Concrete — A Century of Innovation

Introduction to Transport Properties
What they are and what they do

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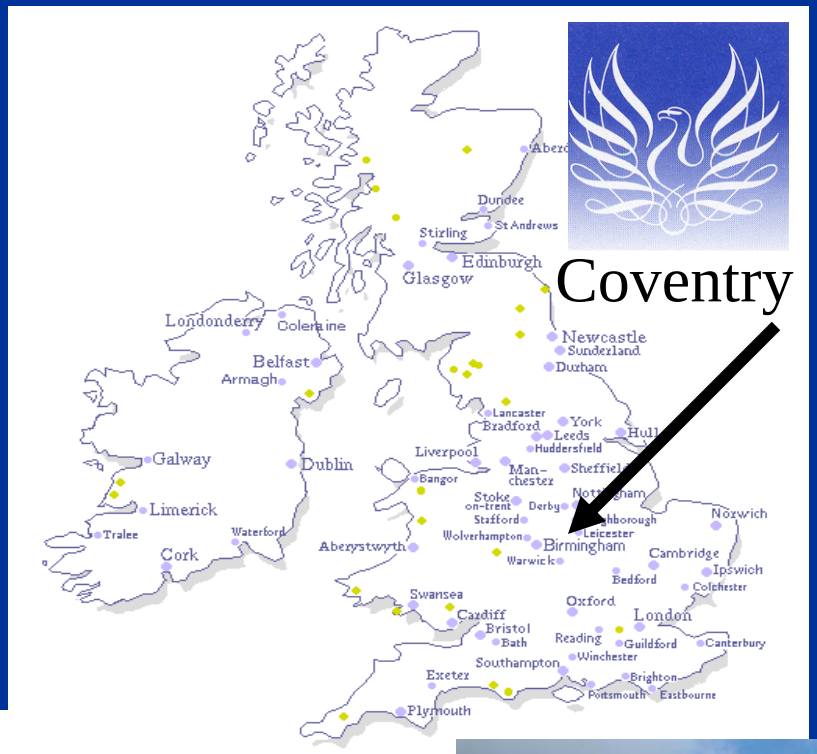
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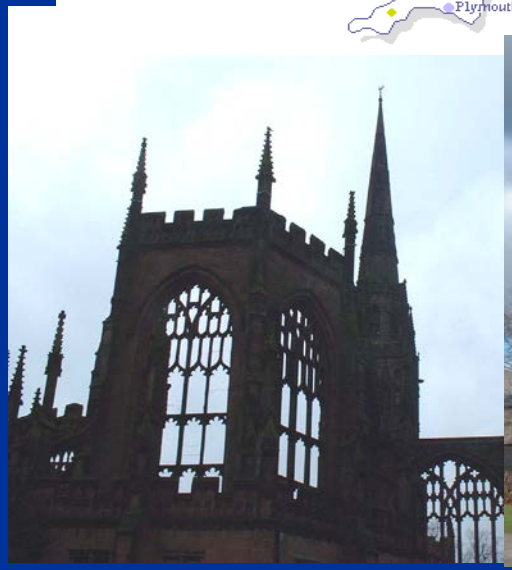


The Transport Processes described in this presentation

- Pressure driven flow
- Diffusion,
- Electromigration
- Thermal migration

Processes which Promote or Inhibit Transport

- Adsorption (inhibits)
- Capillary suction (promotes)
- Osmosis (promotes)

What is being transported ?

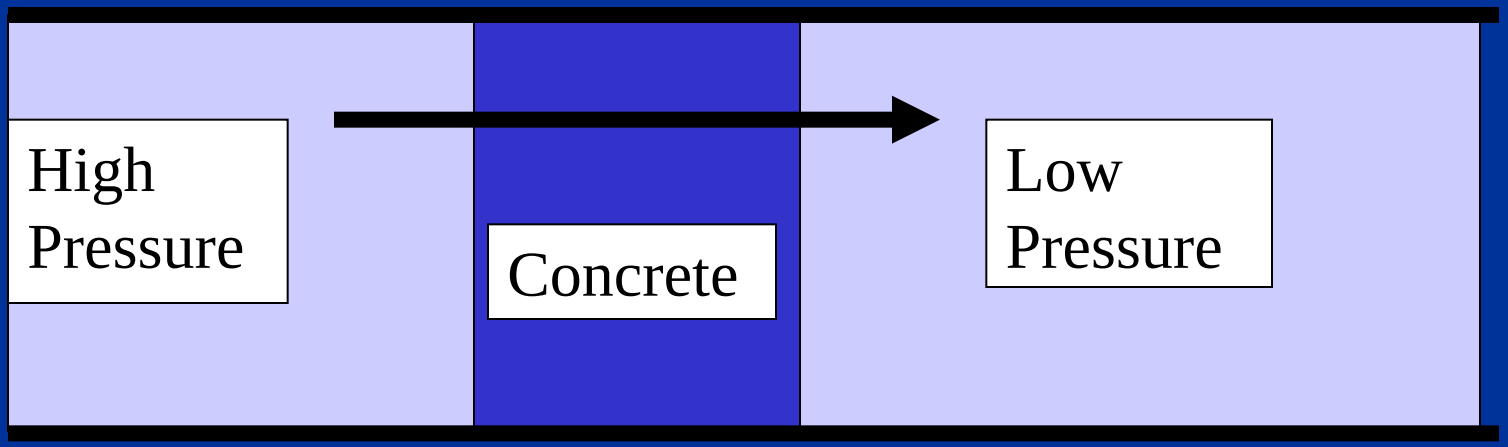
- Ions (e.g. Na^{+} and $Cl^{-)}$ may move through the water

OR

- Water itself may move with the ions in it

Pressure driven flow (Permeation)

- Water (which may contain salt) flows in the direction of the applied pressure.



