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HOCHSCHULE FÜR TECHNIK

Sustainable Life-Cycle-Management for Reinforced Concrete Structures: New Strategies for Durability Assessment

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Institute for Technical Chemistry –
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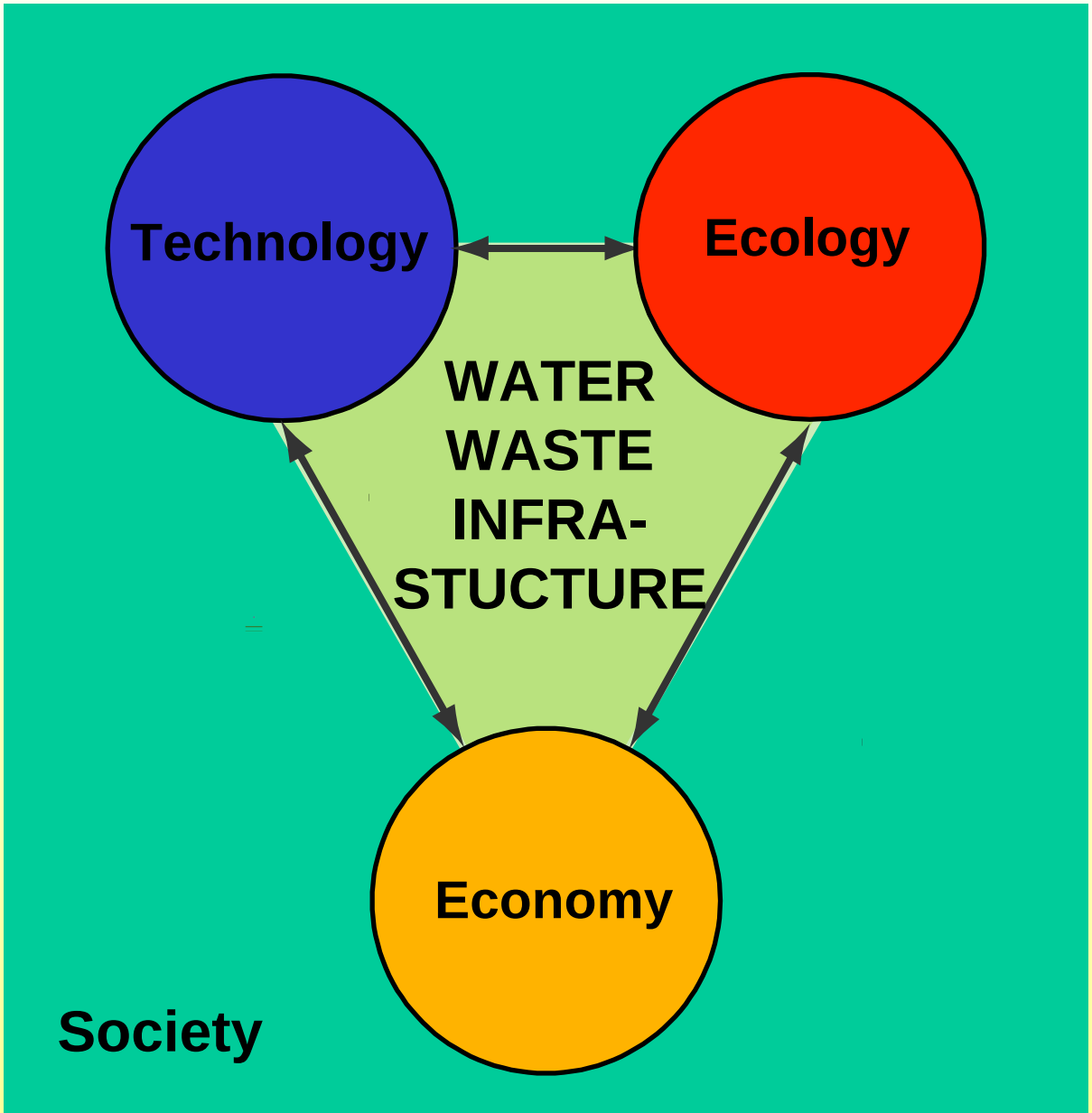
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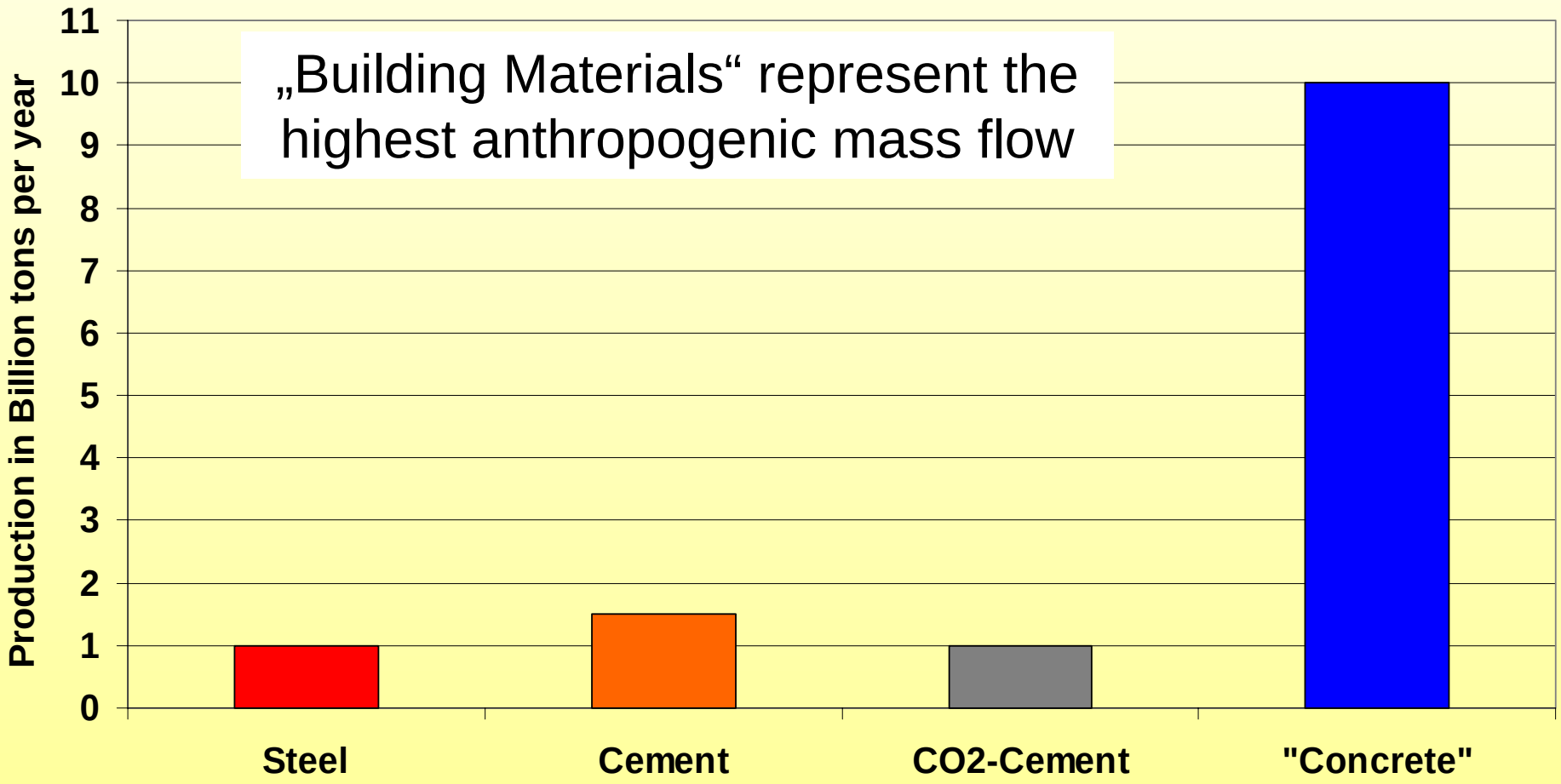
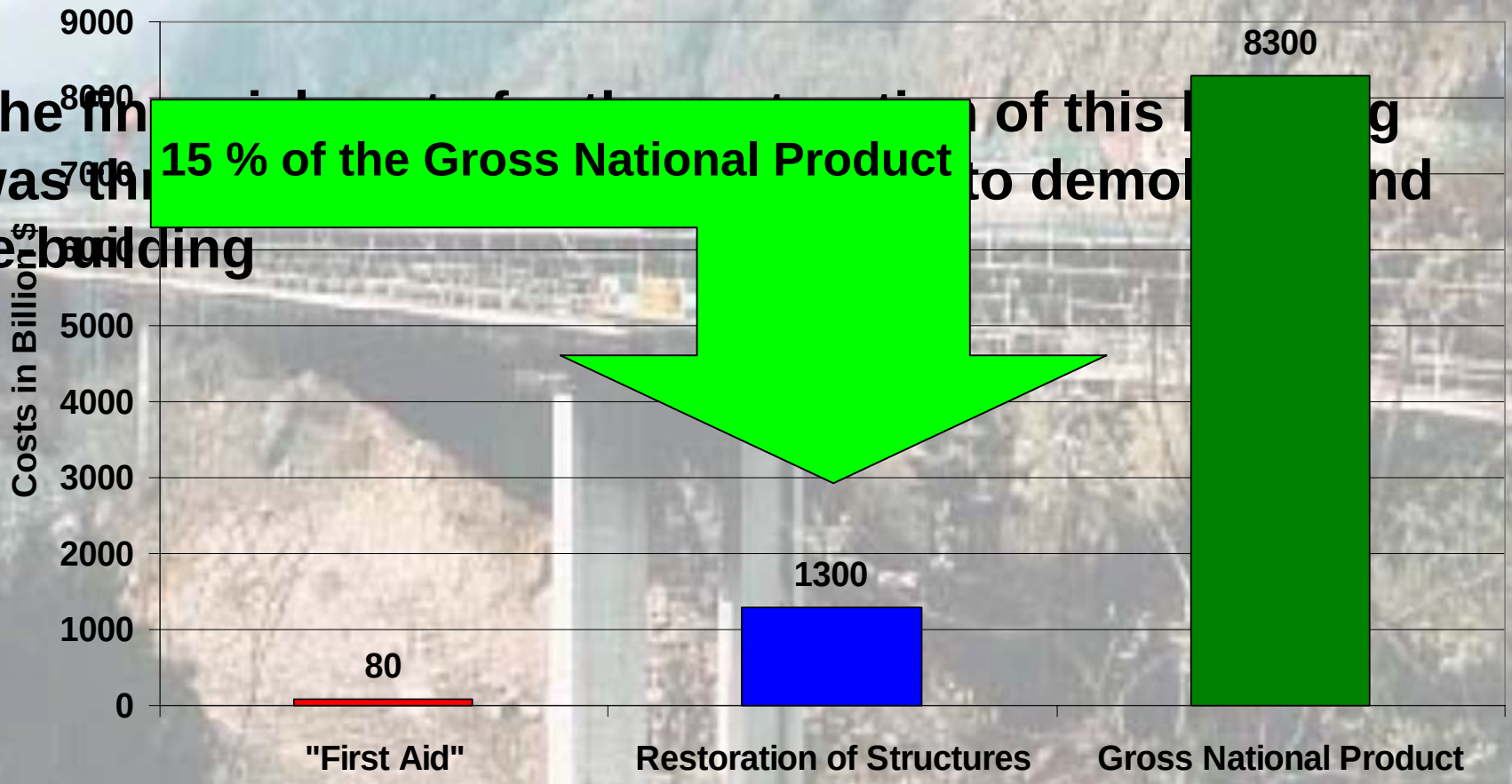
Building Materials - Ecological Aspects



