INFLUENCE OF HIGH NITRATE SALTS CONCENTRATIONS ON DIMENSIONAL VARIATIONS OF MORTARS UNDER WET-CURING

P. Bénard, C. Cau-dit-Coumes, S. Garrault, A. Nonat

Cementation

↓

Widely applied technique for the conditioning of aqueous streams resulting from nuclear decommisioning process

Water from the waste : used for cement hydration

↓

Characterised by a high salinity (300g/L)

Aim of the study :

investigate the dimensionnal variation under water of mortars prepared with nitrate rich solutions

→ Potential accidental scenario

EXPERIMENTAL

Sulphate resistant cement : CEM I 52.5
(1000g of cement, 374 g of sand and 350 g of solution)

↓

Mixed with solutions of KNO_3 or $NaNO_3$ (normalized mixing)

↓

Cast into 4x4x16 cm moulds for 3 days (20°C/ 95% R.H.)

↓

Demoulding

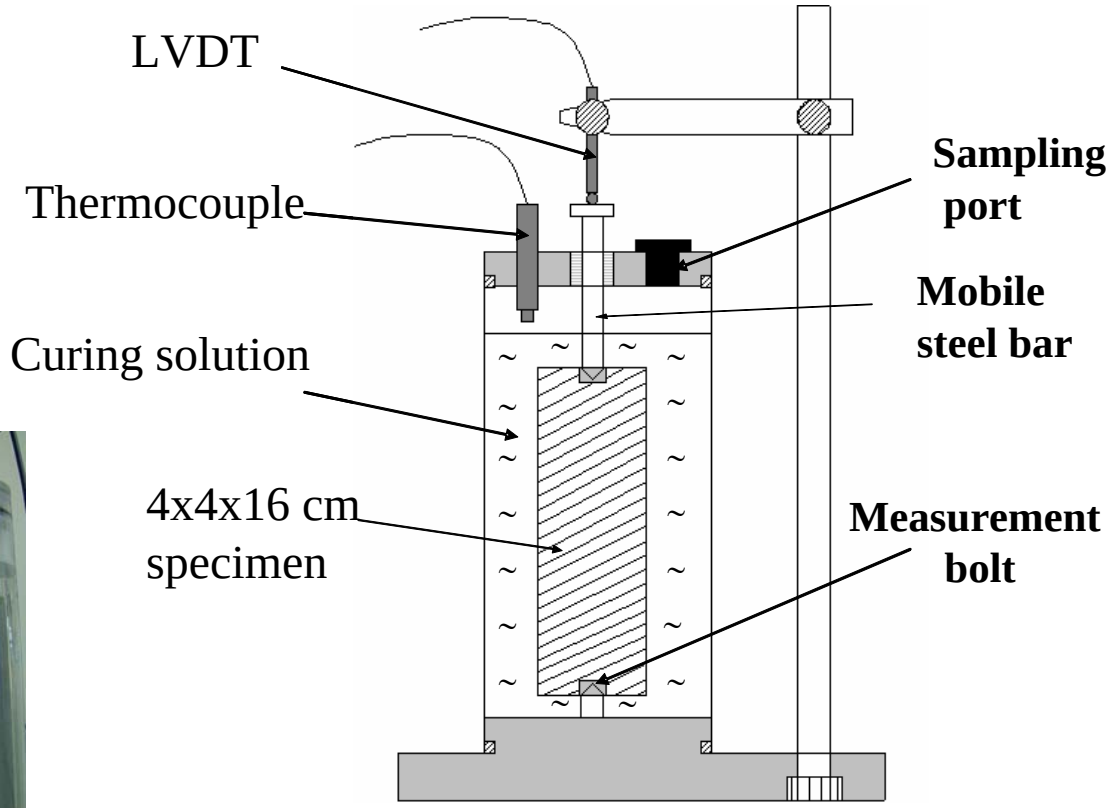
↓

Placed into measured cell filled with demineralised water

EXPERIMENTAL

The length changes :
displacement gauges consisting in linear variable differential transducers (LVDT)

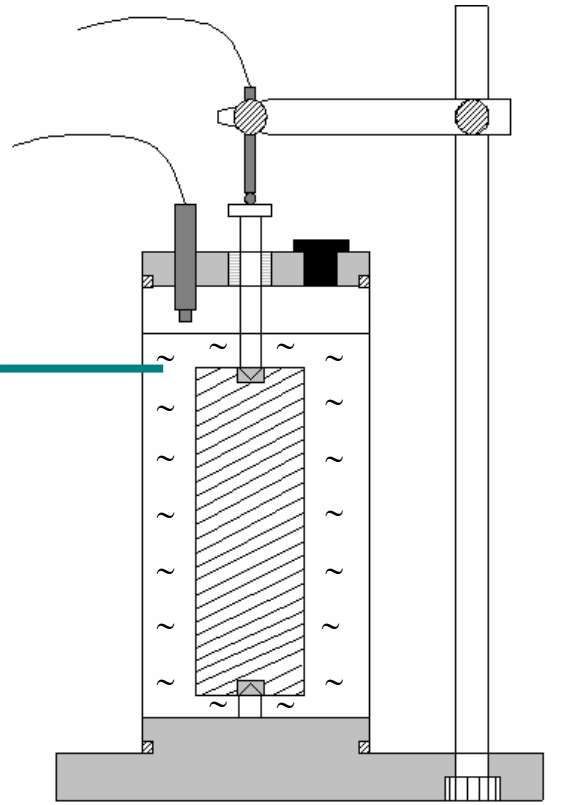
Thermostated room



Measurement recorded every 30 minutes
over 90 days

EXPERIMENTAL

Solution analyzed
at 3, 14, 42 and 68 days
by I.C.P OES



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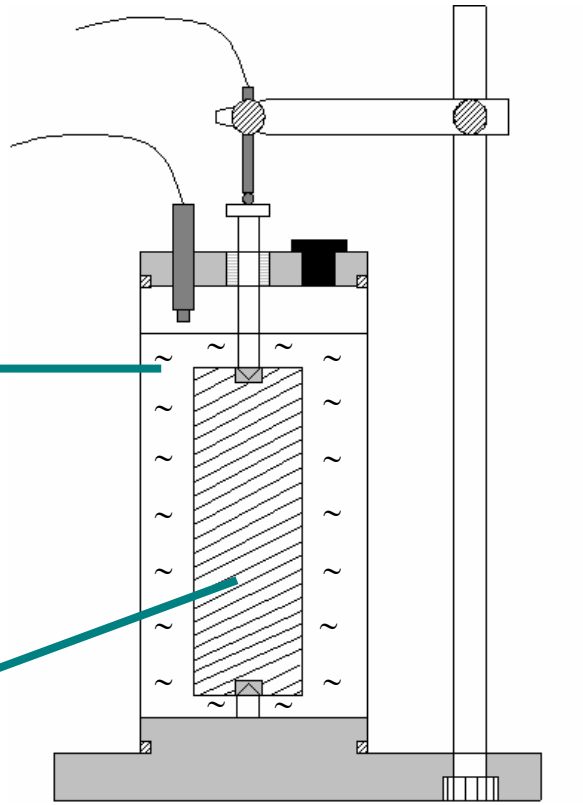
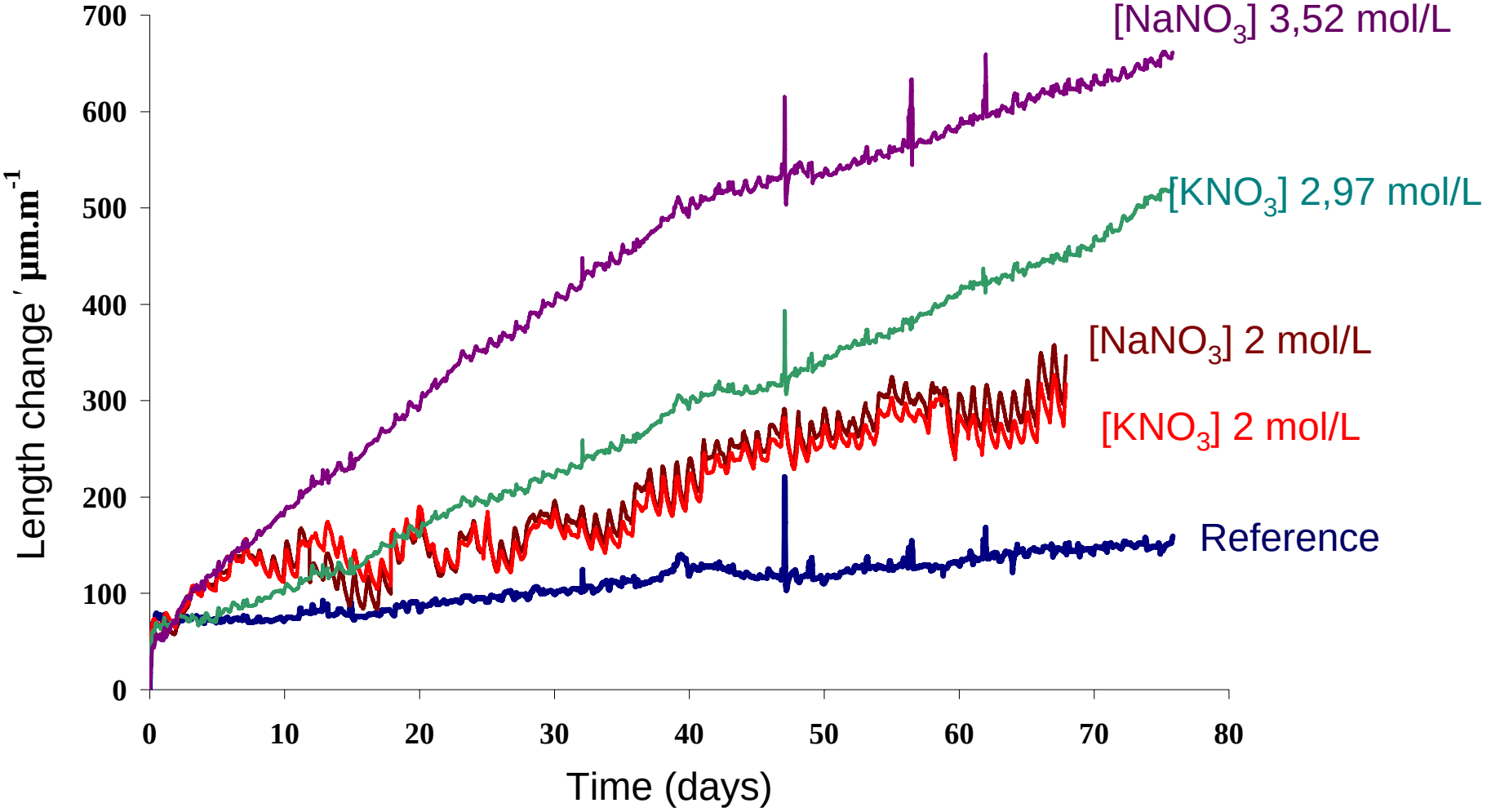