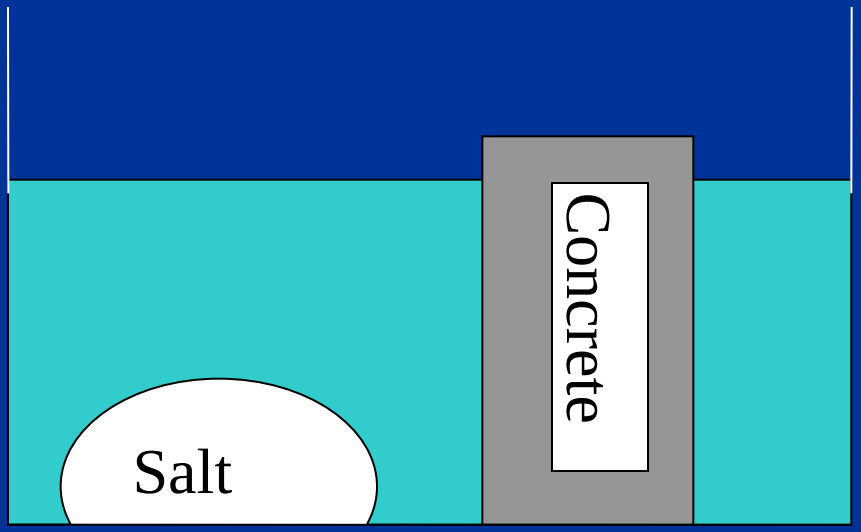
Units of Permeability

- Coefficient of permeability (hydraulic conductivity) of concrete is approximately 10^{-12} m/s

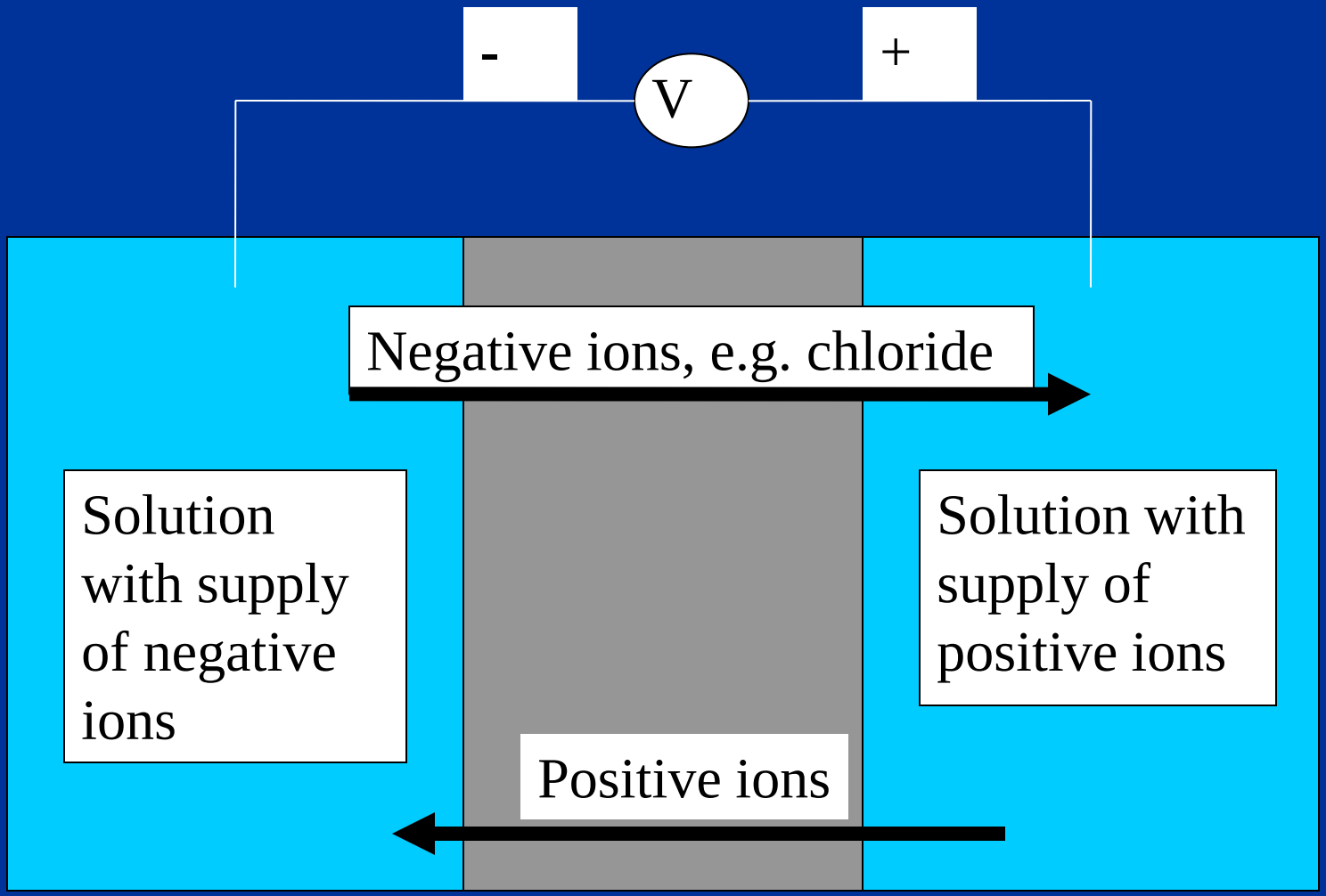
- Intrinsic permeability of concrete is approximately 10^{-19} m^2