Building Materials – Economical Aspects

The fin… …of this b…g was th… …to demol… …nd re-building



Gotthard-Highway, Switzerland

Building Materials - Technical Aspects

2000 years old Water Reservoirs made with „Opus Cementitium“

Durability – also a Problem in Ancient Times


Herrn E. L. Zieglers,
Beantwortung
Preisfrage
über die
Ursachen der Festigkeit
alter
Römischer und Gothischer Gebäude
und die Mittel,
gleiche Dauerhaftigkeit den neuen Mauerwerken
zu geben.
Berlin, 1776.

Reasons for the Strength of Roman and Gothic Brickwalls and the Measures to Achieve this Durability for New Brickwalls.

F.L. Ziegler (1776)

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Durability of Constructions in Modern Times

Deterioration Mechanisms

- Chloride Induced Corrosion
- Carbonation
- Sulphate Attack
- Hydrolysis of Cement-Based Materials in Permanent Contact with Water
- ...

„Reactive Transport of Chemical Compounds“

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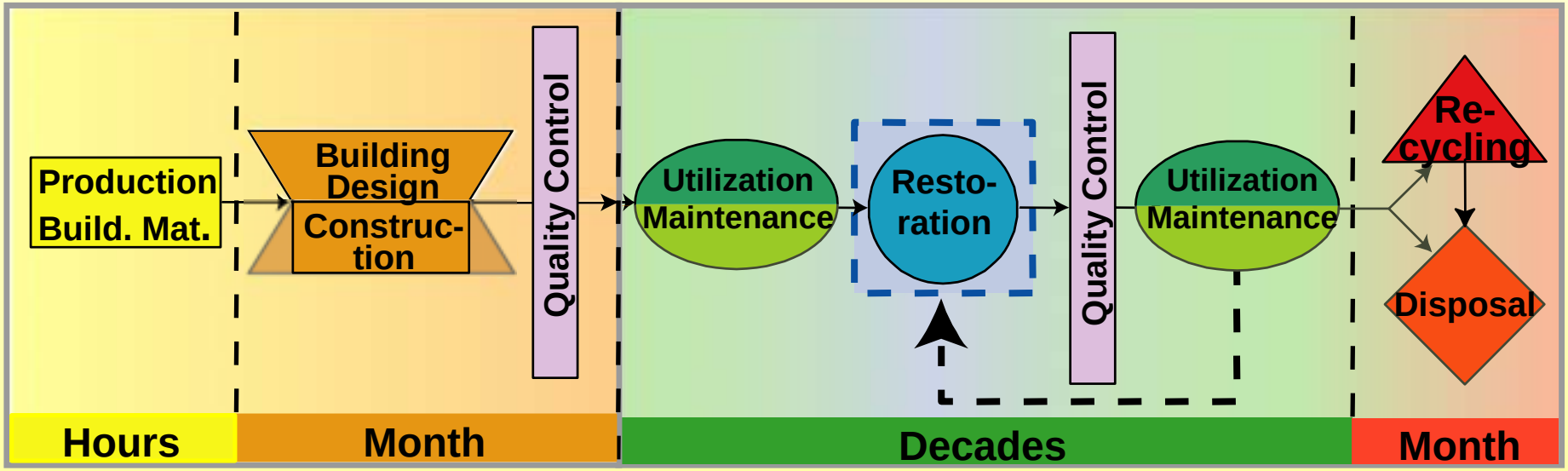
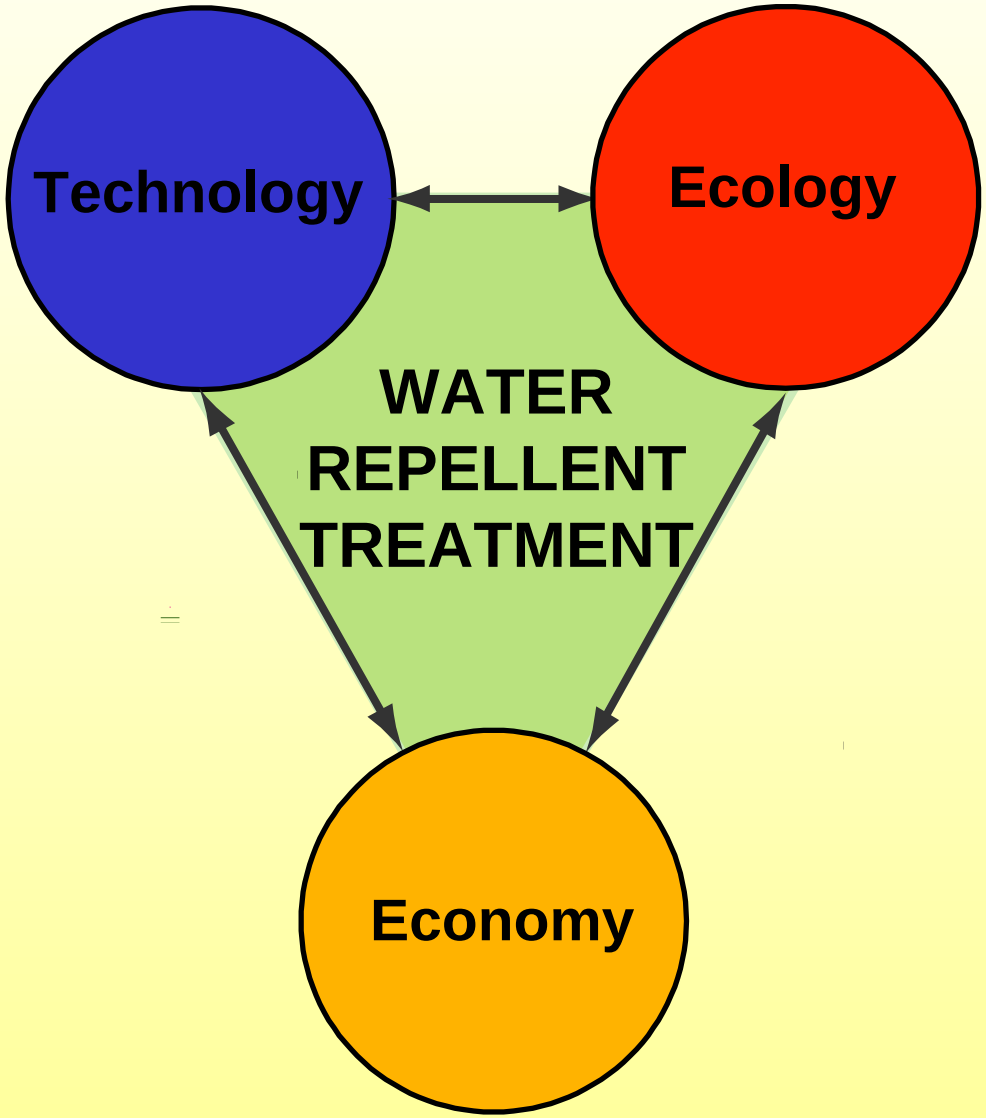
Life-Cycle-Management of Buildings

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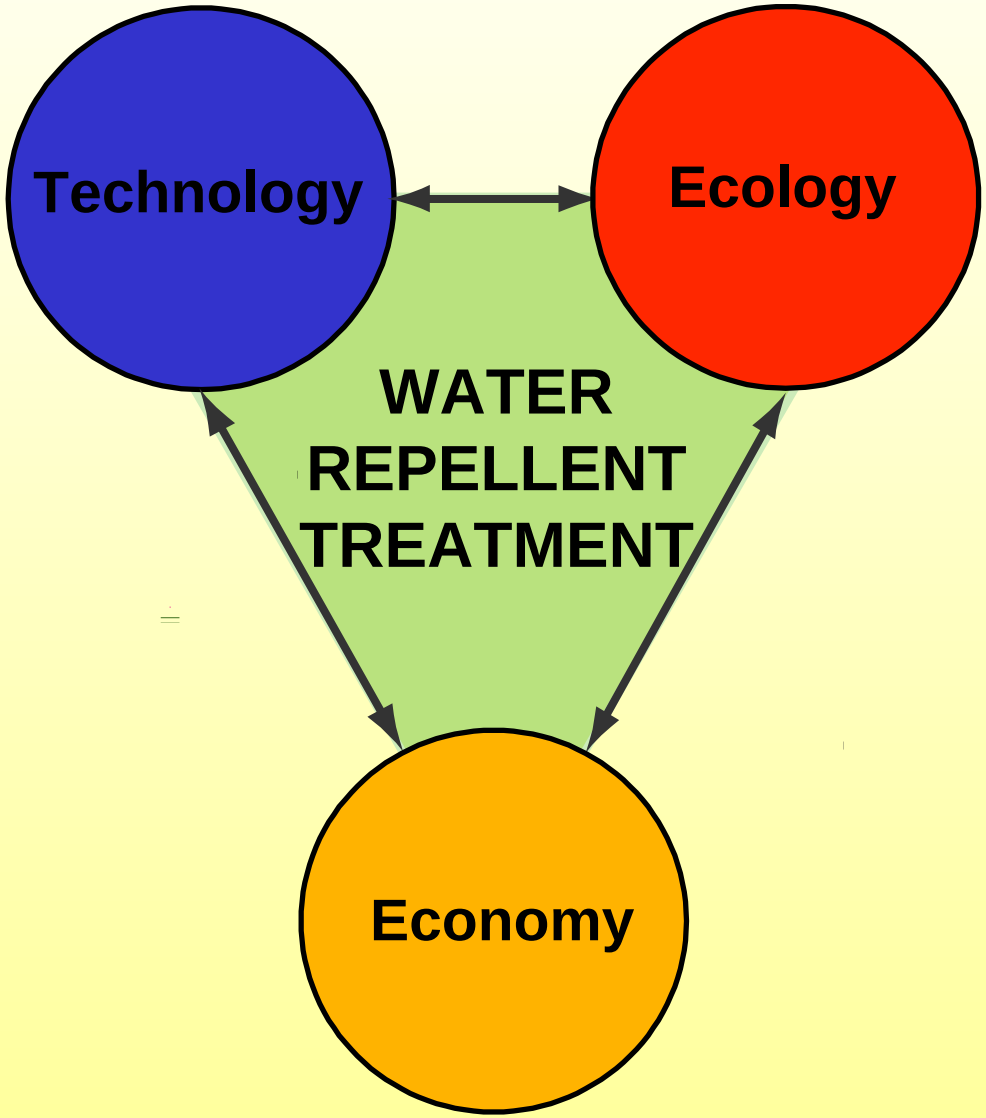
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Application of Water Repellent Treatment to Protect Off-shore Structures