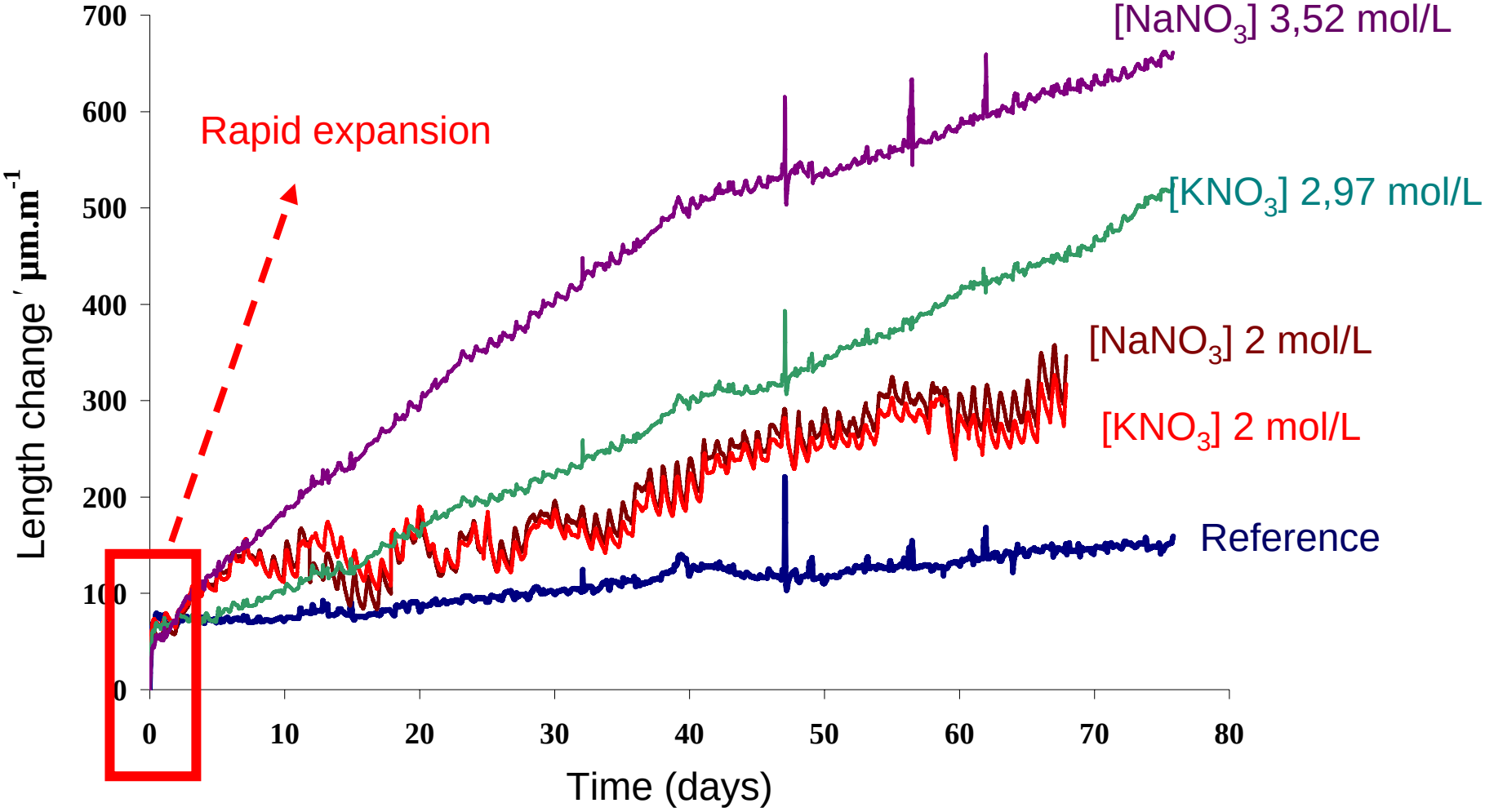
<u>At the end :</u>
Porosity determined using
Mercury intrusion porosimetry

Weighed and measured

RESULTS


[NaNO3] 3,52 mol/L
[KNO3] 2,97 mol/L
[NaNO3] 2 mol/L
[KNO3] 2 mol/L
Reference
Length change ' µm.m-1
Time (days)
0
100
200
300
400
500
600
700
0
10
20
30
40
50
60
70
80

RESULTS


Length change ′µm.m-1
700
600
500
400
300
200
100
0
0
10
20
30
40
50
60
70
80
Time (days)
Rapid expansion
[NaNO3] 3,52 mol/L
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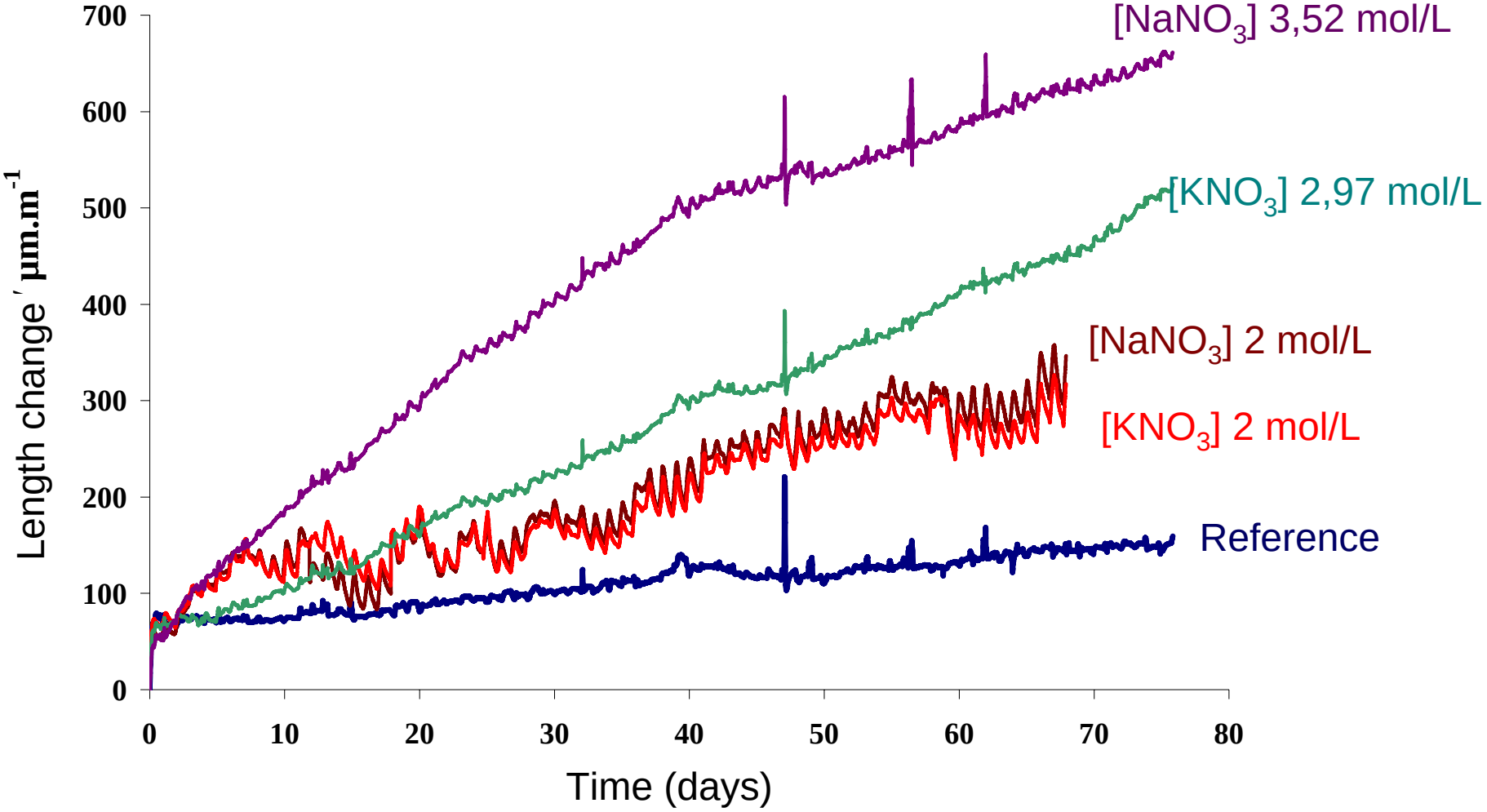
[NaNO3] 2 mol/L
[KNO3] 2 mol/L
Reference

RESULTS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RESULTS

Two processes may be involved:

- diffusion

- osmosis

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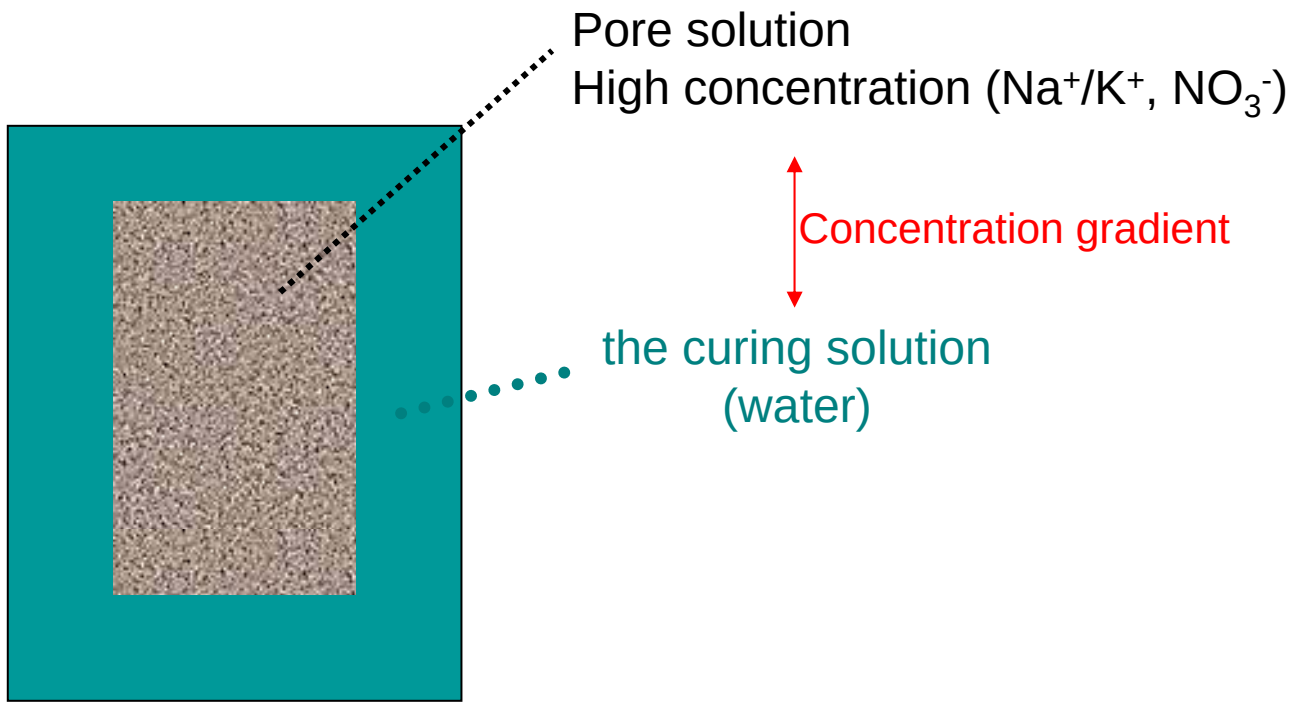