Diffusion

When the salt dissolves into the water it will assume an equal concentration at all points throughout the liquid and will enter the concrete



Electromigration

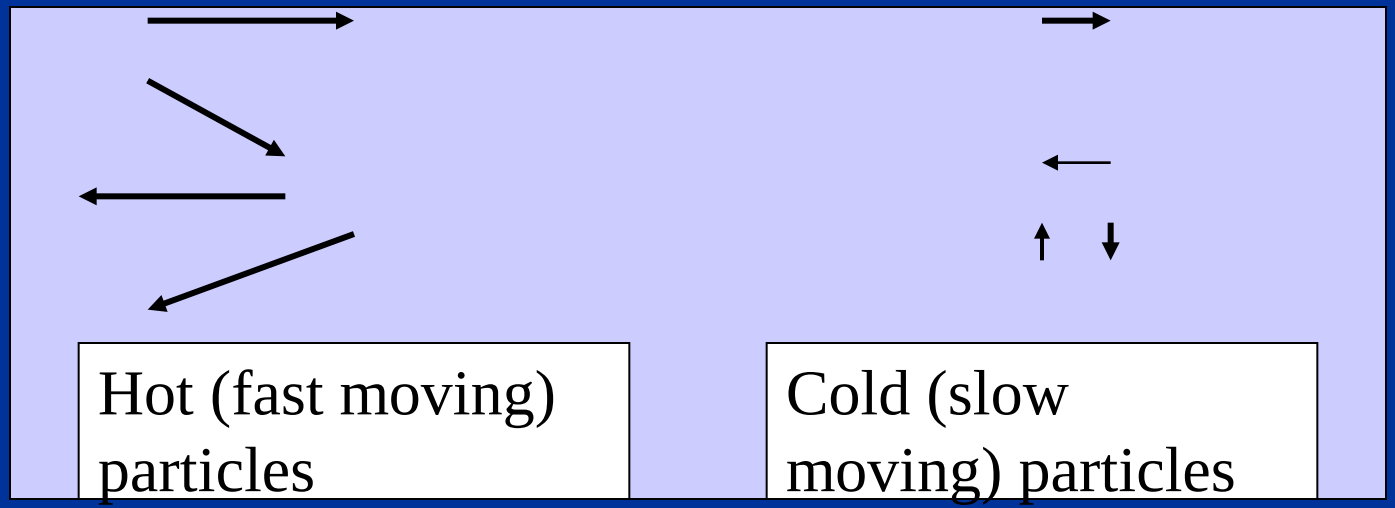


Electromigration - Where Does the Voltage Come from?

- An external source such as leakage from a direct current power supply
- Electrical potential of pitting corrosion on reinforcing steel.

Thermal Gradient

A concrete structure which has been contaminated with de-icing salt heats up in sunlight



Processes which increase or reduce the transport.

Adsorption

Adsorbed ions are fixed into the matrix in various ways and are unable to move and therefore unable to cause any deterioration.

The ratio of total concentration (including adsorbed ions) to concentration in solution is the “capacity factor”.

Measuring Chlorides

- "acid soluble" will extract all of the chlorides including those adsorbed onto the matrix.
- "water soluble" will not measure adsorbed ions (assuming the test is too short for adsorbed ions to dissolve).
- "pore squeezing" can be used to squeeze the sample like an orange (using very high pressures) but will not measure adsorbed ions.

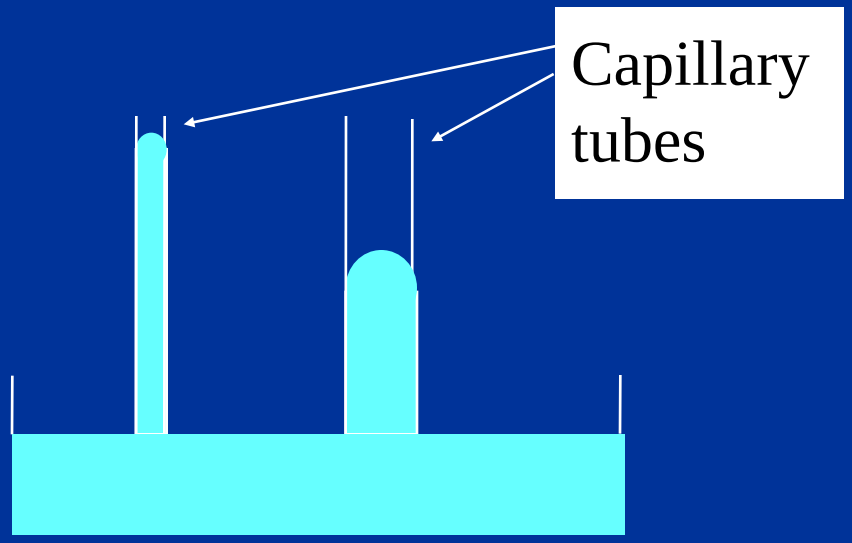
Diffusion with adsorption.

