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Advantages of PVC chemical resistance for pressure pipes

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Background

Selection of a pipe material includes :

- Mechanical criteria (pressure)
- Chemical resistance (corrosive fluids)
- Cost !

- **Industry is aware of chemical criteria and generally uses safe pipe material.**
- **Drinking water distribution has to take into account presence of water disinfectant.**

Background

- During the summer of 2003 some premature failures of plastics pipes for drinking water occurred in France

- The studies showed that it was related to the conjunction of some elements :
  - A particular water disinfectant : ClO_2
  - A high level of this disinfectant
  - High environment temperatures

- ***PVC4Pipes*** **wished to check if PVC pipes could effectively resist strong oxidising conditions**

Common disinfecting agents

- Most common disinfectant used for drinking water : NaOCl
  - Efficient as disinfectant
  - Disadvantage : an unpleasant smell and taste at high levels ($\geq$ 0.5 ppm)
- ClO_2 :
  - Highly efficient
  - Does not give unpleasant smell to the drinking water
  - Is considered as a stronger oxidising agent
- Others : Ozone, chloramine, etc ...

Oxidising efficiency

Oxidation potentials

Chemicals			Potential (V)
MnO_4^-	↔	Mn^{++}	1.49
Cl_2	↔	$2\ Cl^-$	1.36
O_3	↔	O_2	1.24
ClO_2	↔	ClO_2^-	0.95
ClO^-	↔	Cl^-	0.90
I_2	↔	$2\ I^-$	0.54
O_2	↔	$4\ OH^-$	0.40

From CRC Chemical Handbook

Testing method

- PVC is known to have a very good resistance to oxidation at room temperature
- But the literature is poor on the topic of disinfectants and PVC pipes
  (no mention in **ISO/TR 10358**
  and papers only with exposition at 90°C)
- The resistance is assessed on tensile testing specimens according to the mechanical testing of **ISO 4433**

Testing method

- **Resistance of pipes against chemicals is reported in ISO/TR 10358**

Limited

Satisfactory

Non-Satisfactory

ISO/TR 10358:1993(E/F)

Table 1 — Chemical-resistance classification data
Tableau 1 — Classification de la résistance chimique

No.	Chemical	m.p. °C	b.p. °C	Concentration %	T °C	PE-LD	PE-HD	PP	PB	PVC-U	PVC-C	ABS	PVDF	PE-X
364	Sodium hypochlorite			2	100								S	
				5	20			S				S		
					50							S		
					60			S						
				10 to 15	20		S	S	S			NS		
					50							NS		
					60		S		S					
				20	20				S			NS		
					50							NS		
					60				L					

Results reported in this ISO/TR are based on ISO 4433

Requirements of ISO 4433

ISO 4433 expresses the following requirements to assess the resistance of a pipe material :

- Swelling of the material in the presence of the solvent
- Residual mechanical properties after 3 months exposition :

Pipe material	Residual property	Satisfactory if	Limited if	non-satisfactory if
PE, PE-X, PP	E_modulus	Q_E ≥ 38%	38% ≥ Q_E ≥ 31%	Q_E < 31%
	Elong @ rupture	200% ≥ **Q_R ≥ 50%**	50% ≥ Q_R ≥ 30%	Q_R < 30%
PVC	E_modulus	Q_E ≥ 83%	83% ≥ Q_E ≥ 46%	Q_E < 46%
	Elong @ rupture	125% ≥ **Q_R ≥ 50%**	50% ≥ Q_R ≥ 30%	Q_R < 30%

Testing method and samples

- 1st study with ClO_2 (see Plastics Pipes XIV)
- 4 pipes have been investigated :

★1 PVC Ca-Zn stabilised
★1 PVC OBS stab
★1 PVC Tin stab
★ 1 PVC molecularly bioriented

★1 PE80 as reference material

Tensile test specimens (ISO-2) were cut out of the pipes
(DN 110 mm except the Tin-stab : DN 160).