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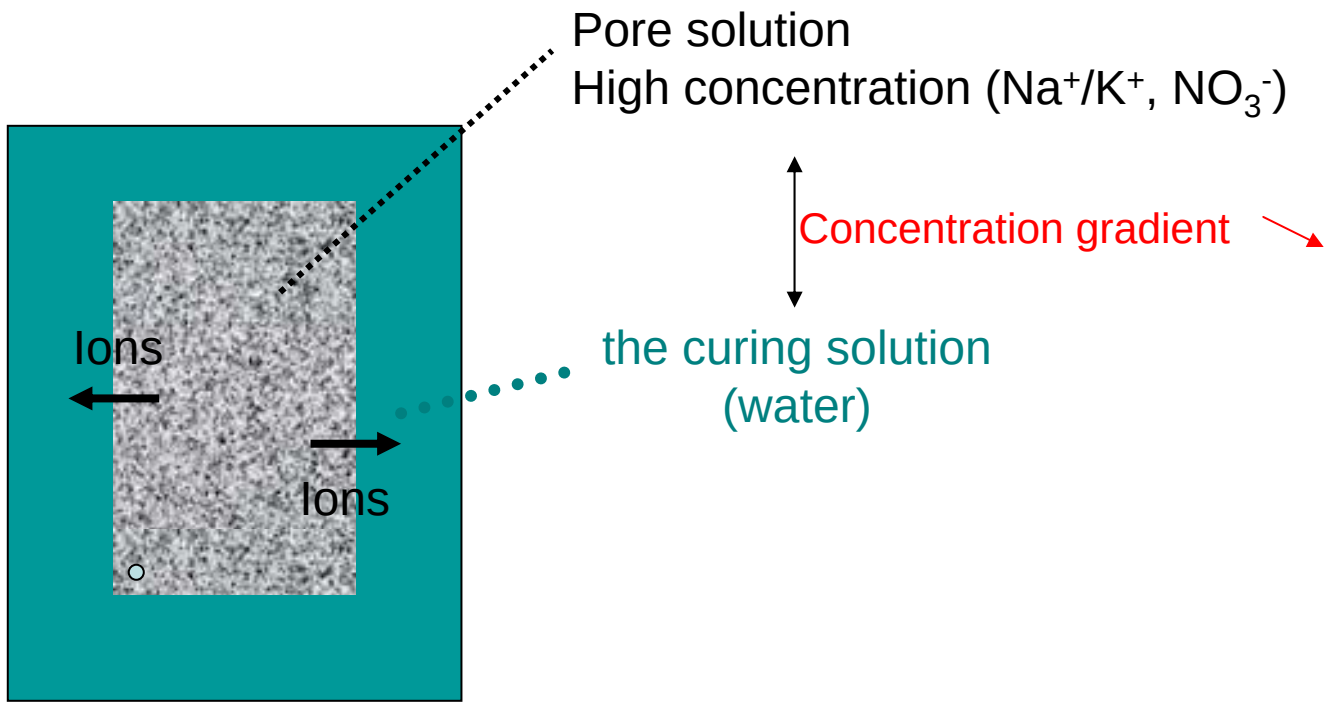
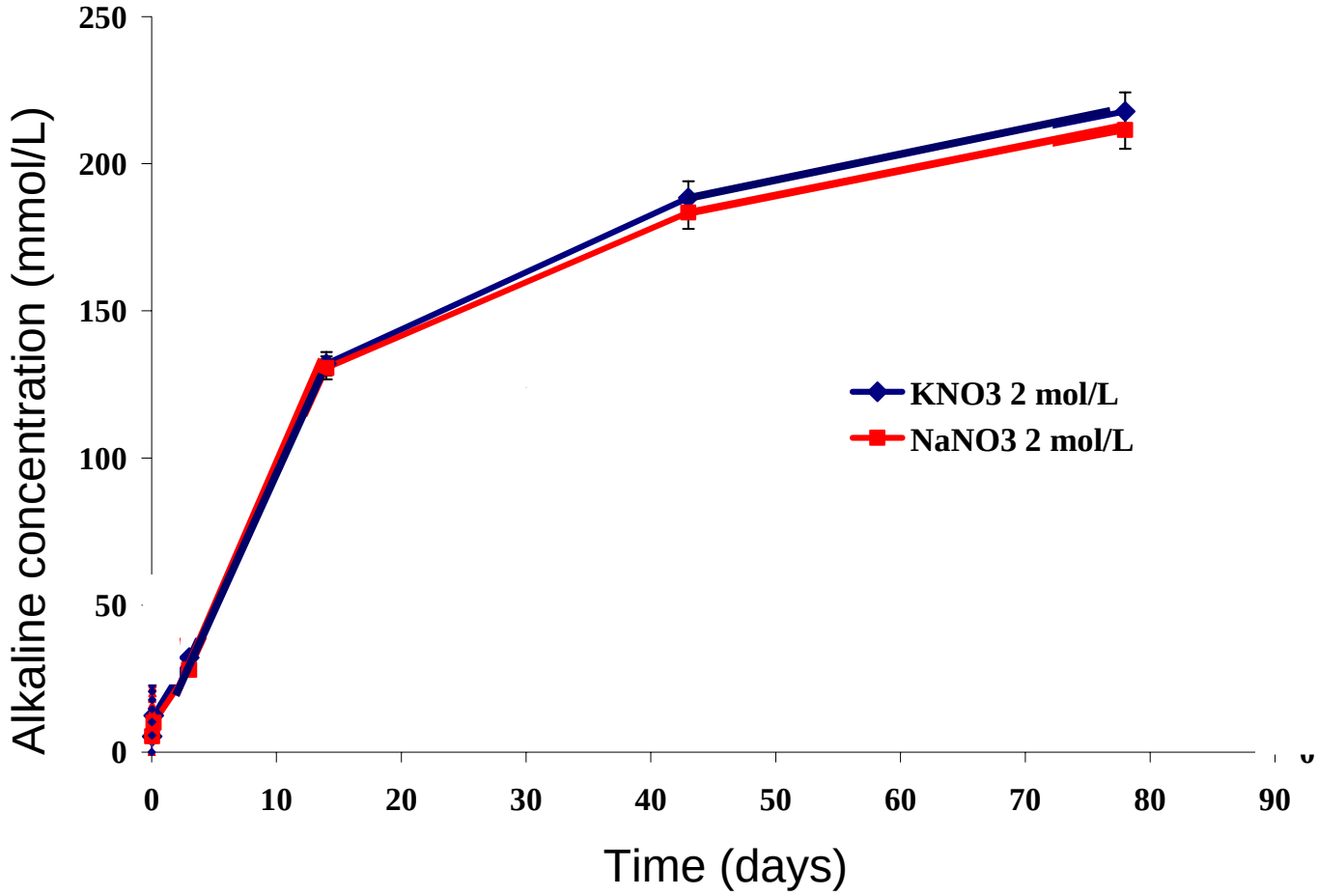
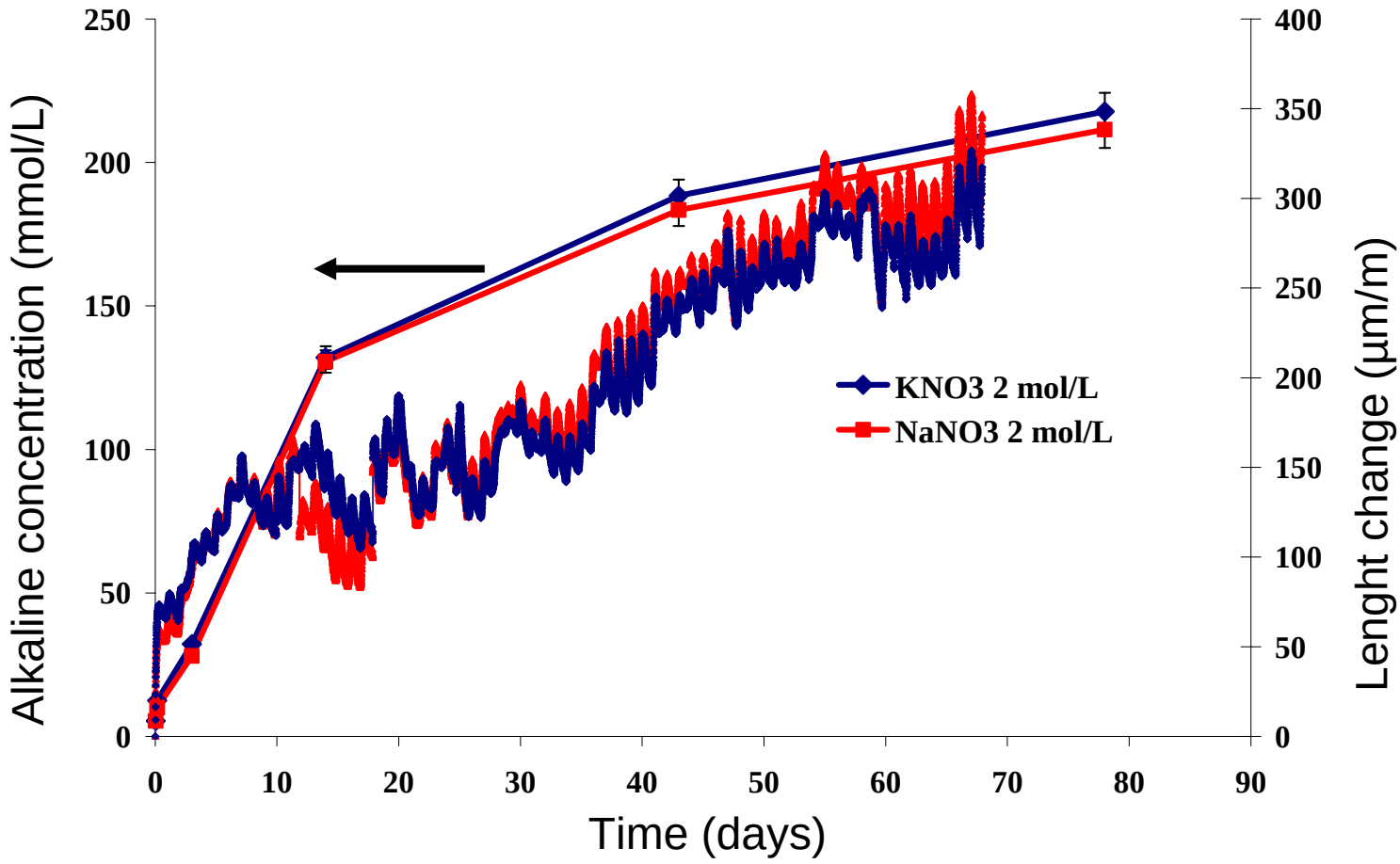


→ Reducing the concentration gradients

RESULTS


Alkaline concentration (mmol/L)
250
200
150
100
50
0
0
10
20
30
40
50
60
70
80
90
Time (days)
KNO3 2 mol/L
NaNO3 2 mol/L