- The apparent diffusion coefficient is defined from measurements of total concentration in the solid.

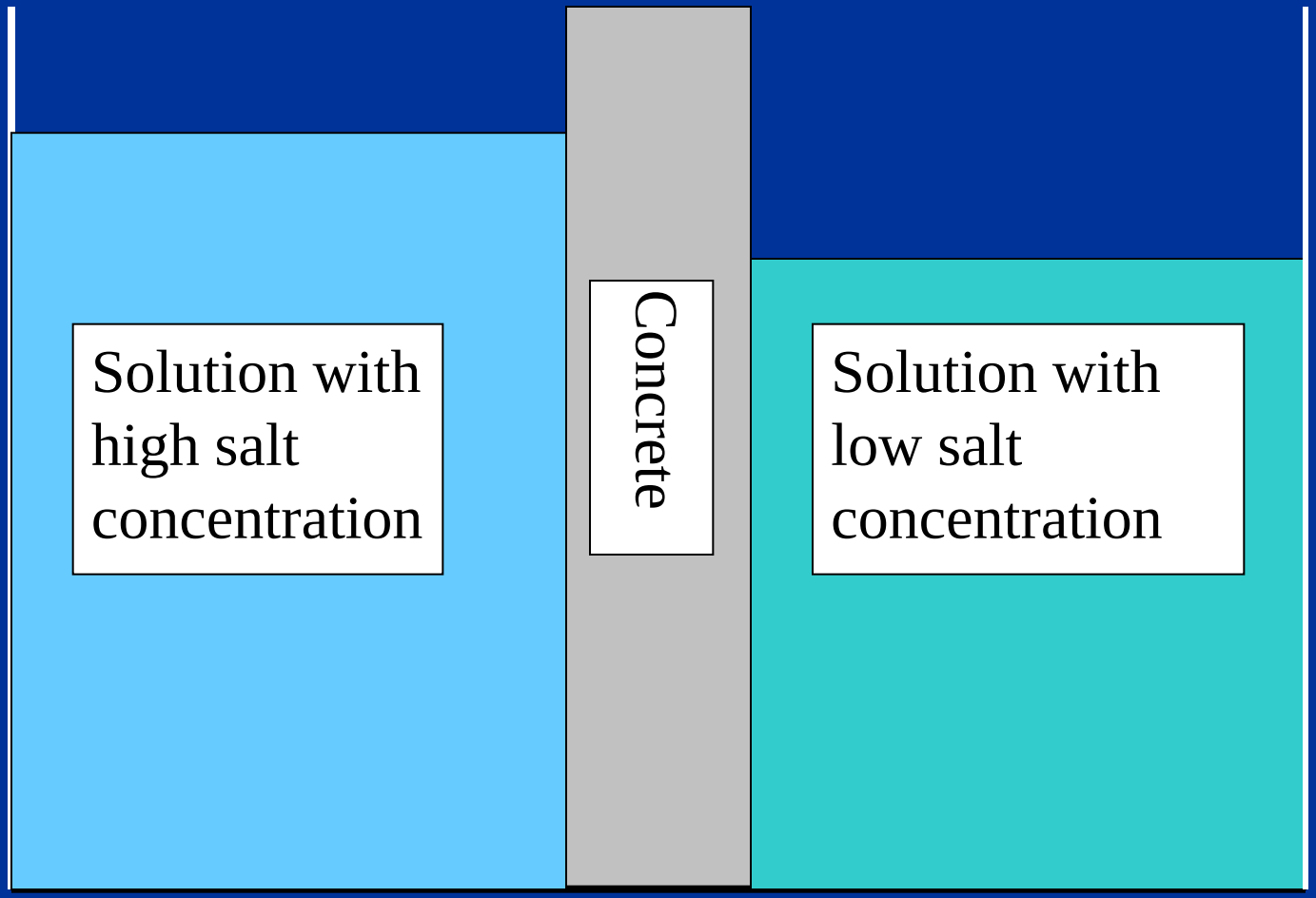
- The intrinsic diffusion coefficient is defined from measurements of the pore solution concentration.

Capillary Suction

Water rises higher up a smaller diameter glass capillary tube



Osmosis


Solution with high salt concentration
Concrete
Solution with low salt concentration

Factors Affecting Durability

Factors which can be controlled	Properties of the matrix	Transport Processes	Deterioration Processes
	Hydrate Structure	Pressure driven flow	Freeze-Thaw
Water to cement ratio	Pore interconnection (formation factor)	Diffusion	Sulphate Attack
Curing conditions	Porosity (total pore volume)	Electromigration	Alkali-silica reaction
Environmental conditions	Pore fluid content	Thermal Gradient	Reinforcement Corrosion
Degree of compaction	Pore fluid chemistry	Osmosis	Salt Crystallisation
Cement Type	Matrix chemistry	Capillary suction	
		Adsorption	

w/c ratio and curing

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Cement type and electromigration

