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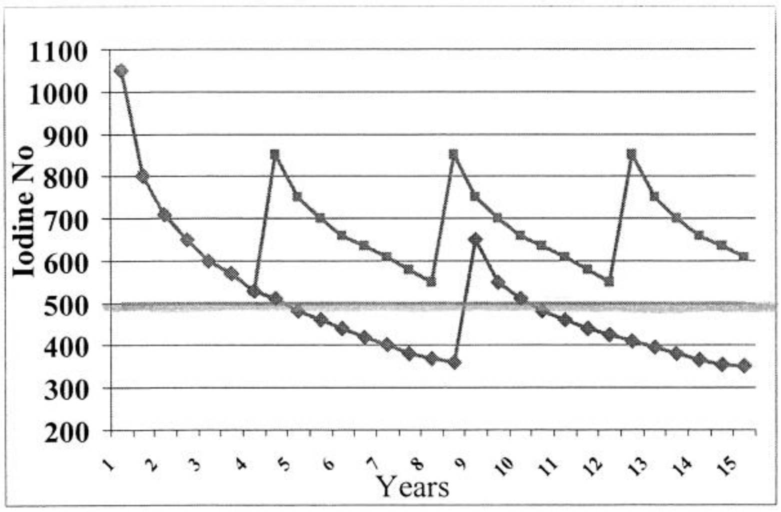


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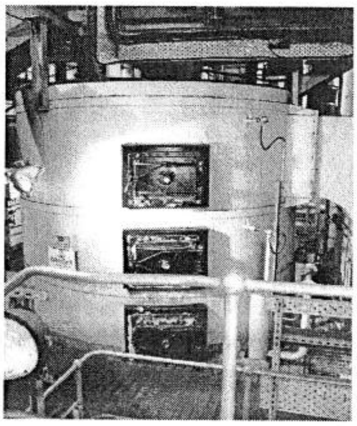
## Regeneration

- When GAC exhausted
- Regenerate with a thermal process (900 °C)
- Heat burns off adsorbed material
- Leaves carbon skeleton Intact
- Adsorption sites once again available
- Increases Iodine No. ( 250 - 300 pts)



## Applications

## Applications

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- How do I know if GAC will work
- What are potable water configurations
- What do process look like
- What do I need to know to design a contactor
- What else is used apart from activated carbon



## Activated Carbon

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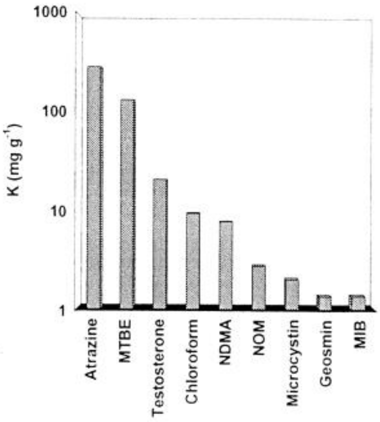
- Activated carbon (AC) is widely used in the water industry to remove organic and inorganic compounds.
- There are some general rules that can be used to predict if AC is likely to remove a molecule:
  - larger molecules adsorb better than smaller molecules.
  - non-polar molecules adsorb better than polar molecules.
  - slightly soluble molecules adsorb better than highly soluble molecules.
  - pH may have an influence on the extent of adsorption as it can control both polarity and solubility of a molecule.

## Contaminants

- natural organic matter and colour
- pesticides
- taste and odour
- algal toxins
- EDCs

- Guideline – GAC suitable when $k > 0.2$ mg $g^{-1}$

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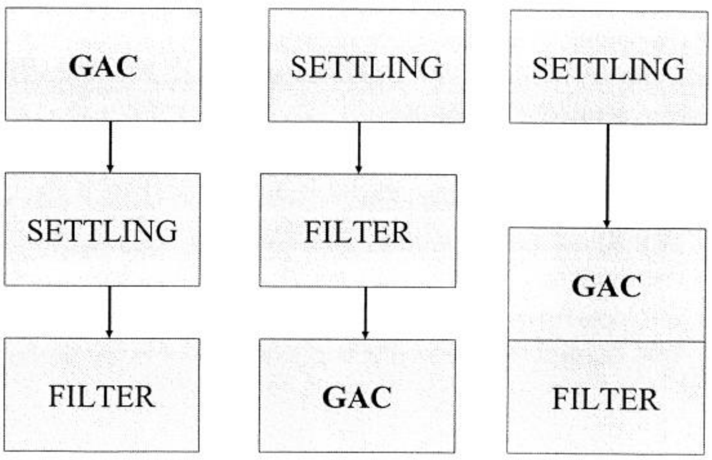
## Flowsheets