Impacts on Concrete Structures in a Marine Environment

Structures in Marine Environment

- Bridge pillars
- Piers in harbours
- Off-shore wind Parks

... are exposed to sea water with a very high chloride content

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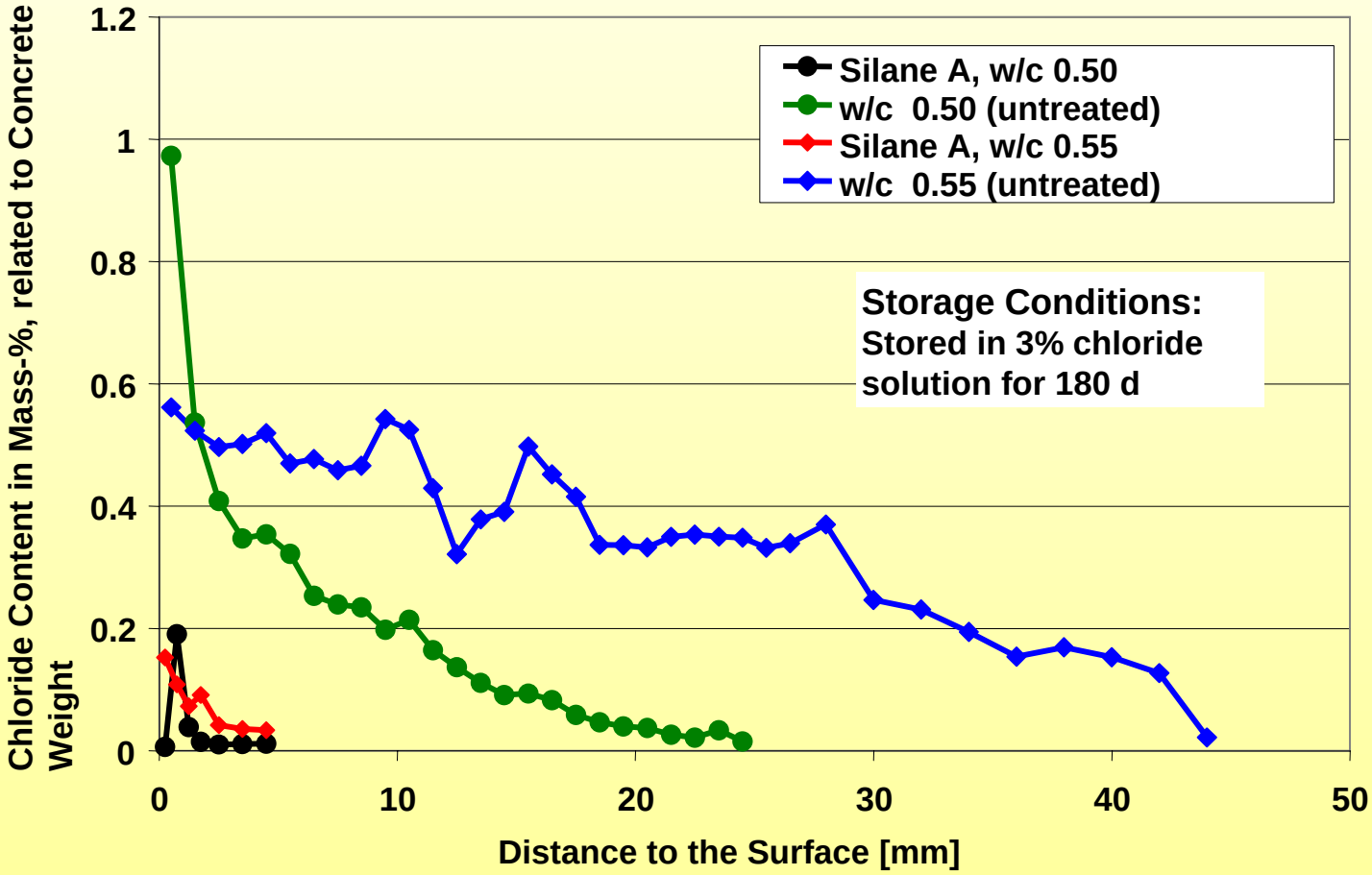
Protection of Concrete Structures in a Marine Environment

Structures in Marine Environment ...

... are protected by

- using concrete with a low w/c ratio
- Mortars (shotcrete)
- Polymer coatings
- mass impregnated mortars
- water repellent treatment ?
- ....

Performance of an Impregnation



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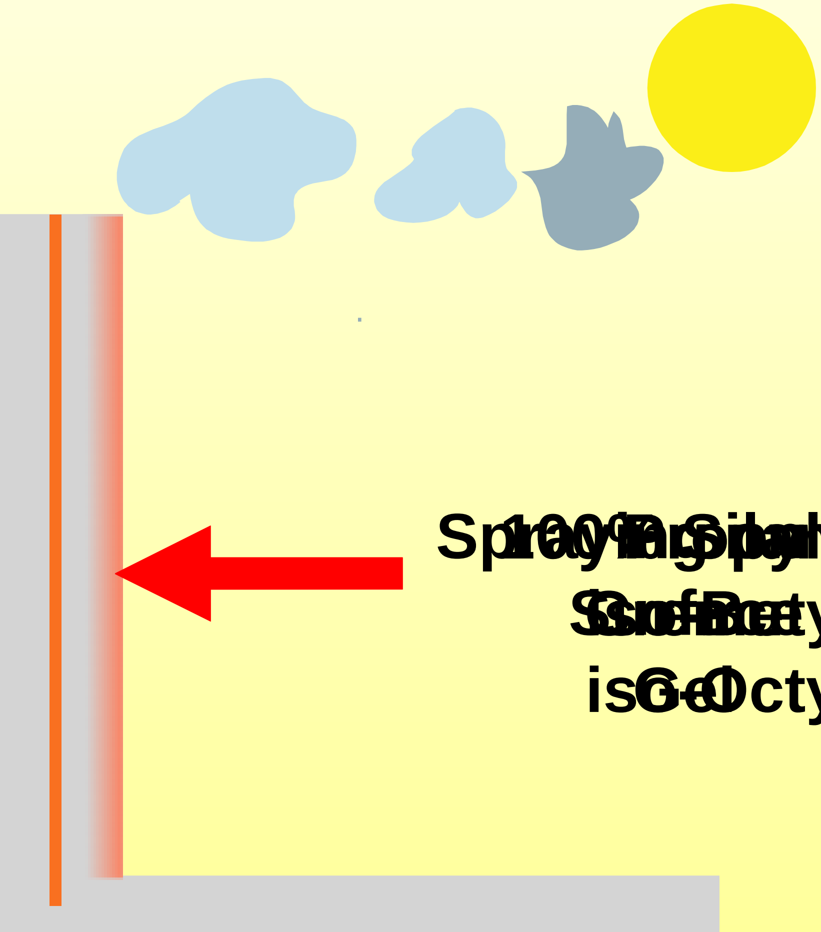
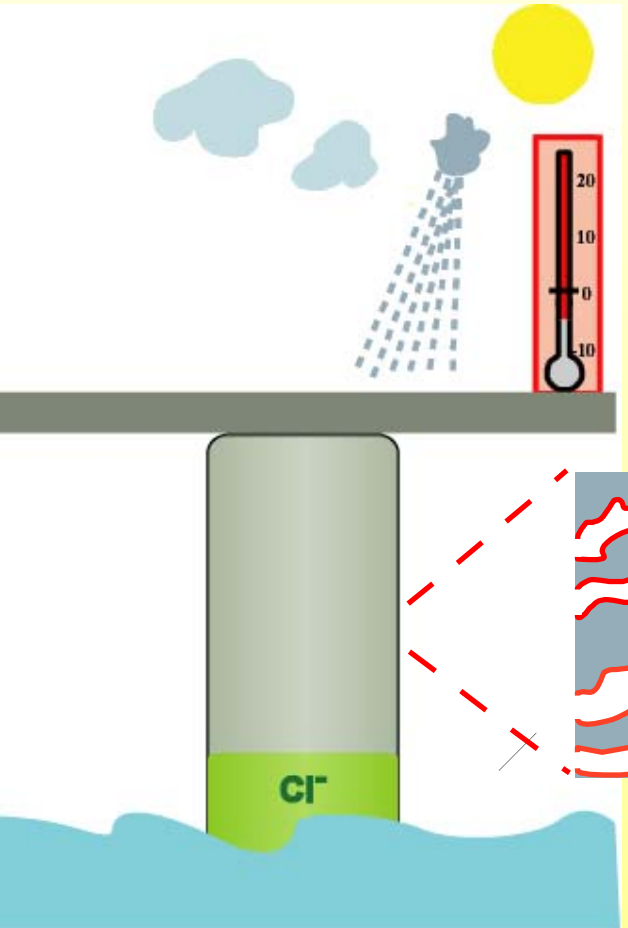
Water Repellent Treatment of Concrete



Spraying the Surface
100% Silane
Propyltriethoxysilane
isoButyltriethoxysilane
isoOctyltriethoxysilane
Gel