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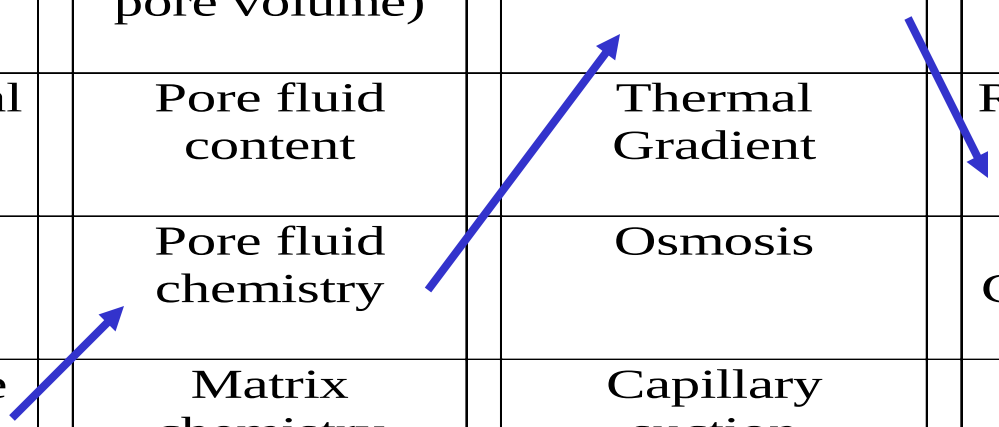

Cement type and adsorption

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