RESULTS


Alkaline concentration (mmol/L)
Lenght change (µm/m)
Time (days)
KNO3 2 mol/L
NaNO3 2 mol/L
0
50
100
150
200
250
300
350
400
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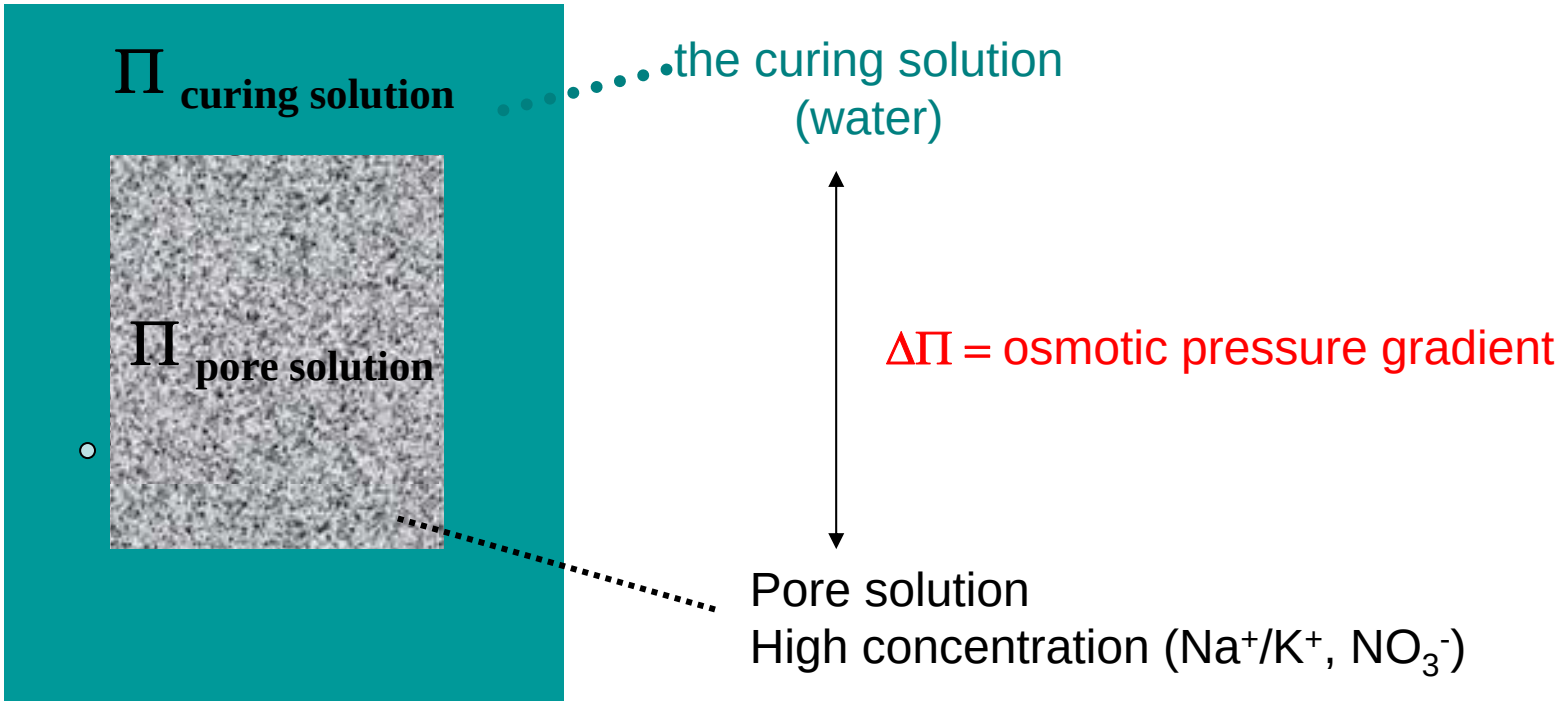

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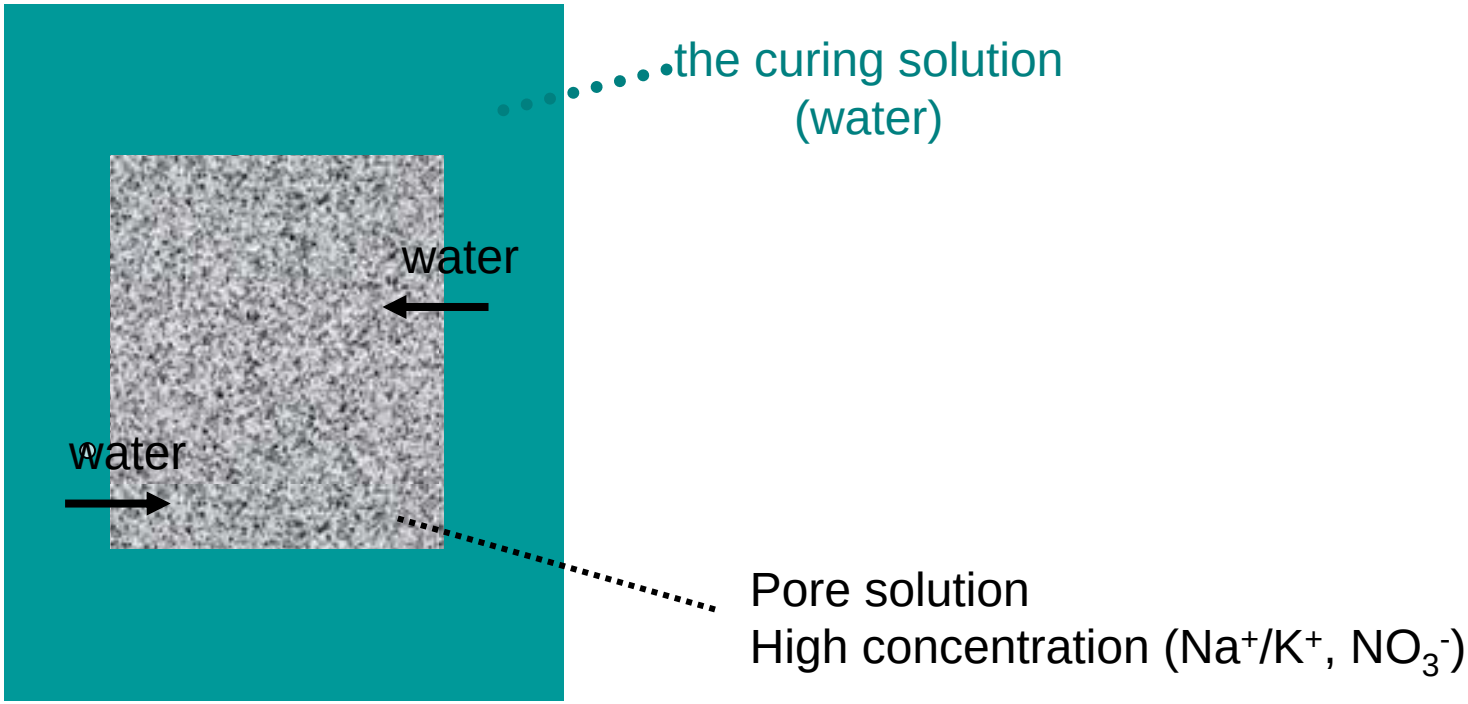

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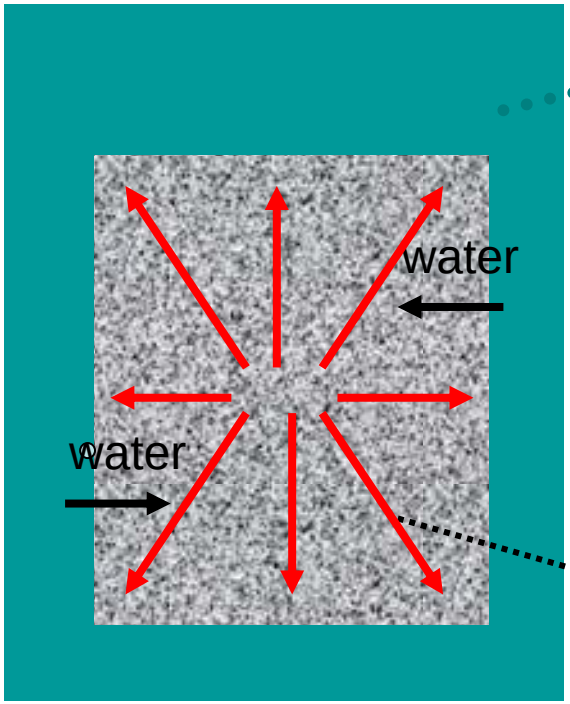

the curing solution
(water)

mechanical pressure =G.γ

G = Young modulus (Pa)
and γ = length change (m/m)

Pore solution
High concentration (Na^+/K^+, NO_3^-)

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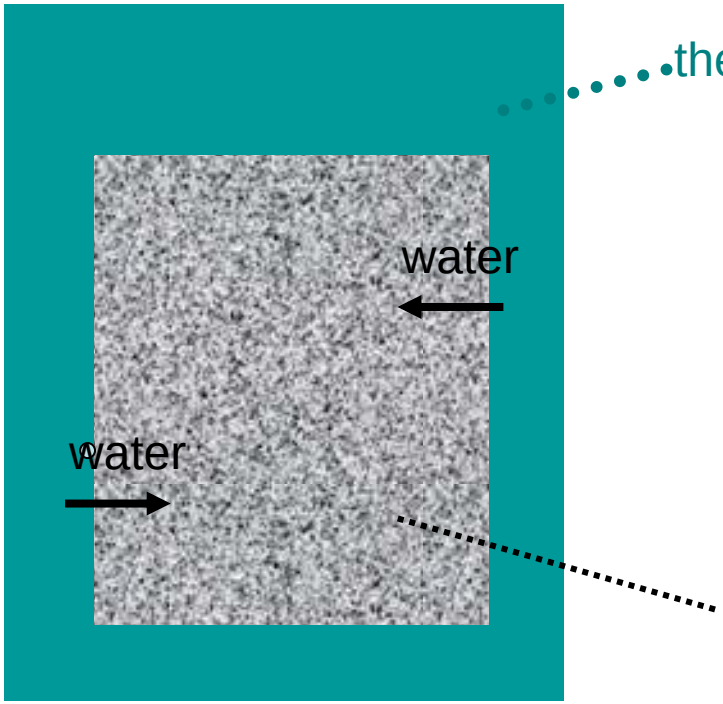

the curing solution
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Equilibrium :
$\Delta\Pi$ = mechanical pressure = $G.\gamma$

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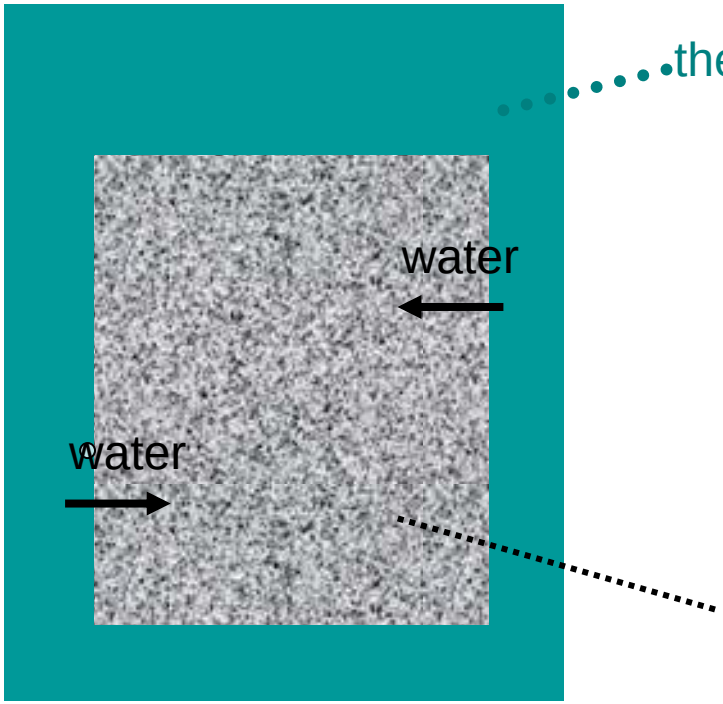

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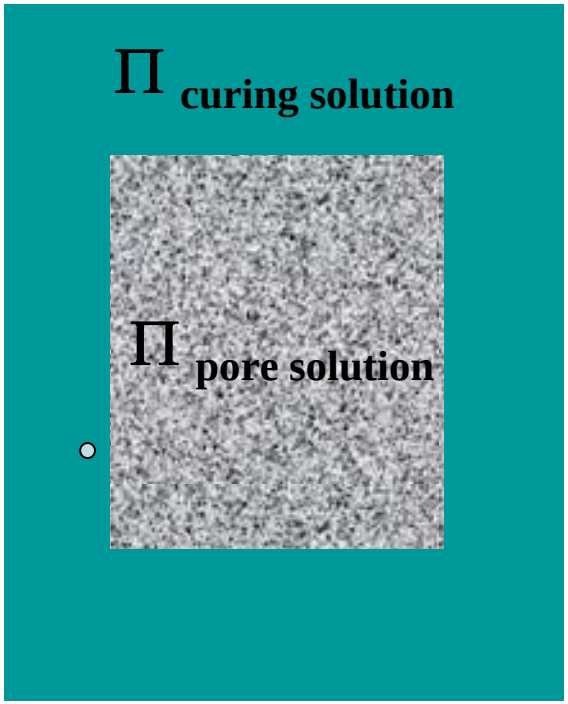