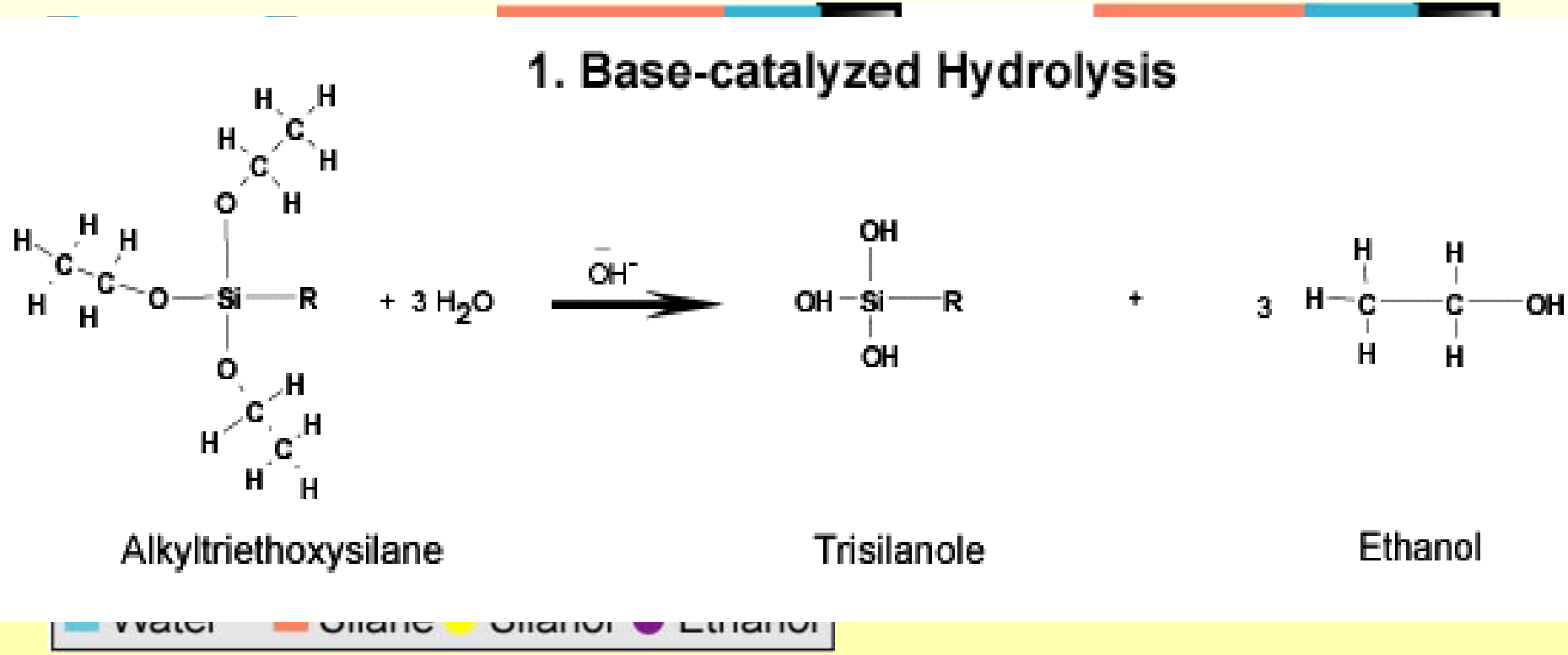
Performance of water repellent agents



Penetration profiles=
Transport + Chemical
Reactivity...
... of Silanes

- Depth
- Content of Active Substance
- Penetration profiles

Reactive Transport of Silane

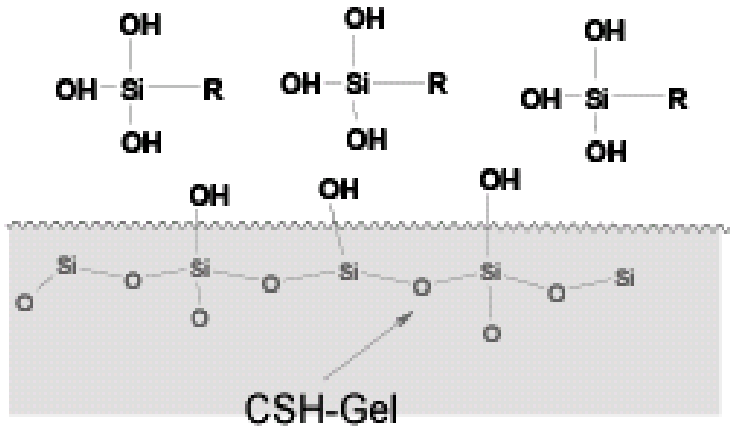


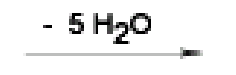
Silane uptake:

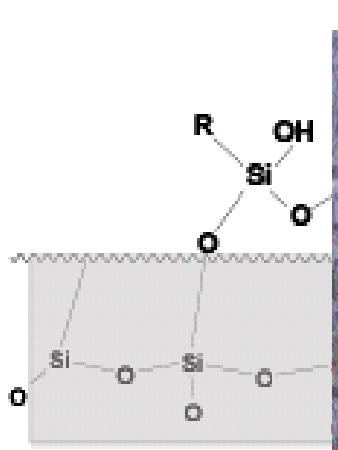
$$m = \sqrt{\frac{\sigma \cdot r_{eff}}{2\eta}} \cdot \sqrt{t} = A \cdot \sqrt{t}$$

Bonding on the Surface

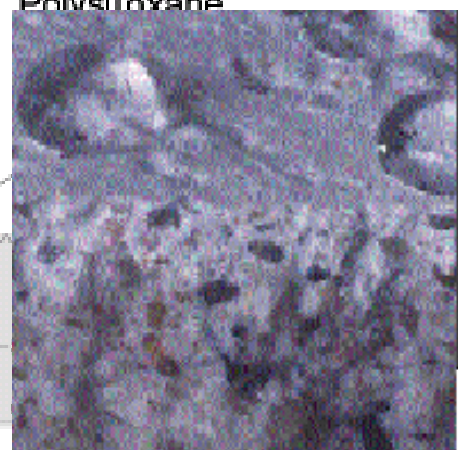
2. Polykondensation







Polysiloxane



Goal of the project

- **Experimental characterisation of the „Reactive Transport“ of silanes in concrete**
- **Modelling of the „Reactive Transport“ of chemical compounds in cement-based materials**

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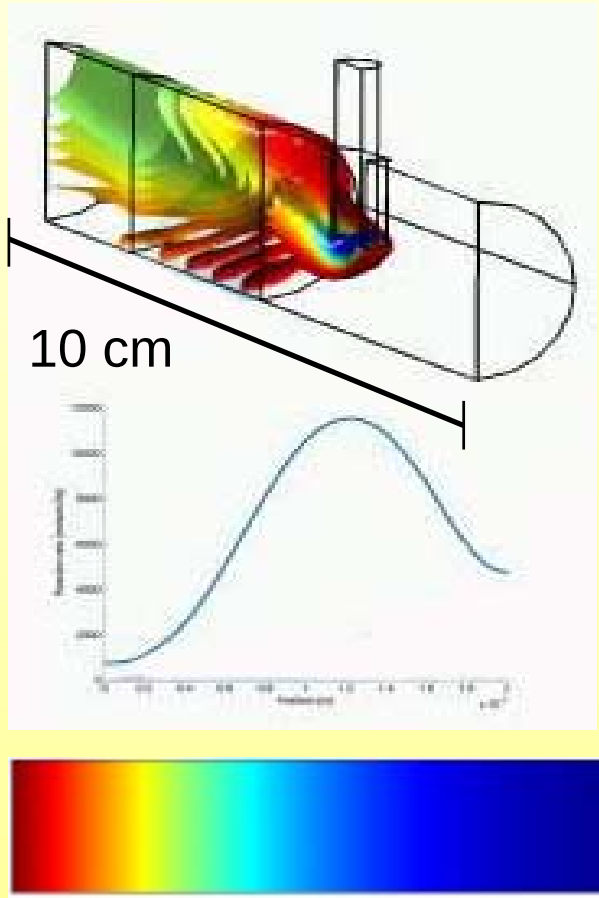
Numerical Simulation of the „Reactive Transport“ of Silane with FEMLAB

FEMLAB is a ...

... FEM-Software for Modelling Chemical Reactors in the Chemical Industry

Goal is the Modelling ...

... of the reactive transport of inorganic (e.g chloride) and organic compounds (e.g. Silane) in concrete.



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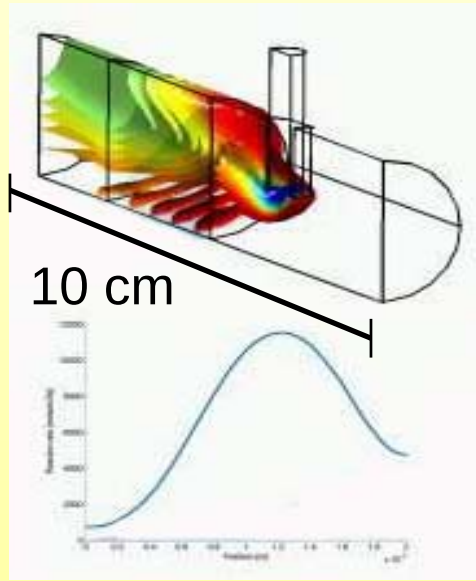
Numerical Simulation of the „Reactive Transport“ of Silane with FEMLAB

1. Characterisation of the kinetic of the chemical reaction



Experimental set-up

EQUIPMENT:

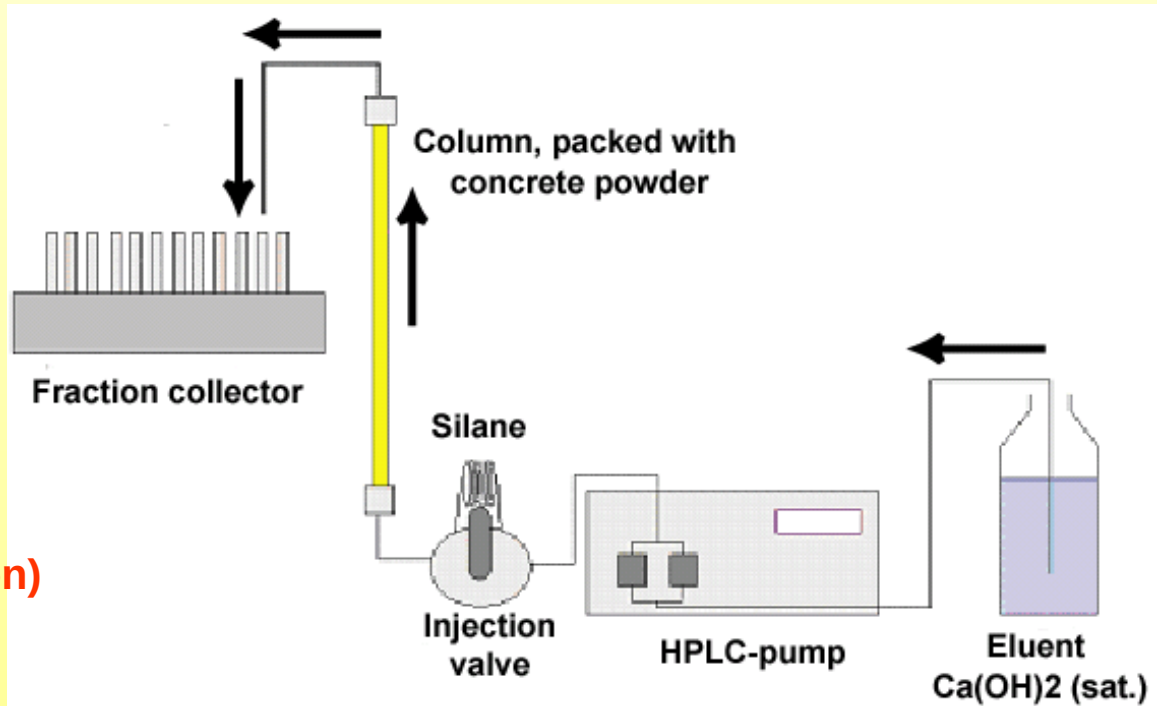
- HPLC-pump
- Injection valve
  (Volume: 1 ml)
- HPLC column
  (Diameter: 8 mm, Length: 50 mm)
- Fraction Collector

ELUENT:

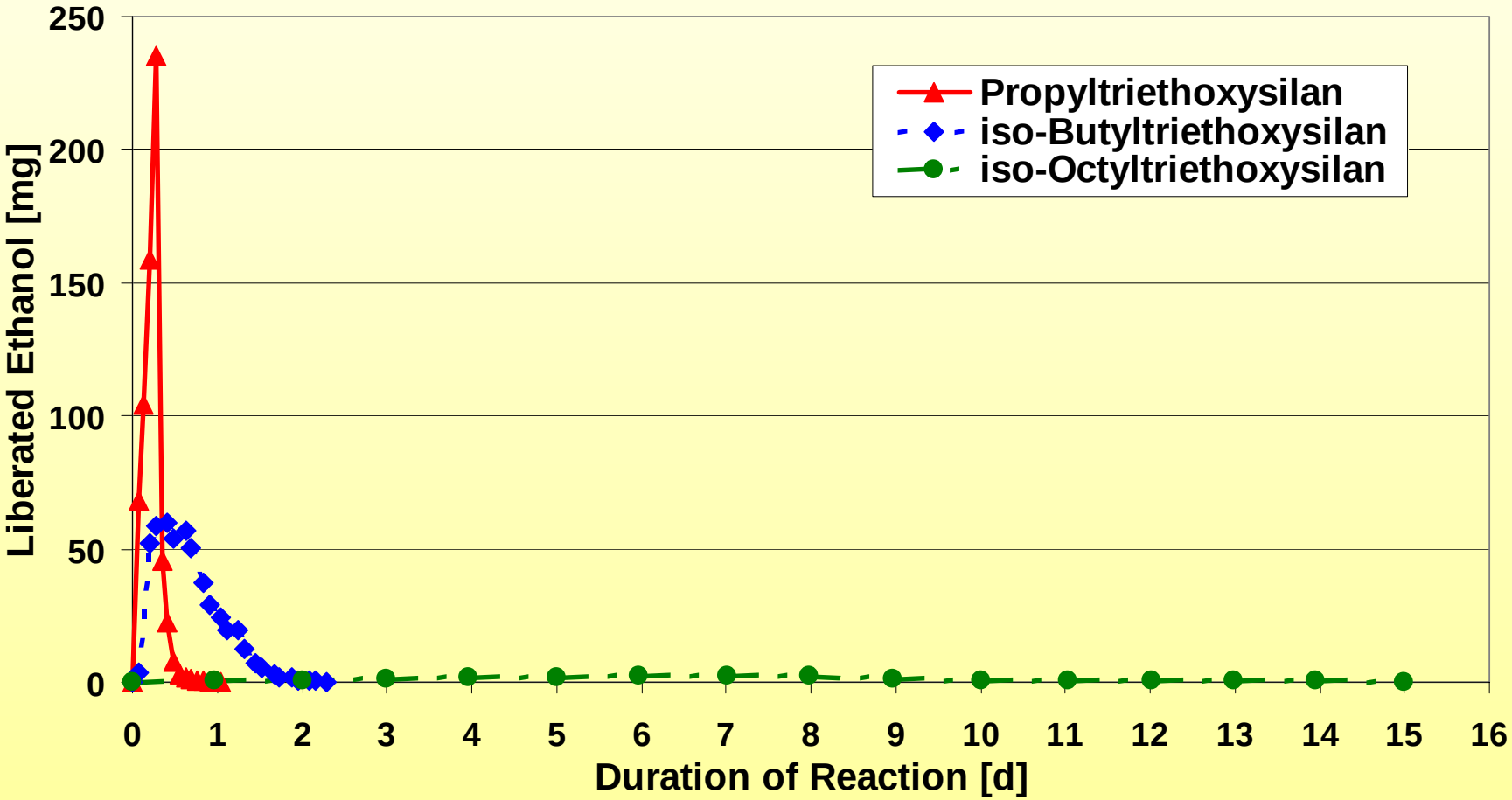
-$Ca(OH)_2$-solution, sat.
(Flux: 0.05 ml/min)

ANALYTICAL TECHNIQUES:

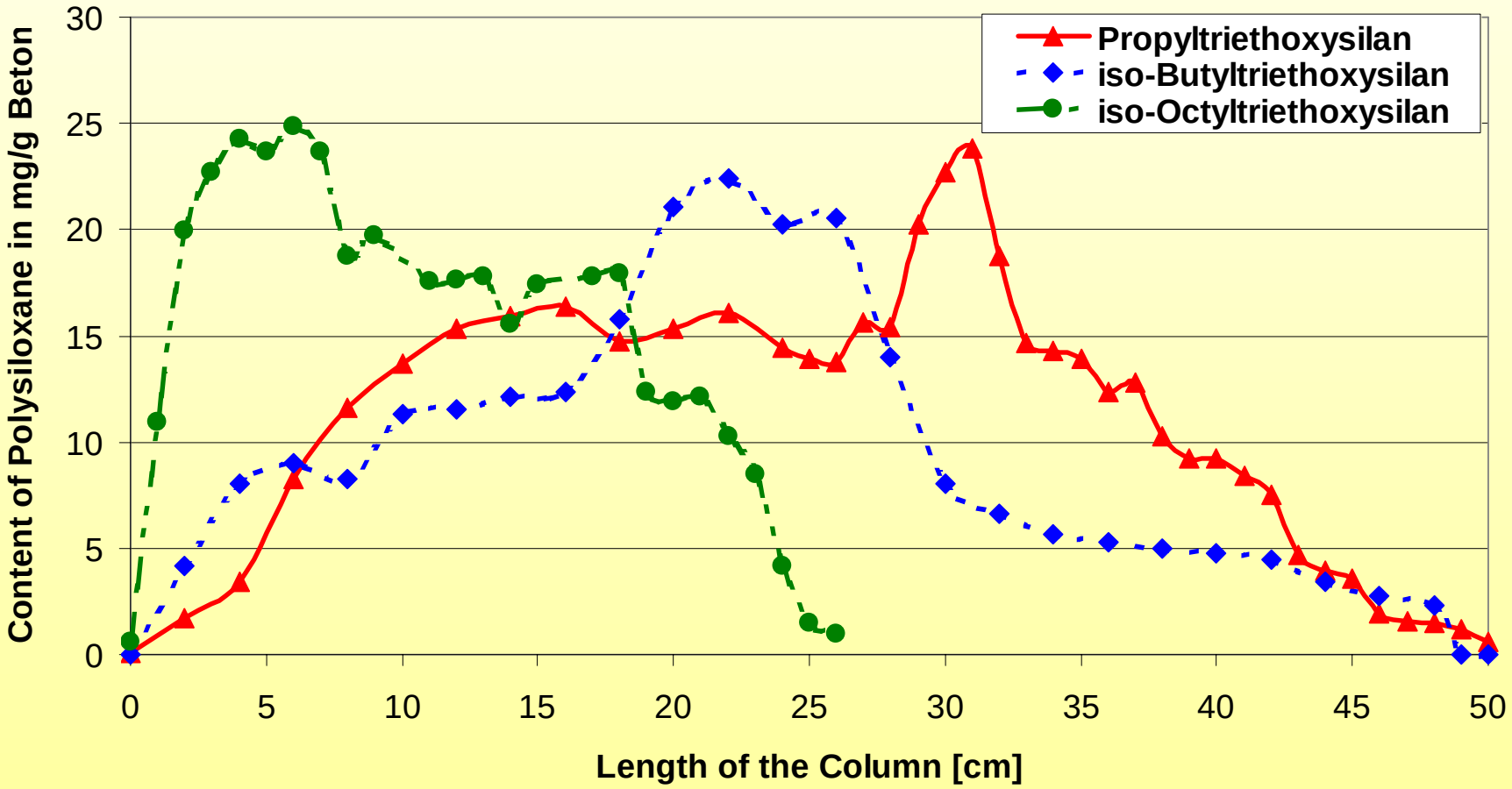
-GC-MS
(Ethanol- und Silane determination)



Breakthrough-Curves for Different Silanes



Distribution of Polysiloxane



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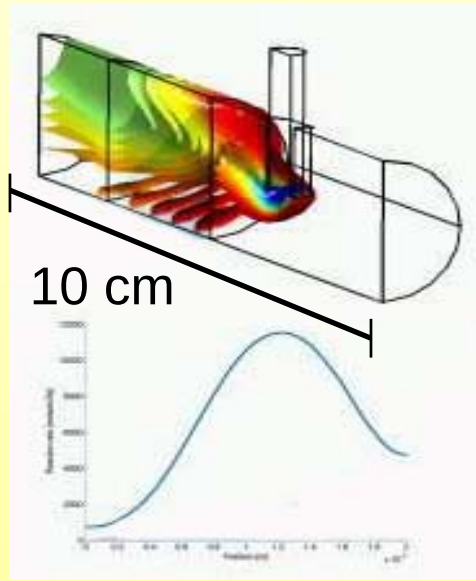
Numerical Simulation of the „Reactive Transport“ of Silane with FEMLAB