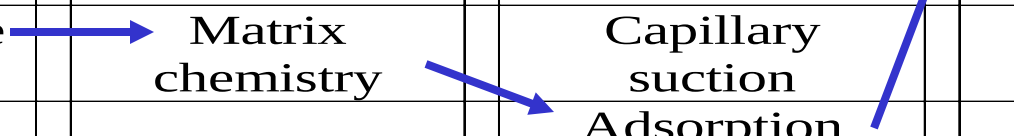
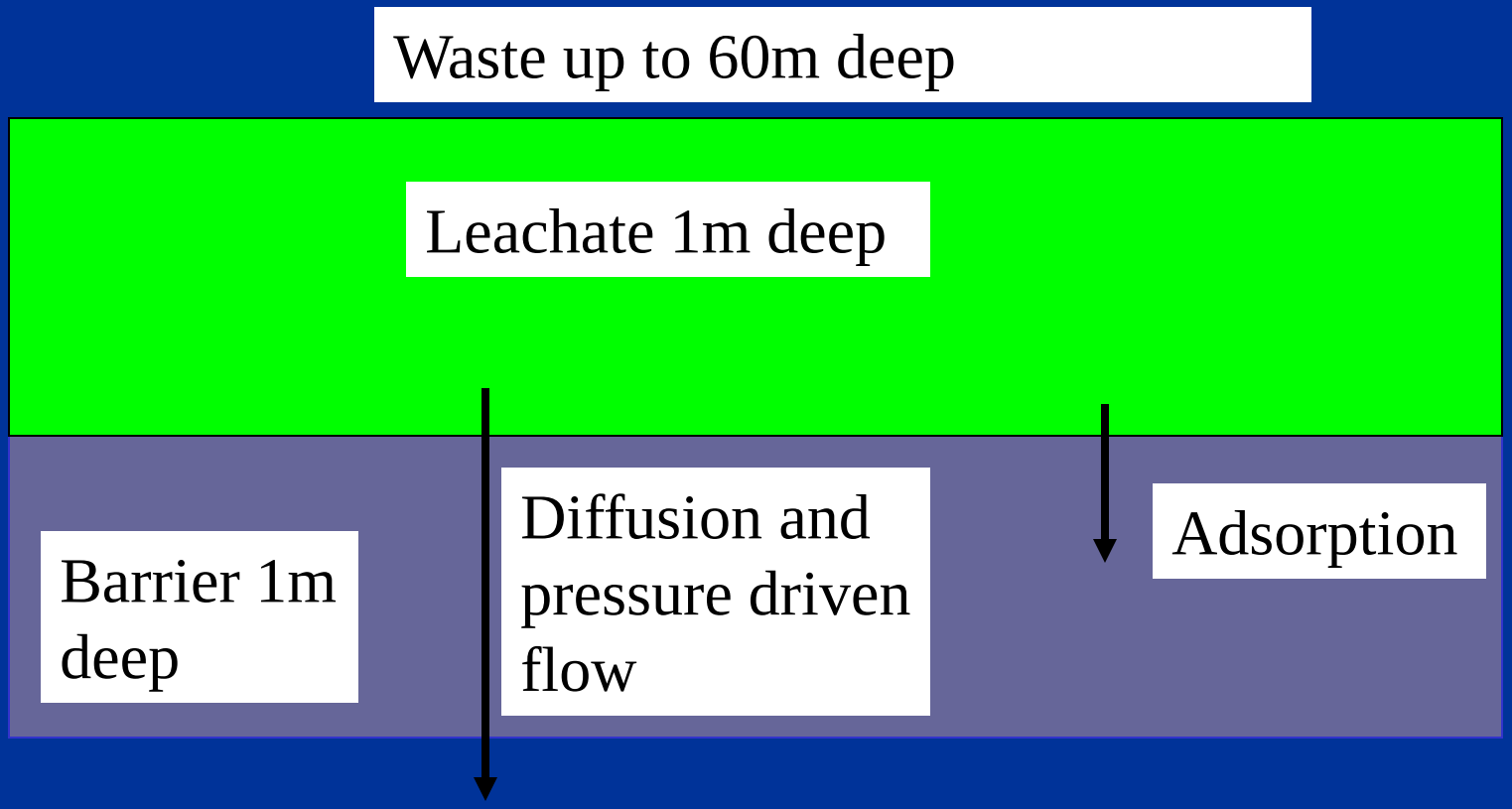
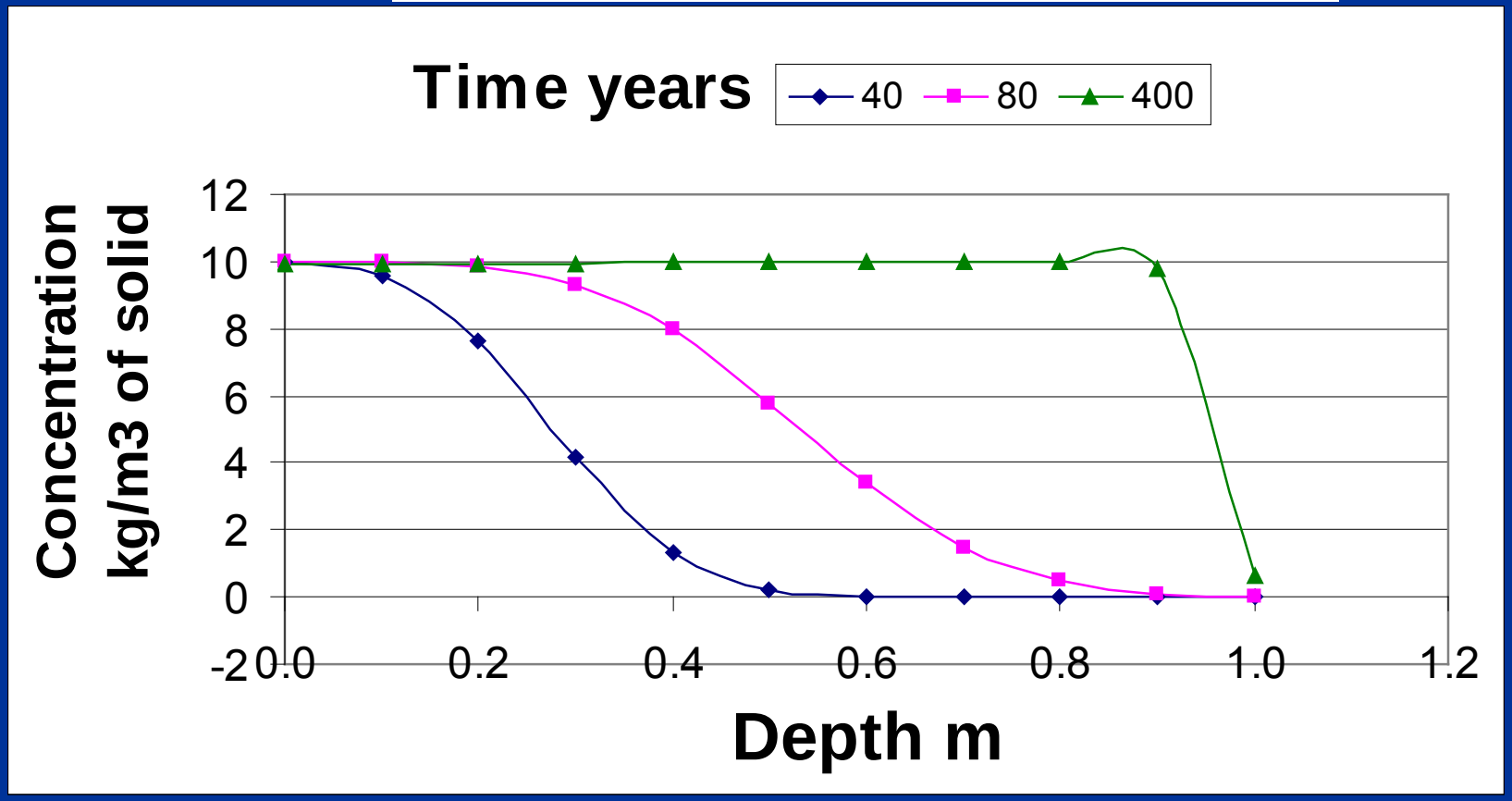