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## Gravity

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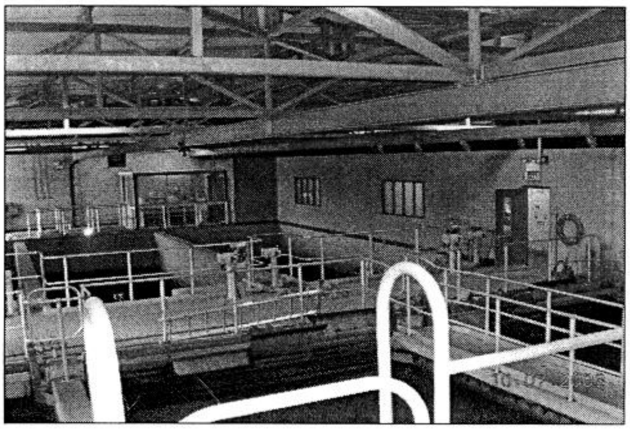

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## Gravity Contactors

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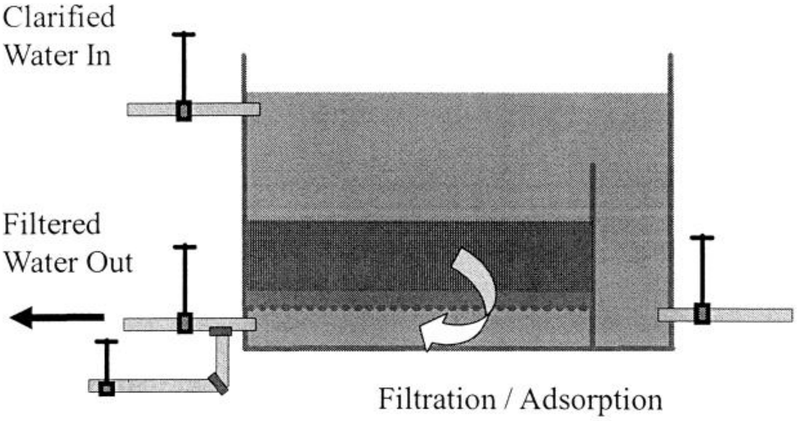


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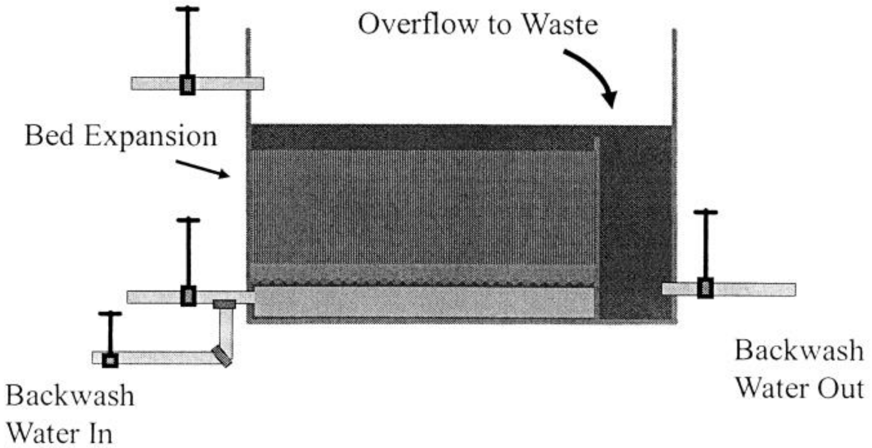
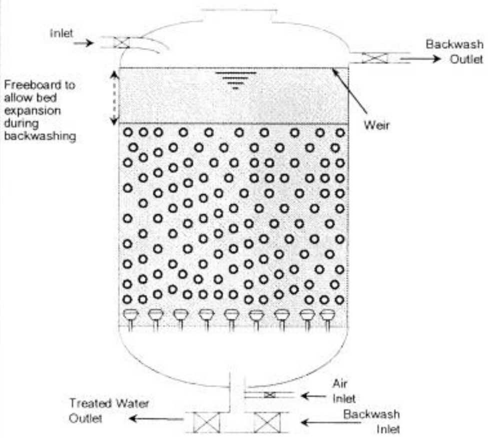
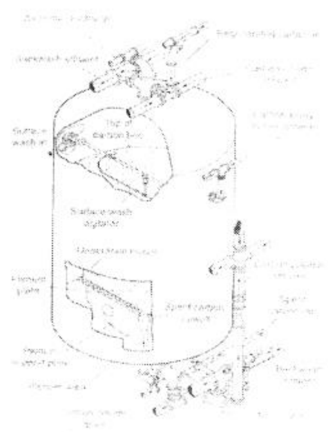
## Backwash Routine