2. Characterisation of the transport of the silane



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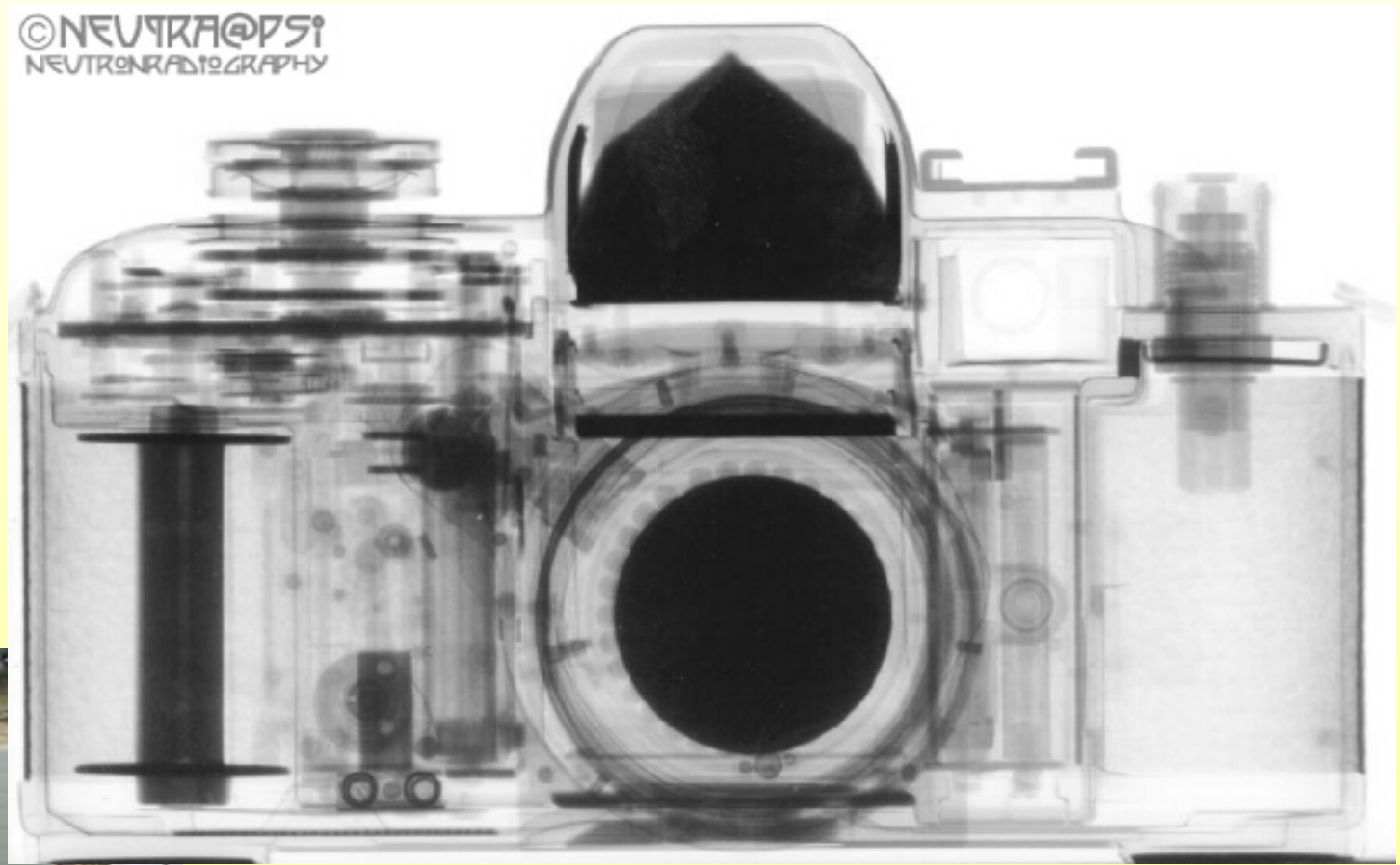
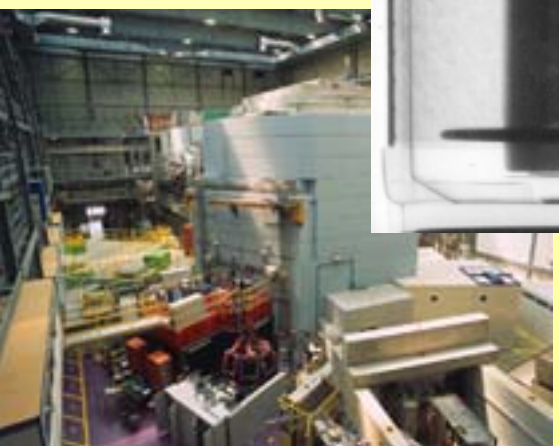
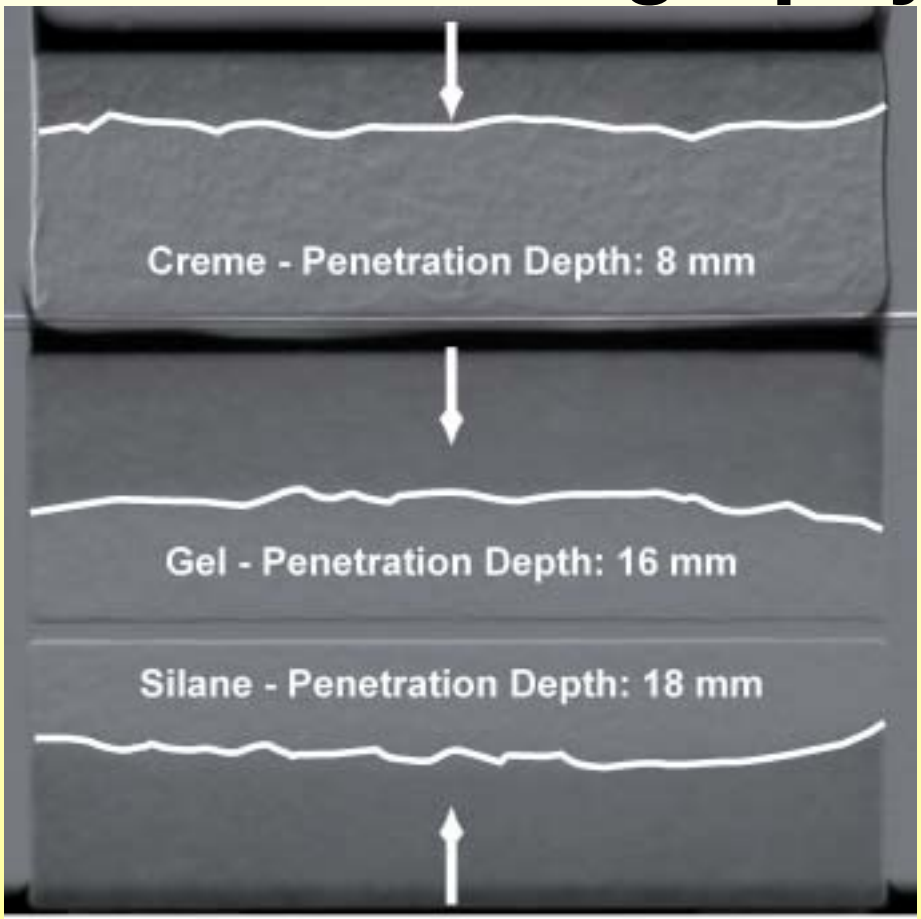
Neutron Radiography - Basics