Calculations for a waste containment barrier.



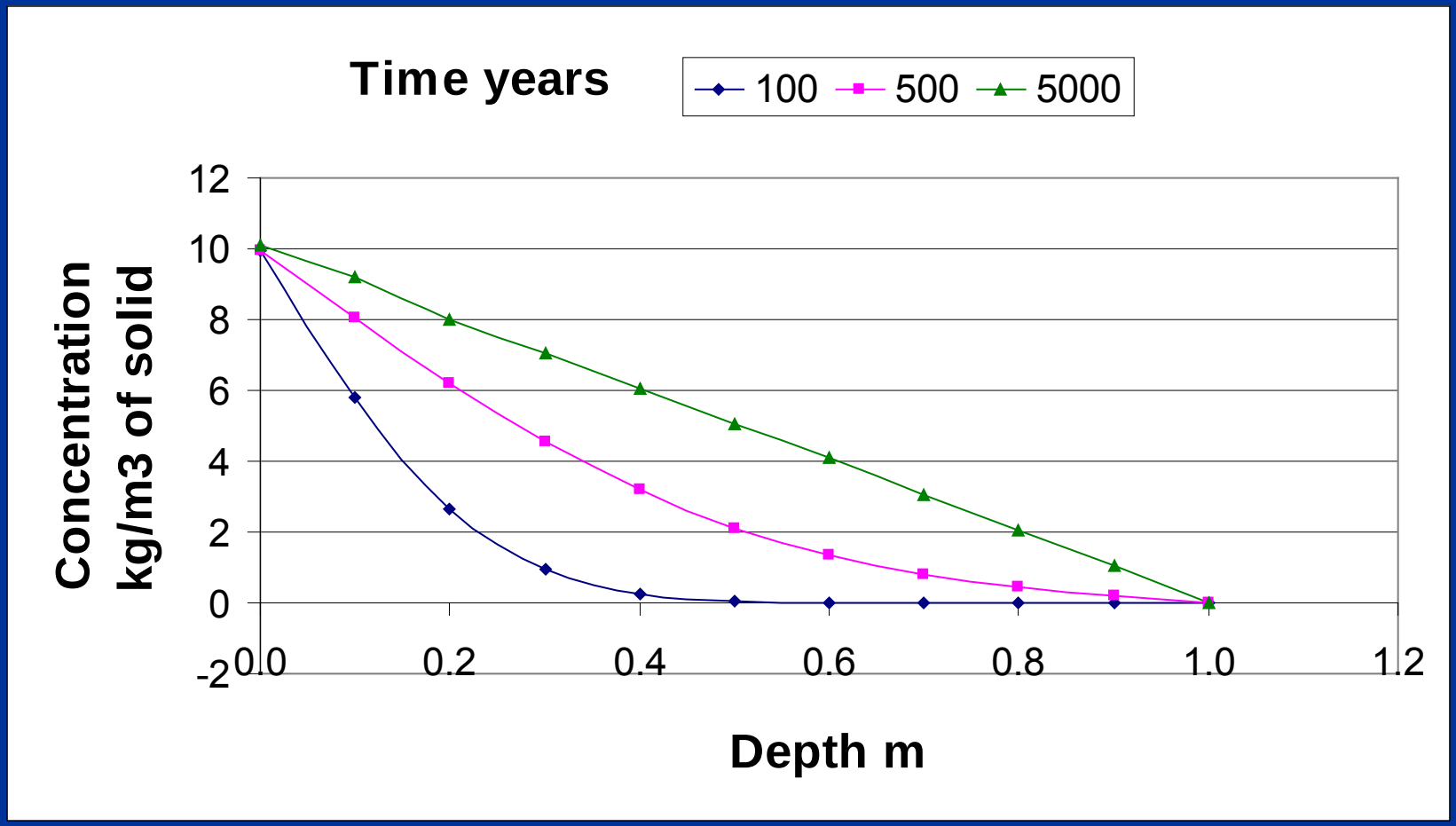
Permeability Control

$k = 10^{-9}$ m/s $D = 5 \times 10^{-12}$ m^2/s

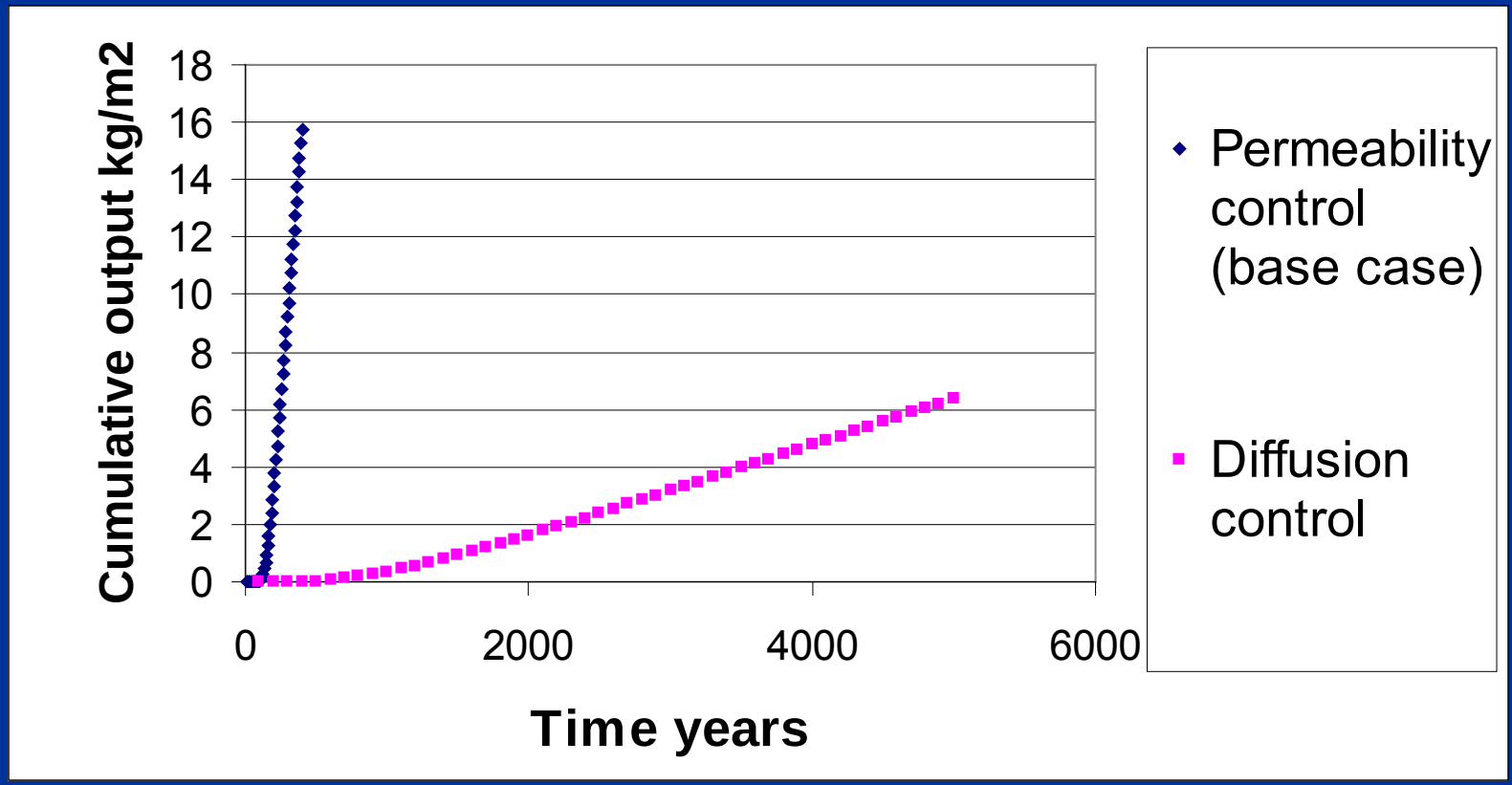