$\Pi = 2\, C_{alkalis}.R.T$

with $C_{alkalis}$ = concentration of Na^+ or K^+ (mol/m^3),
R = gas constant ($8.314\ J.K^{-1}.mol^{-1}$),
T = temperature (K)

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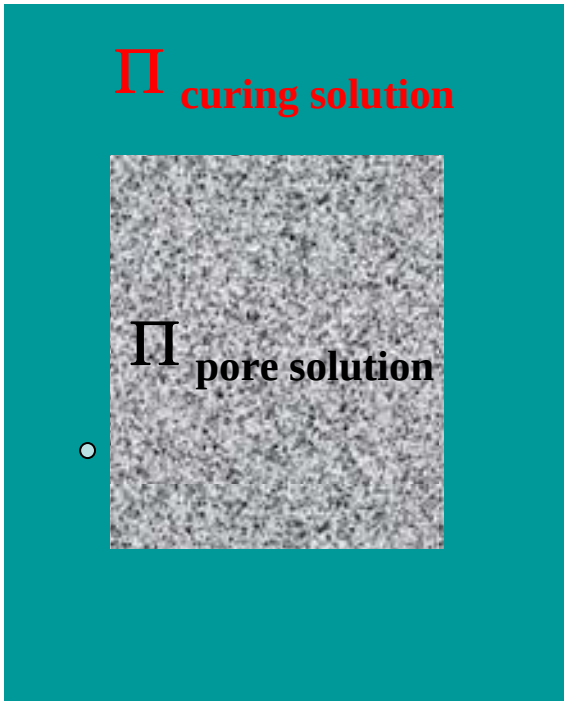

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$C_{alkalis}$ = determined by ICP.OES

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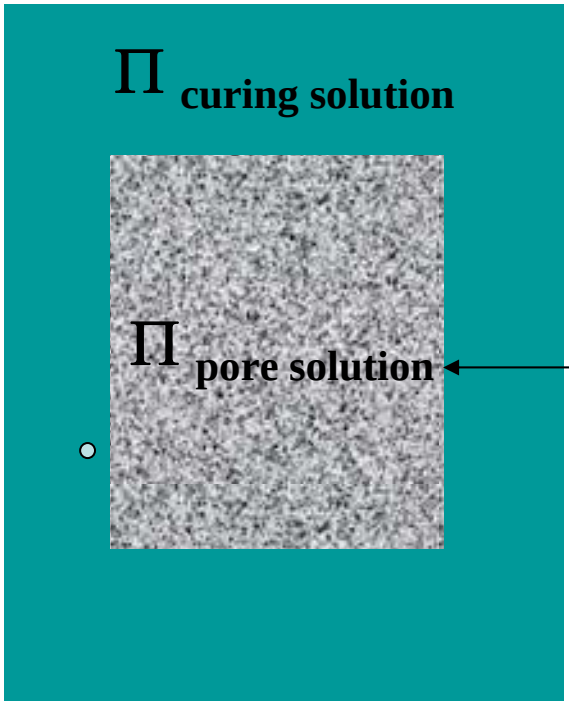

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$n_{alkalis\ (pore)}$

mass balance
(considering also alkalis from cement)

RESULTS

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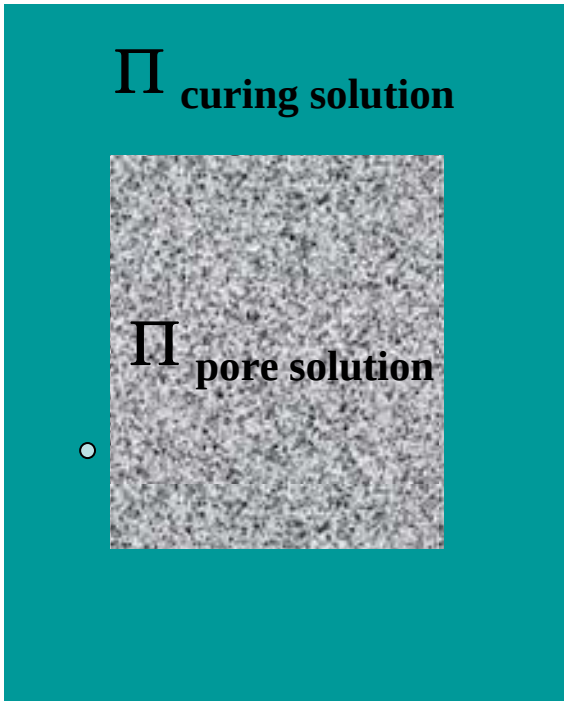

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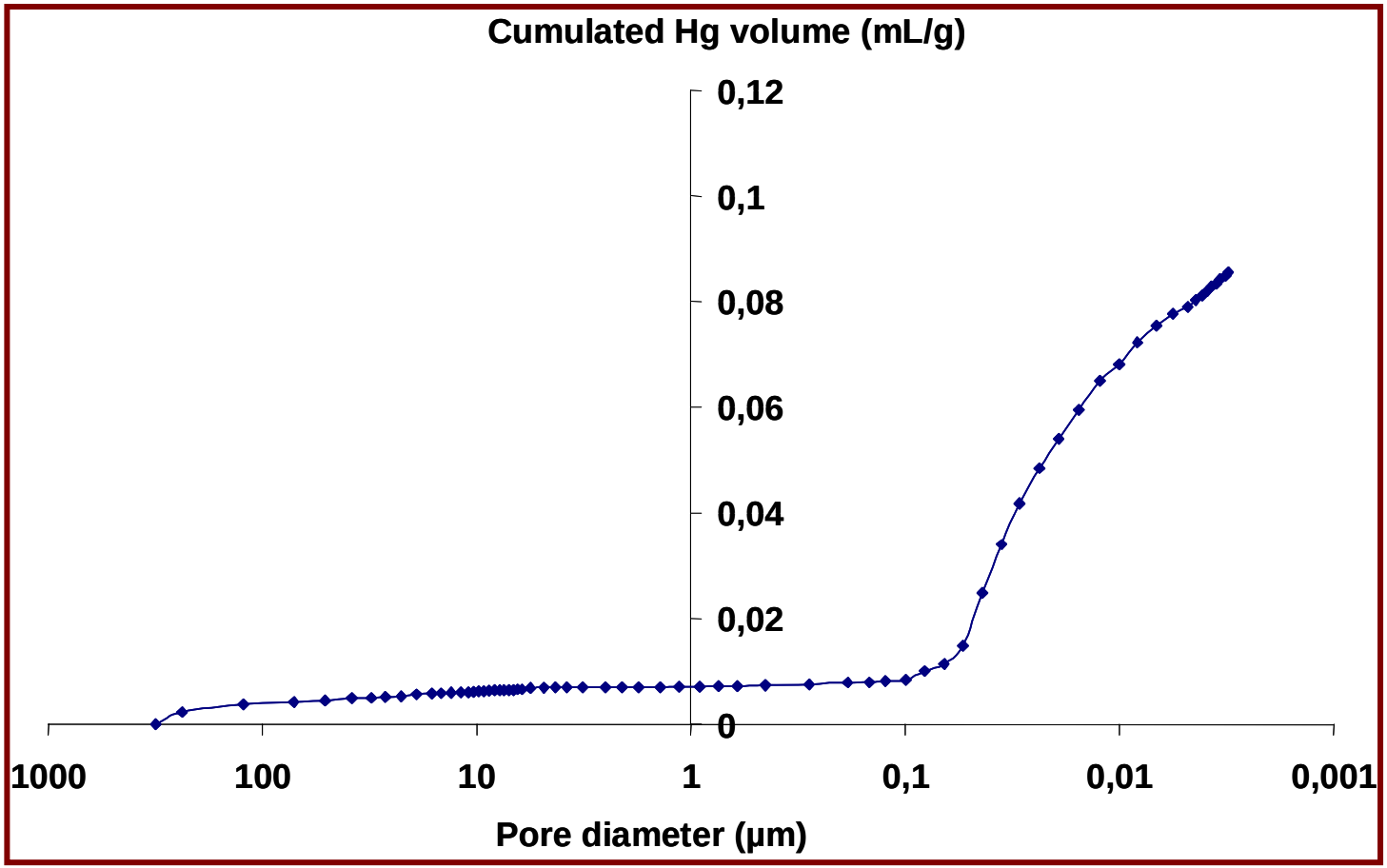
RESULTS



Volume of pores solution

RESULTS

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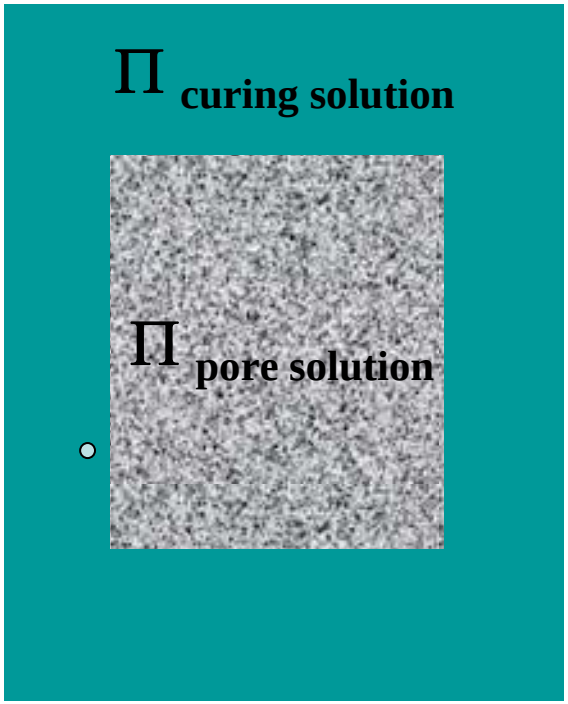