Transport of Silane Observed by Neutron Radiography



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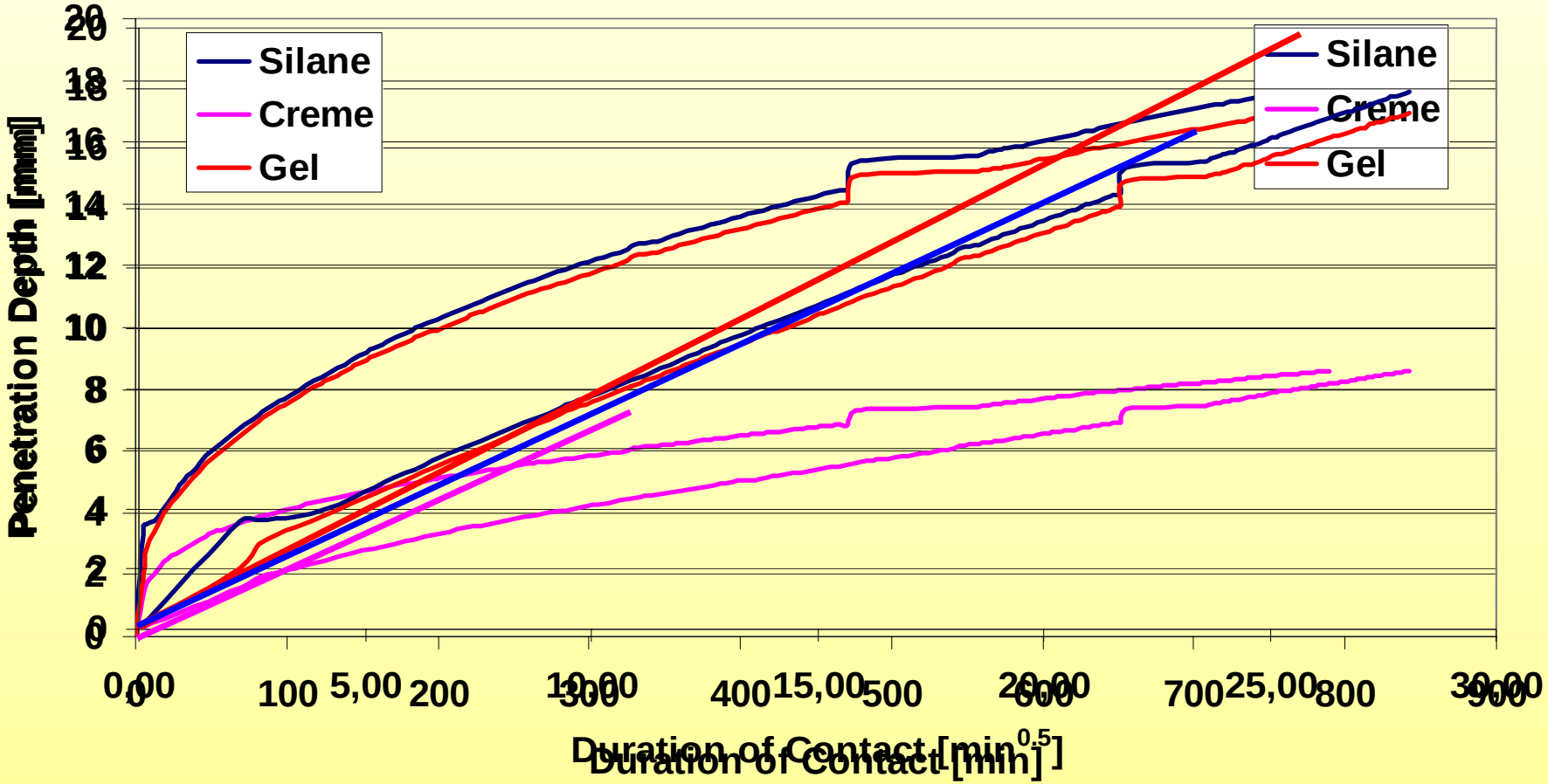
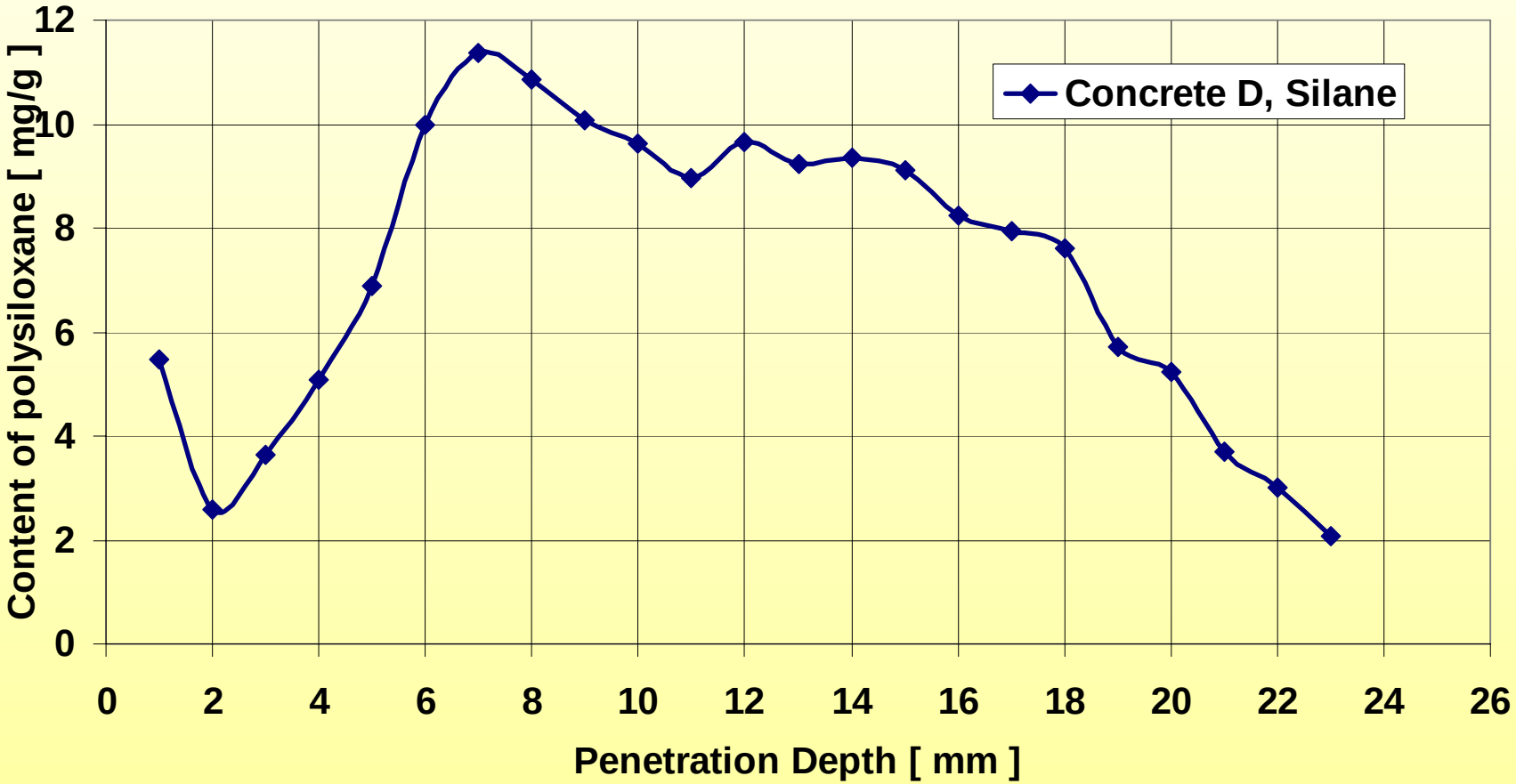
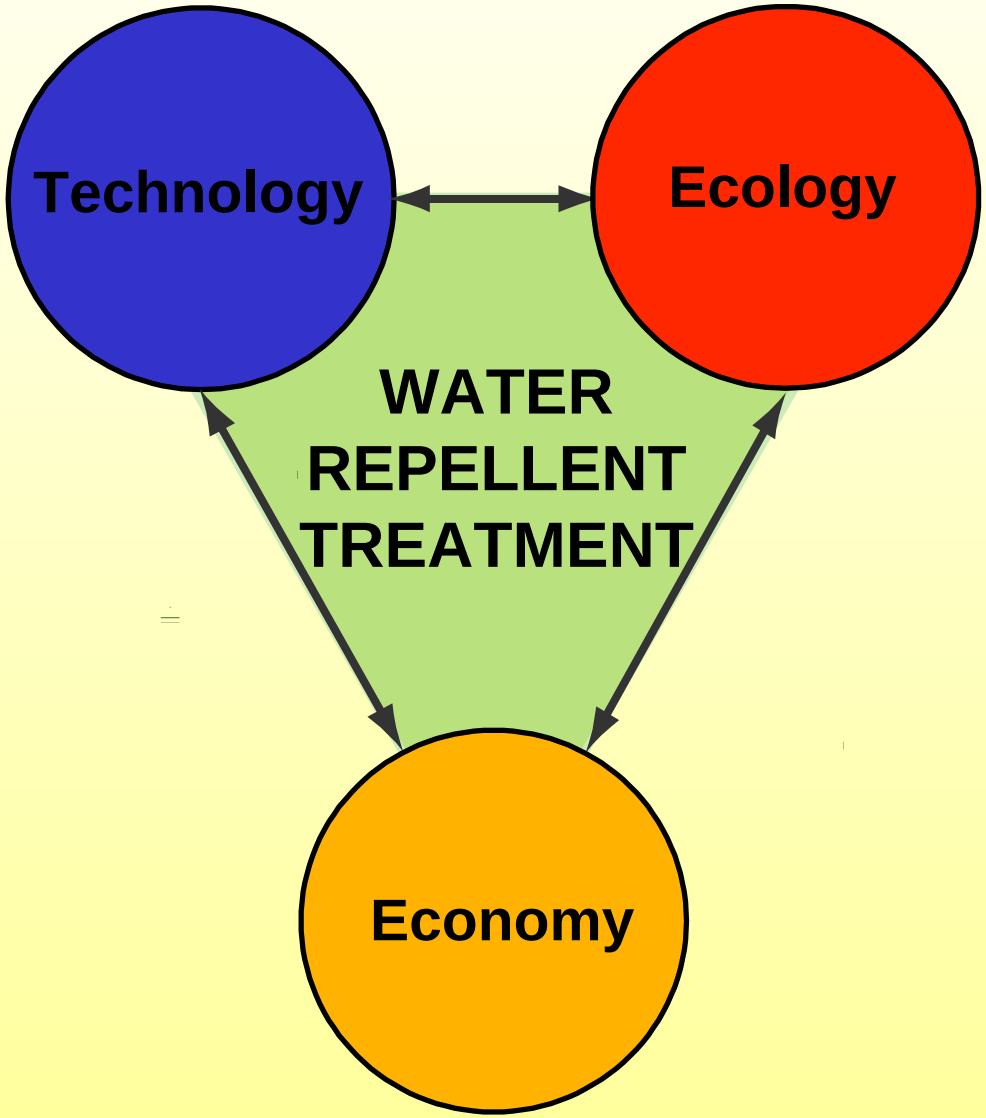