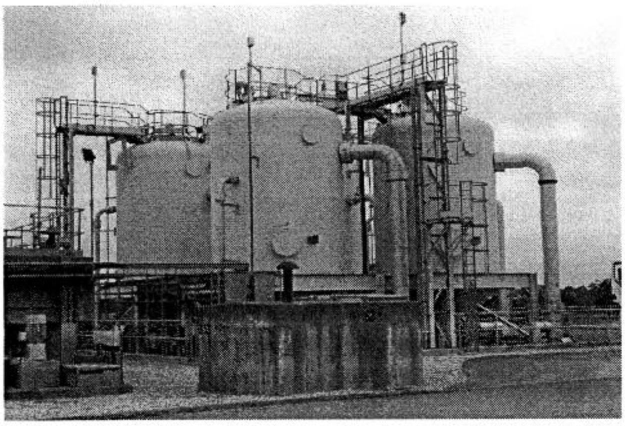

## Pressure Contactor



## Contactors







## Important Design Factors



- Design flow rate and system hydraulics
- Type and amount of organics/inorganics
- Type of GAC
- EBCT
- Adsorber type, volume and bed depth
- Surface loading rate
- Backwashing requirements
- Carbon usage rate

## EBCT & Bed Life

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$$EBCT = \frac{\text{carbon vol } (m^3) \times 60 \text{ (min/hr)}}{Q\ (m^3/hr)}$$

| | EBCT (mins) | Bed life (yrs) |
|---|---|---|
| • T&O | 6 – 12 | 2 - 4 |
| • Pesticides | 10 – 15 | 1 - 3 |
| • NOM | 15 – 30 | 1.5 - 3 |

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## What is covered in this lecture?

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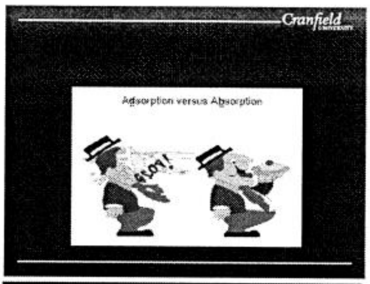


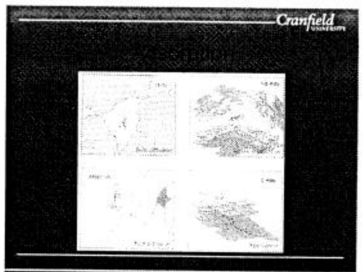

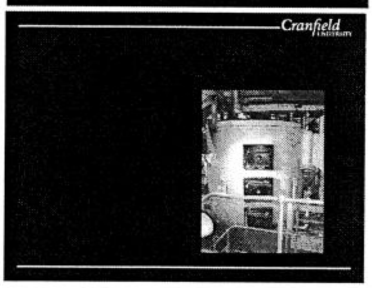

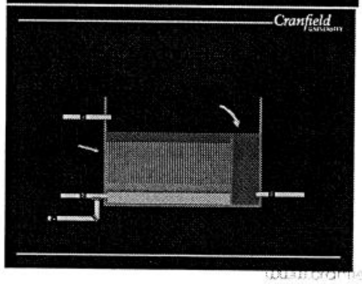

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## Simms, Nigel

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**Sent:** 30 September 2009 18:37
**To:** Simms, Nigel
**Subject:** Invoices raised on your projects

The following invoices have been raised:

| Cost C | Job | Job Title | Invoice No | Invoice Date | Amount | Invoice Text |
|---|---|---|---|---|---|---|
| WU8 | WU38424Z | Corrosion testing - high temp. degradation of gas turbine materials | 1251325 | 11/09/2009 | -9975.00 | Your reference 3580010224 |
| WU8 | WU38426Z | High Temperature degradation of gas turbine materials | 1251327 | 11/09/2009 | -19345.00 | REFERENCE PO: 3580011846 |
| WU8 | WU38427Z | High temperature oxidation/corrosion of gas turbine materials | 1251328 | 11/09/2009 | -17090.00 | REFERENCE PO: 3580010392 |

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