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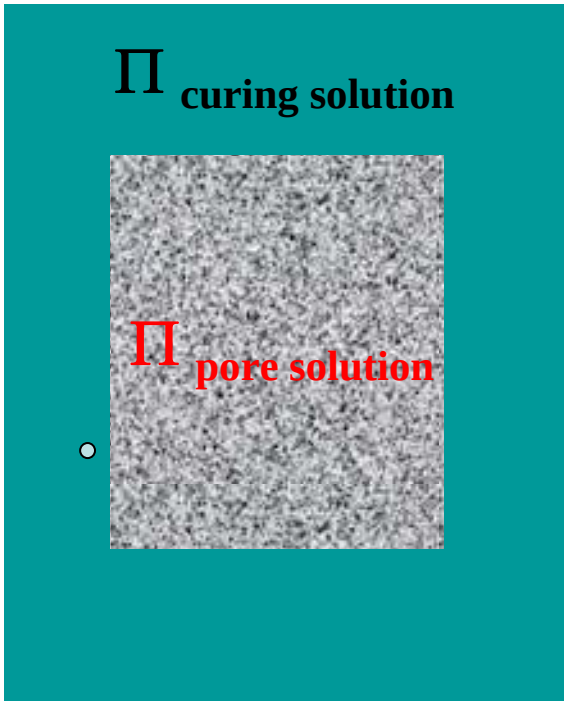
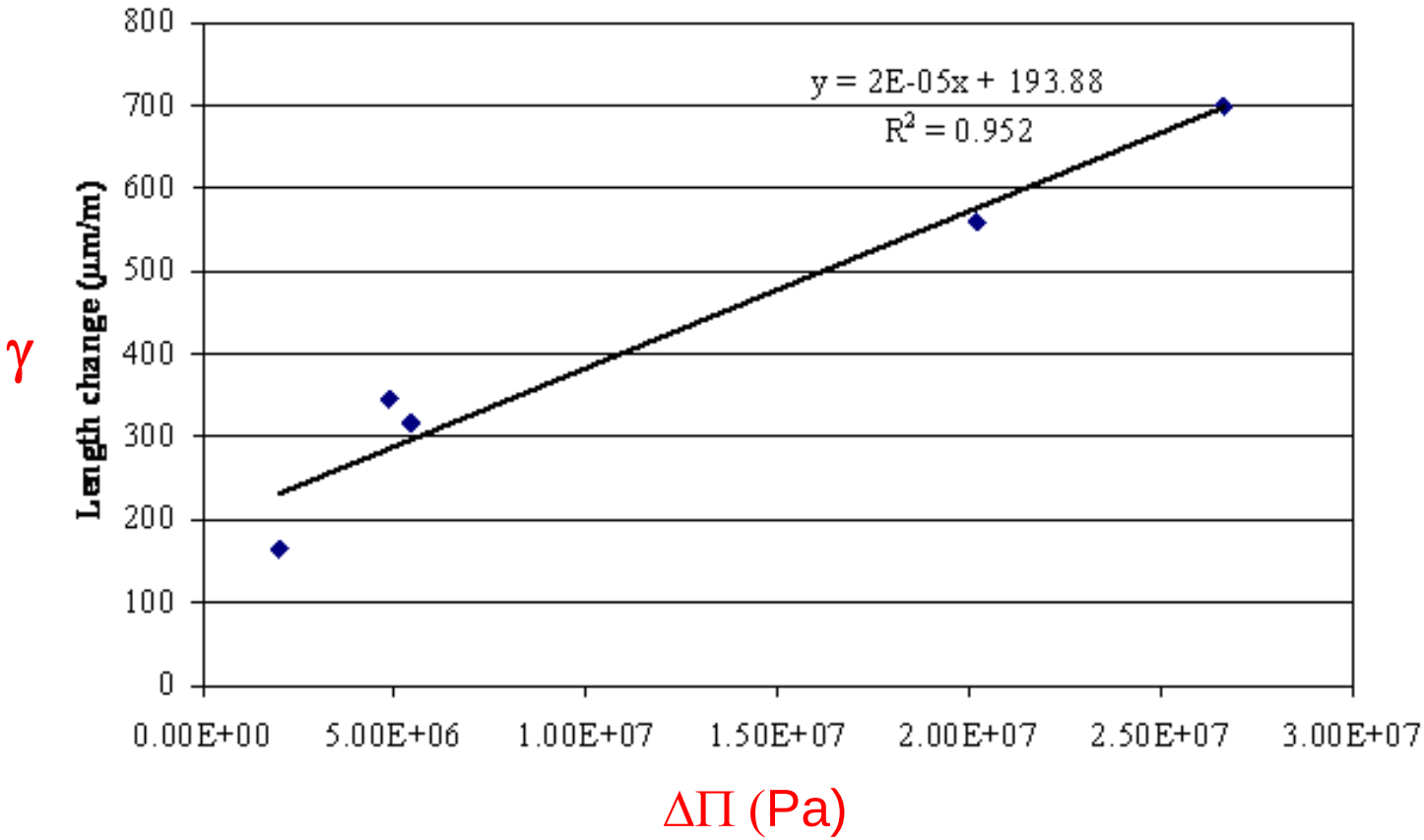


$$\Pi = 2\, C_{alkalis}.R.T$$

RESULTS

$G.\gamma = \Delta\Pi$



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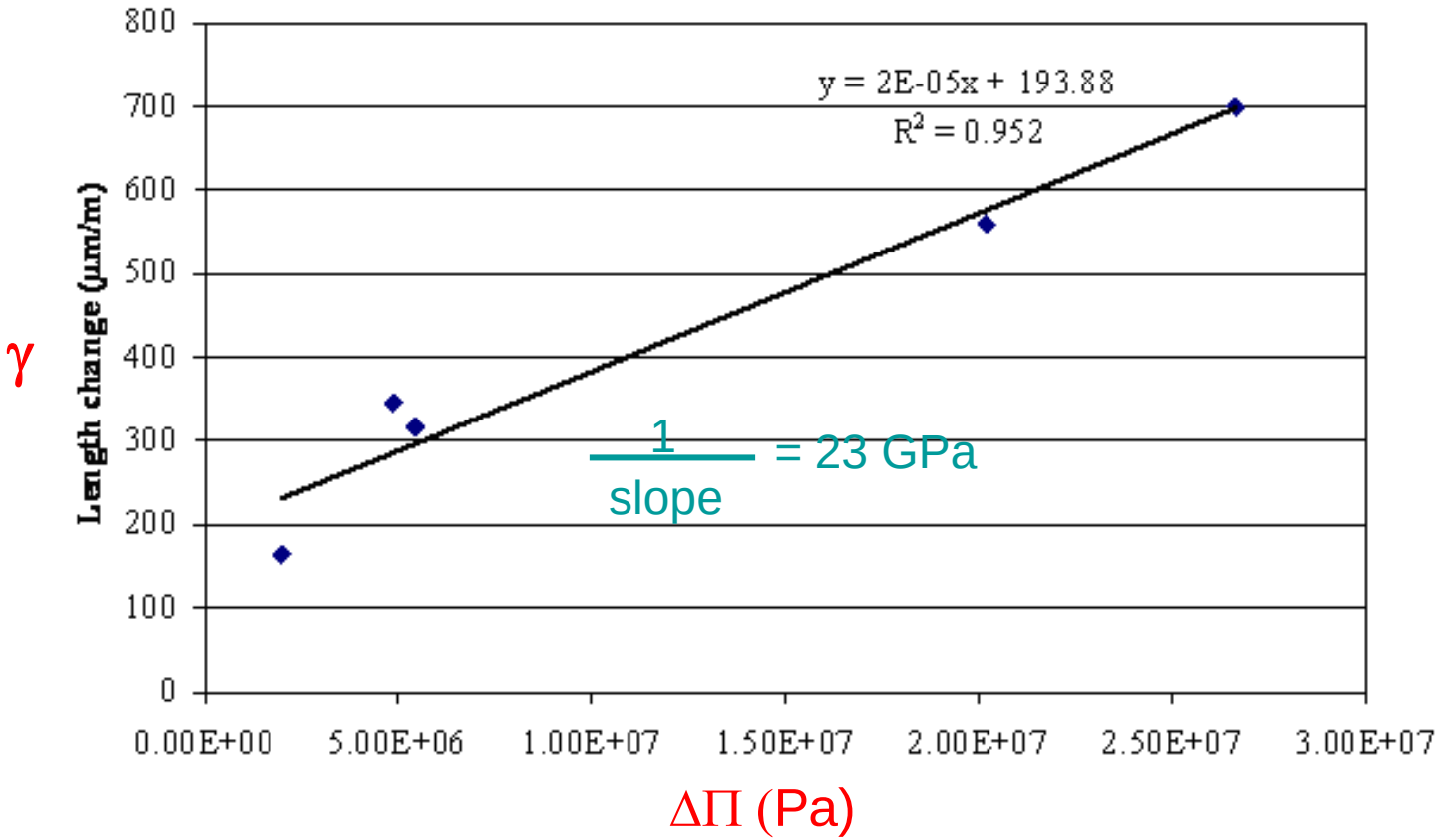
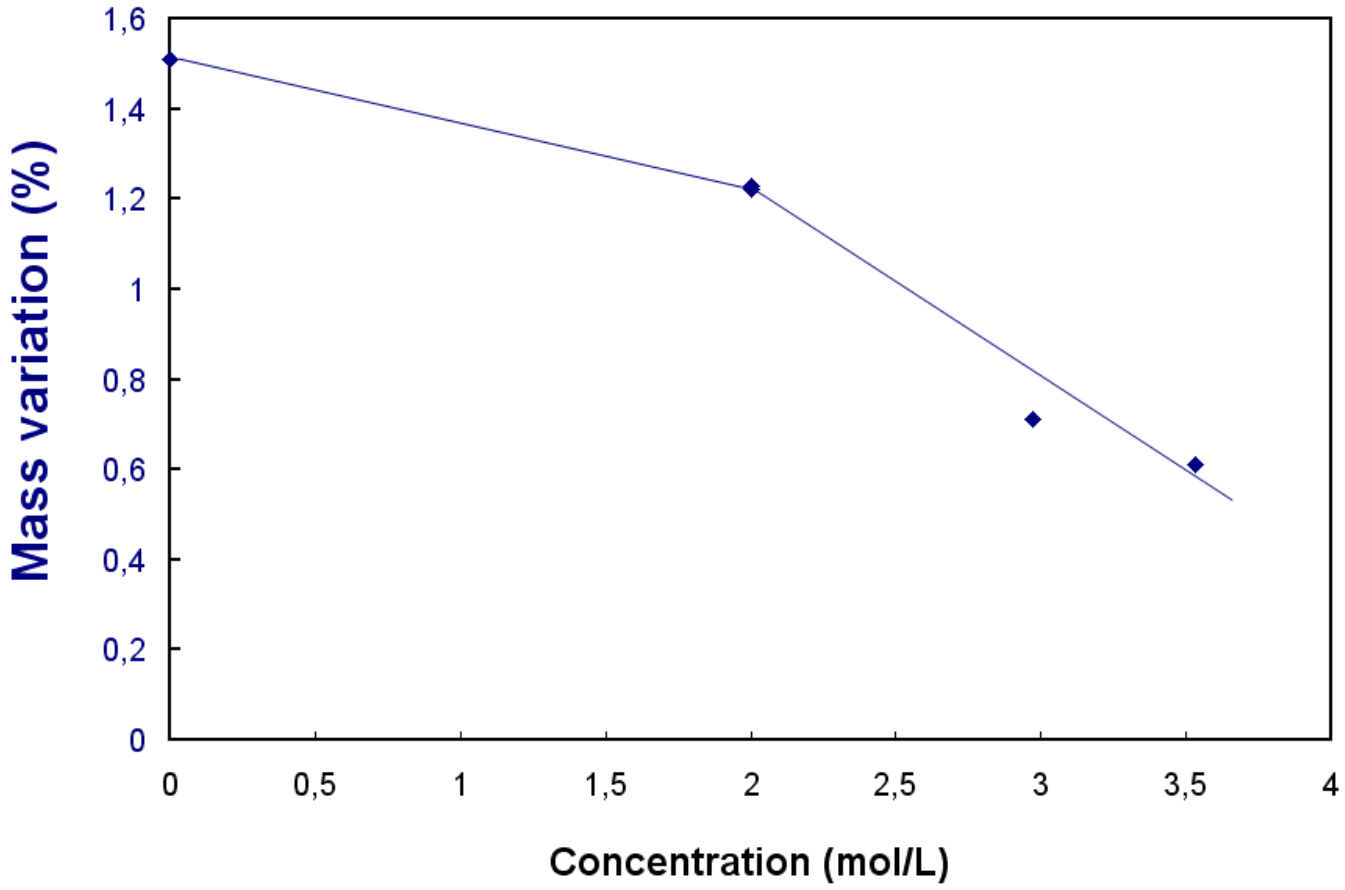