Diffusion Control

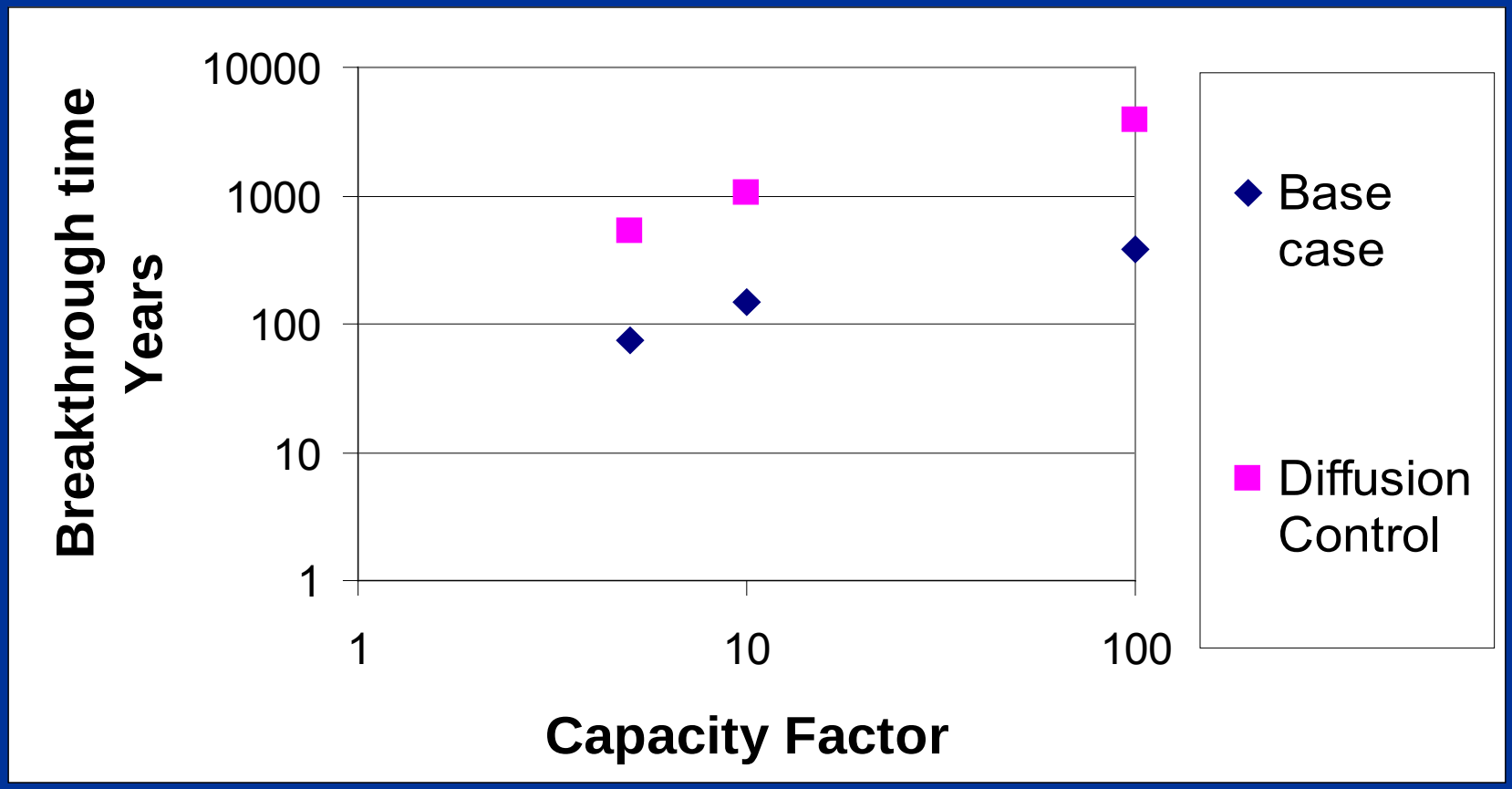
$k = 10^{-12}$ m/s



Output of contaminants from base of barrier



Effect of Capacity Factor



Thank You

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