Distribution of Octyl-polysiloxane

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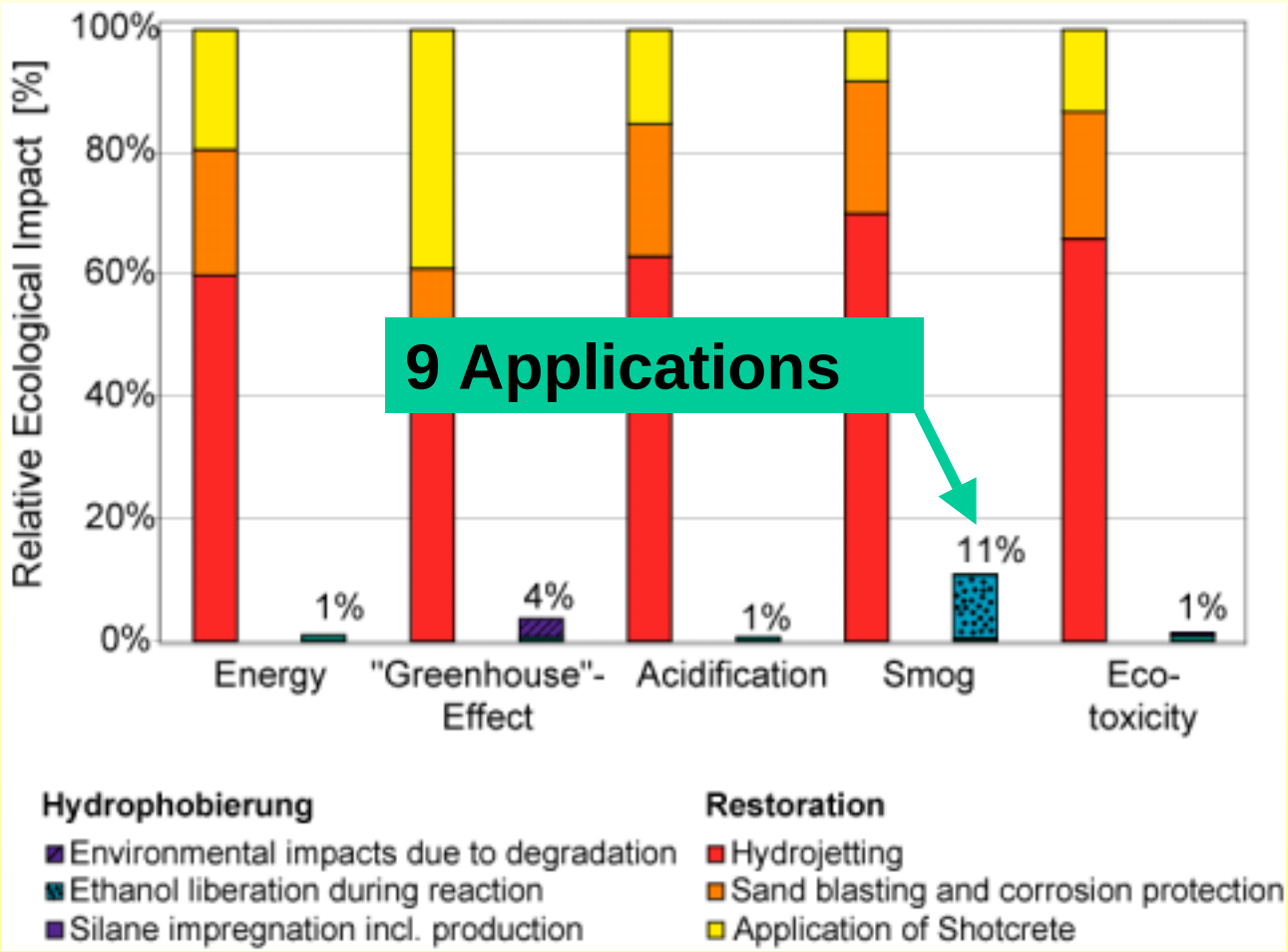
Water Repellent Treatment – Ecological Aspects



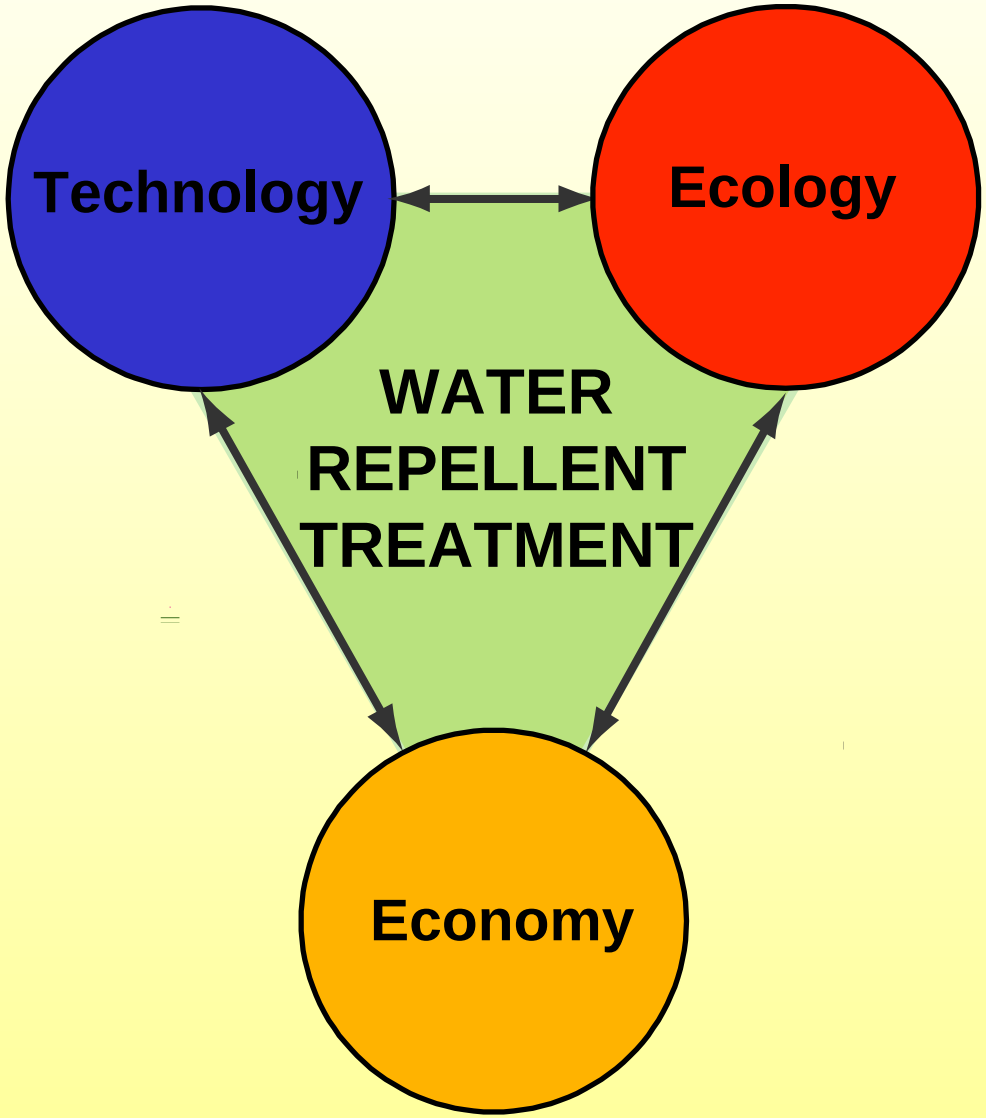
Water Repellent Treatment – Ecological Aspects

Example: Bridge Pillar in Seawater

„Life cycle assessment“ - Results

If thirty years after construction restoration measures are necessary, an impregnation can be carried out every three years before the ecological „break even“ is reached.

In practice the service life of an impregnation is in the range of 10-20 years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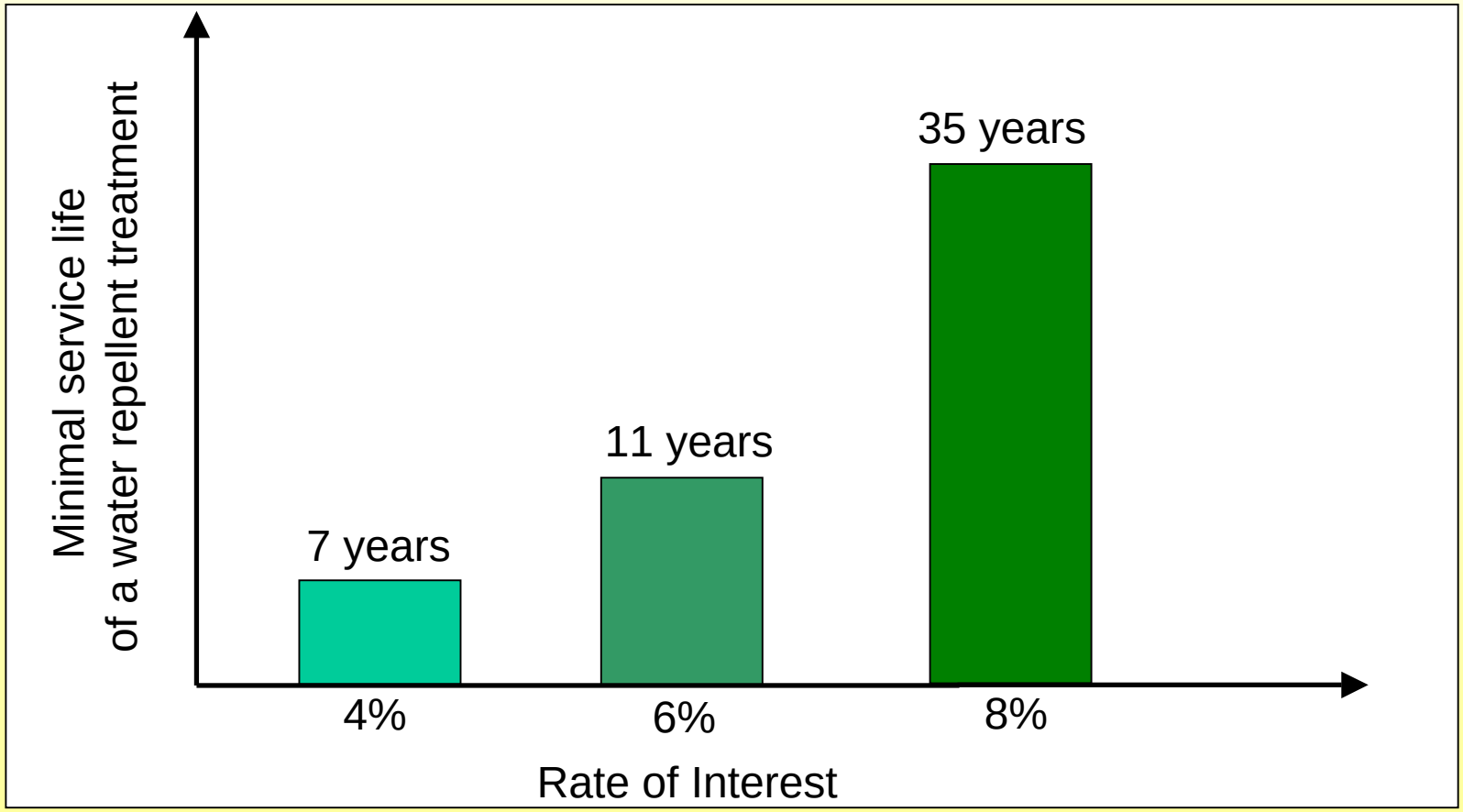
Water Repellent Treatment – Economical Aspects



Water Repellent Treatment – Economical Aspects

Example: Bridge Pillar in Seawater

Results of Economical Calculations

If thirty years after construction restoration measures are necessary, an impregnation can be carried out every seven years (4% rate of interest) before the economical „break even“ is reached.

In practice the service life of an impregnation is in the range of 10-20 years

Outlook

The next steps in this project are:

- Calculating the parameters for the kinetic of silane reaction
- Investigation of different silanes in order to characterise the influence of the chemical structure on the chemical reactivity („Molecular modelling“)
- Investigation of the transport properties of different silanes in order to characterise the influence of the chemical reactivity on the reactive transport („Modelling of reactive transport“)
- Combining the „Reactive Transport“ with the „Mechanical Behaviour“ of cement-based materials