RESULTS

Mass increase at the end of experiment



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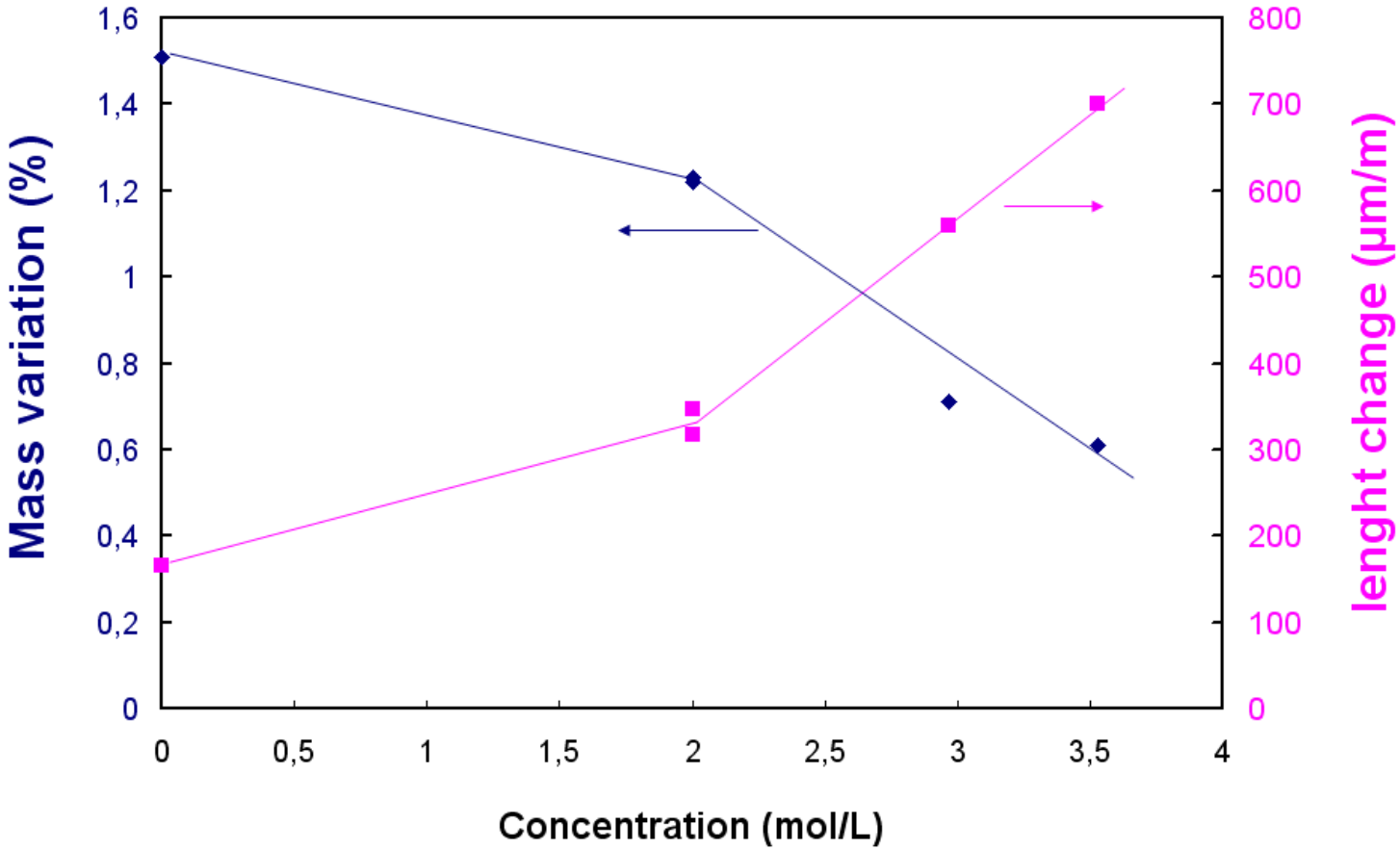

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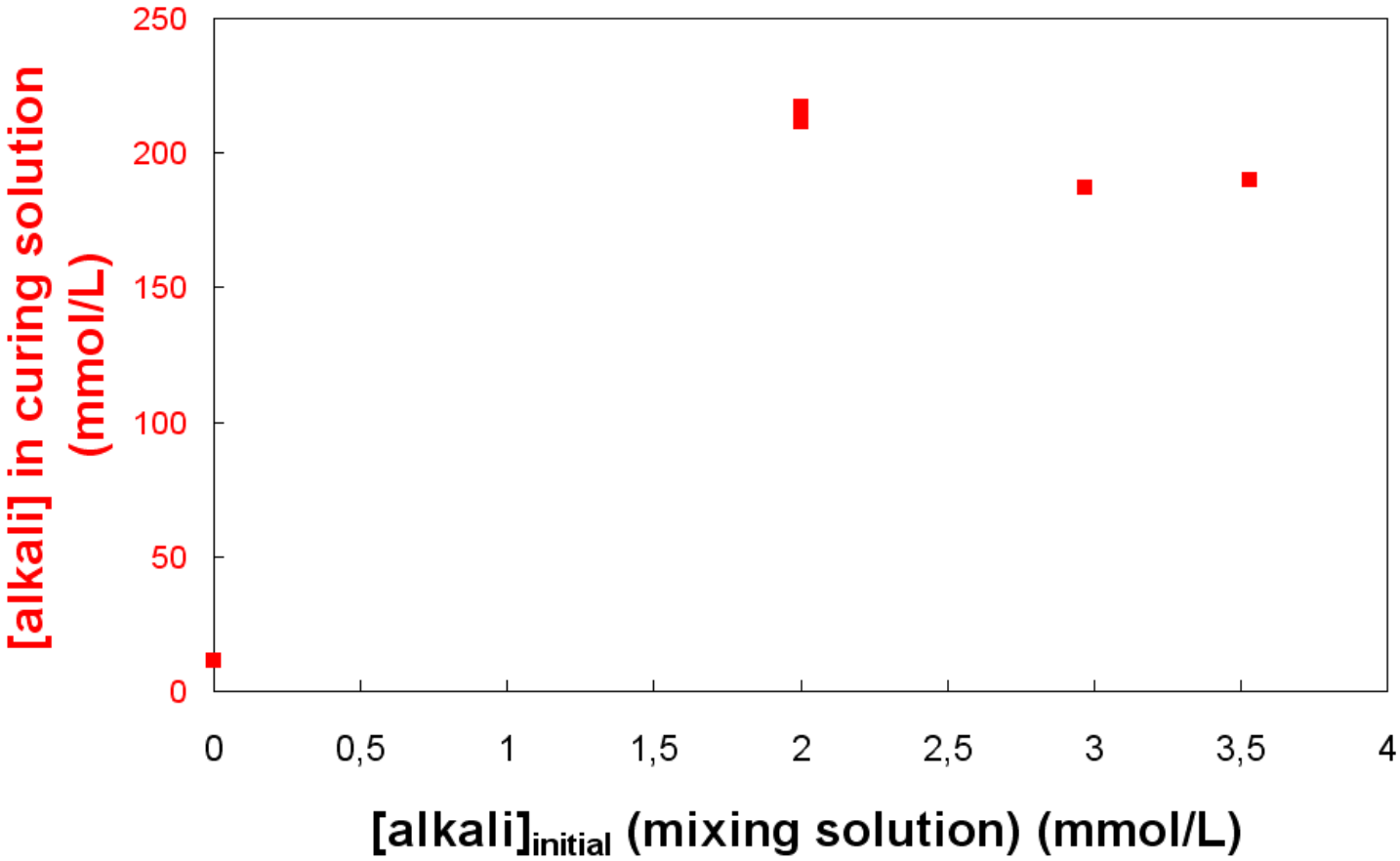
-Mass gain can result to two antagonist processes :
water penetration / diffusion of salts

Weight loss

RESULTS

At the end of experiments



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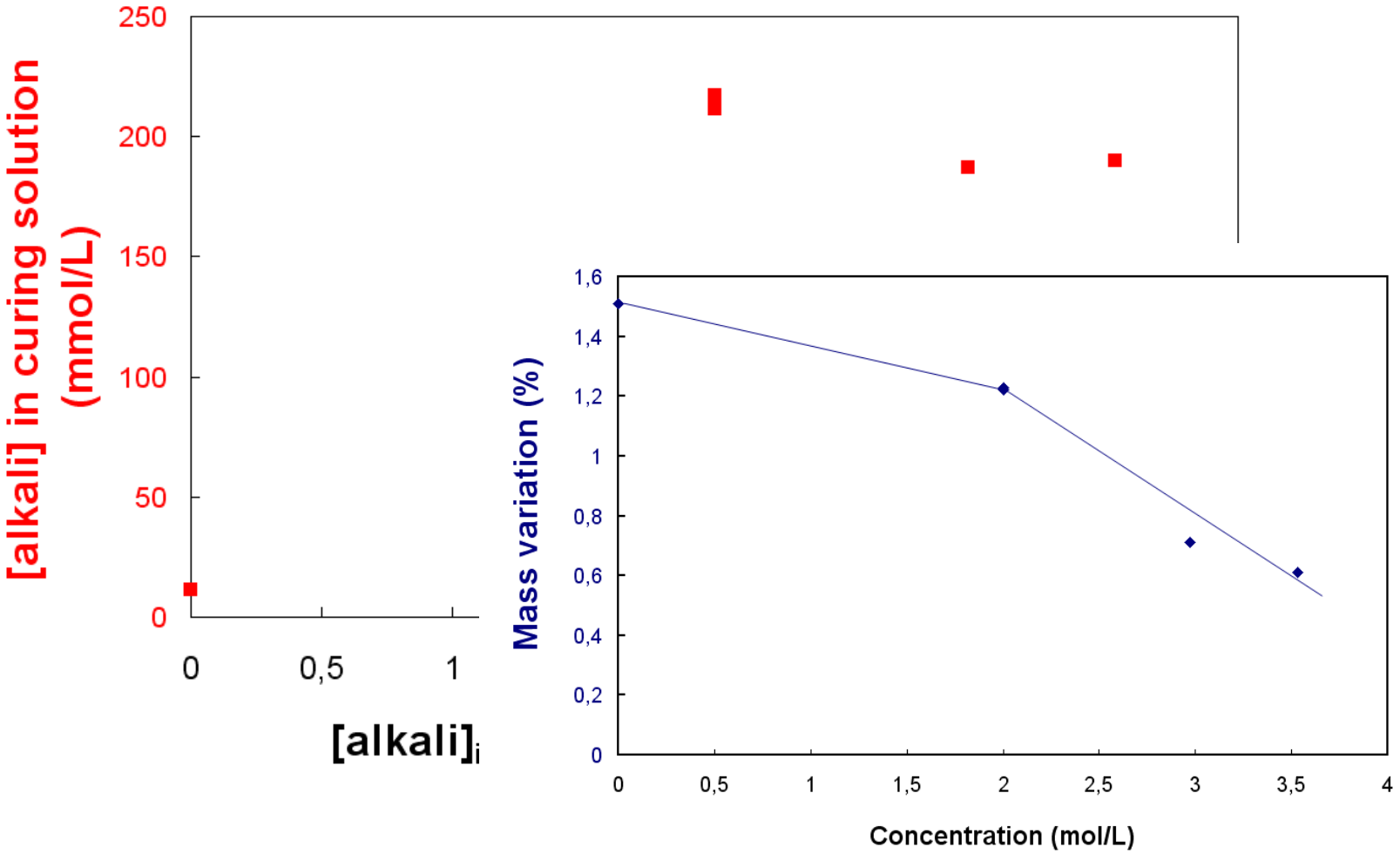


RESULTS

Mass increase at the end of experiment

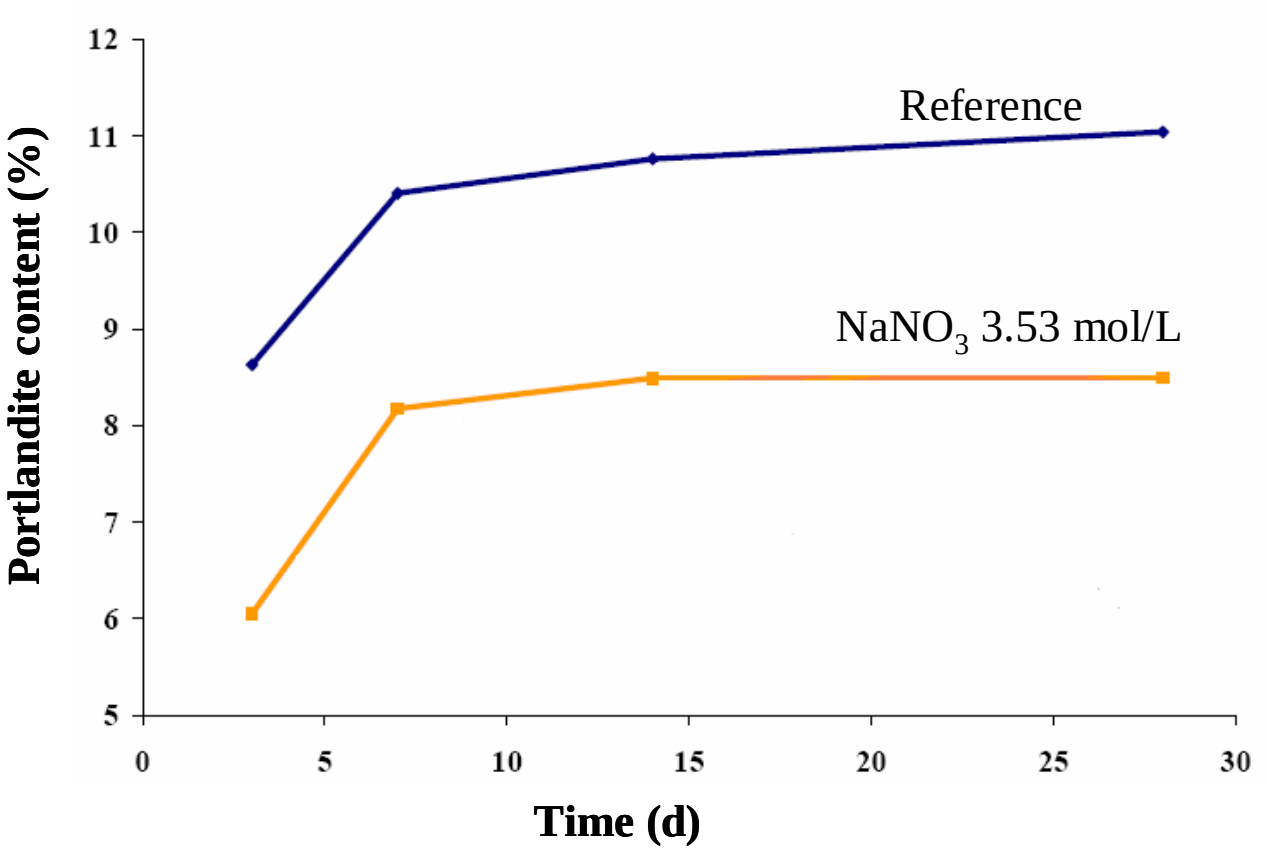
-Not due to osmosis
(effect should increase with ionic concentration of mixing solution)

-Mass gain can result to two antagonist processes :
water penetration/diffusion of salts

-Difference in the degree of hydration

RESULTS

Nitrates retard cement hydration



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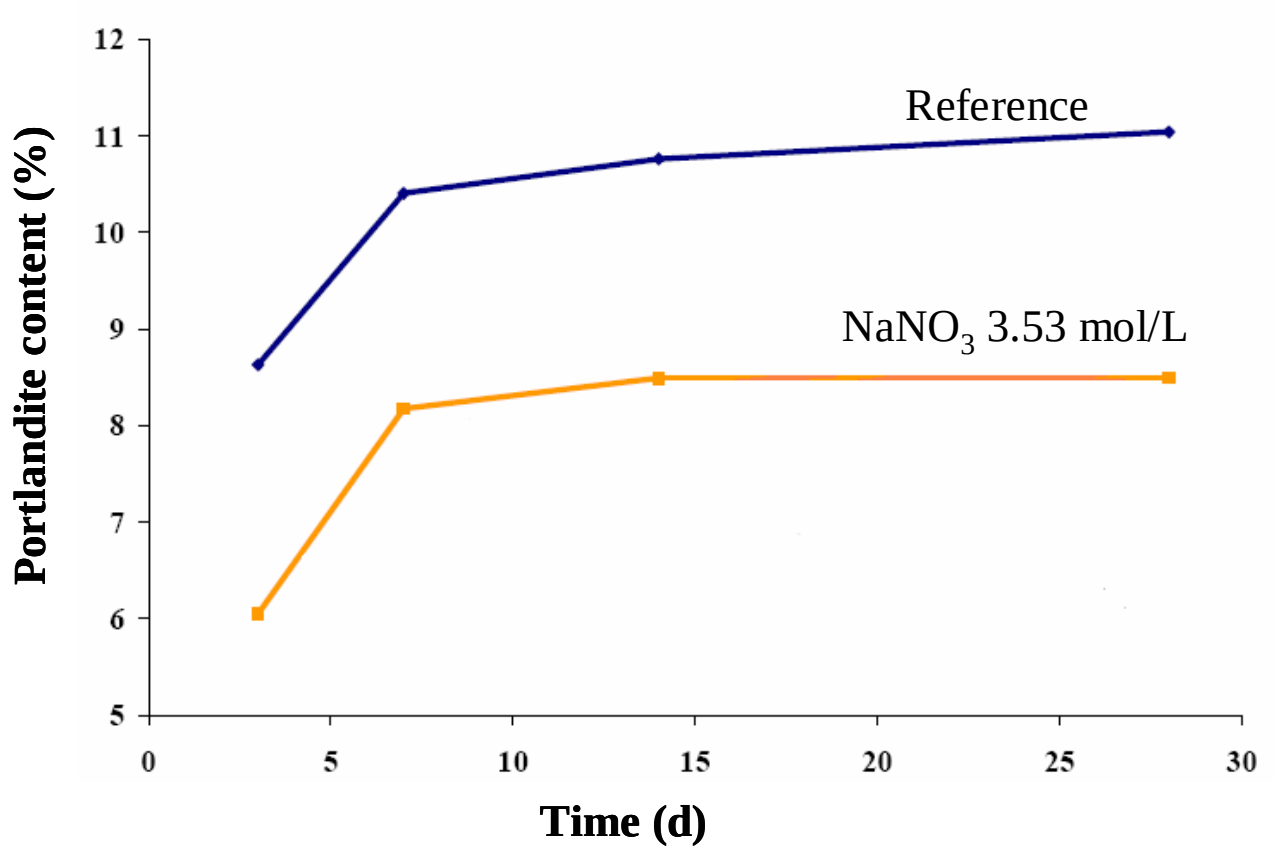

Mass gain can be due to water uptake due to capillary suction
=compensation for water depletion by hydration

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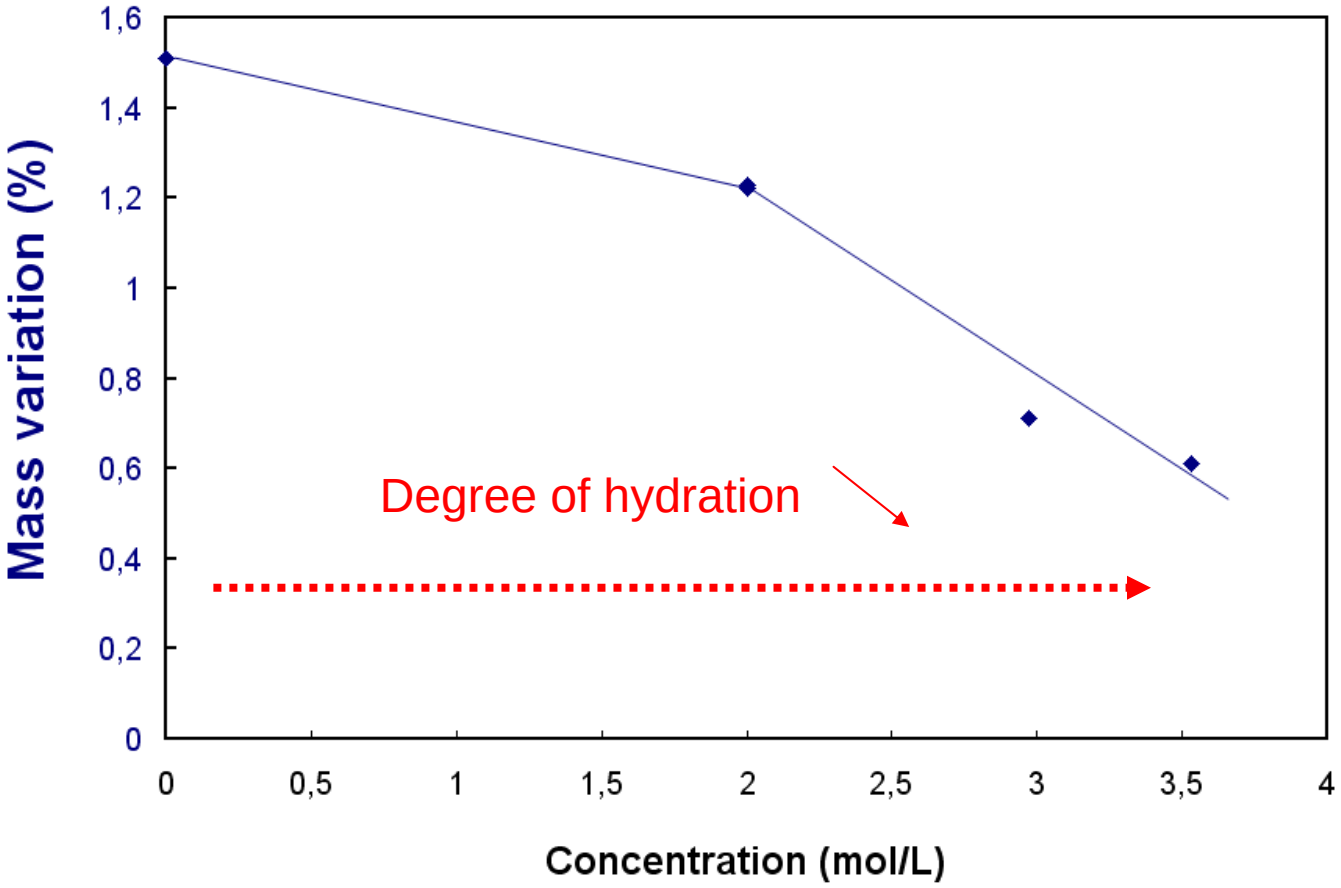

CONCLUSIONS

Mortars prepared with solutions of KNO_3 or $NaNO_3$ exhibited expansion

Expansion increases with the nitrate concentration in the mixing solution, whatever the associated cation.

Swelling was controlled by a concentration effect which involved diffusion and osmosis:

-diffusion of the ions of the pore solution into the less concentrated curing solution,

- water uptake by the material due to the osmotic pressure gradient between the pore and curing solutions.