ClO_2 Disinfectant

- ClO_2 disinfectant is not stable and can not be purchased as such

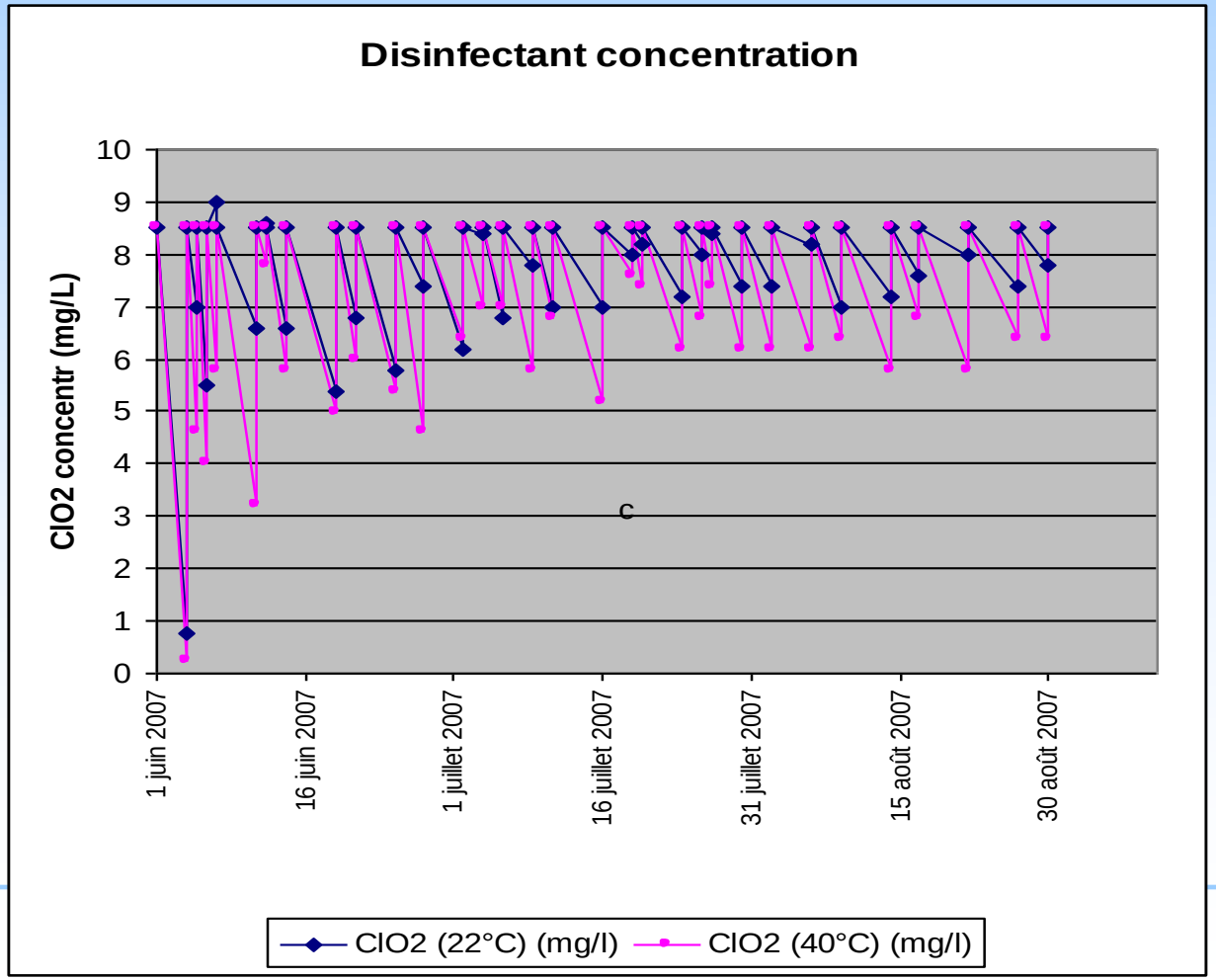
- ***$2\ NaClO_2 + NaOCl + 2\ HCl \rightarrow$***

  $2\ ClO_2 + 3\ NaCl + H_2O$

- ClO_2 Disinfectant was introduced using a commercial kit (Accepta ®)

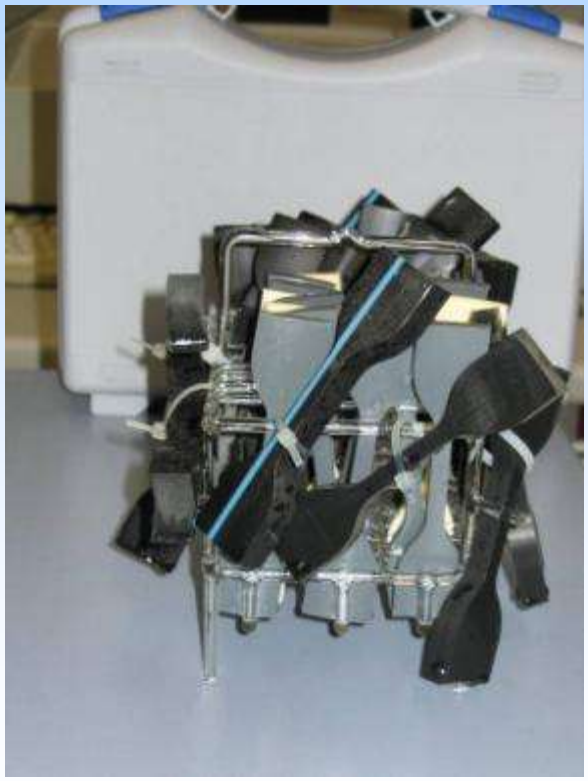
ClO_2 Concentration

- The concentration of ClO_2 was decreasing with time (decay of ClO_2) and was kept approximately constant by checking and addition of the missing amount.



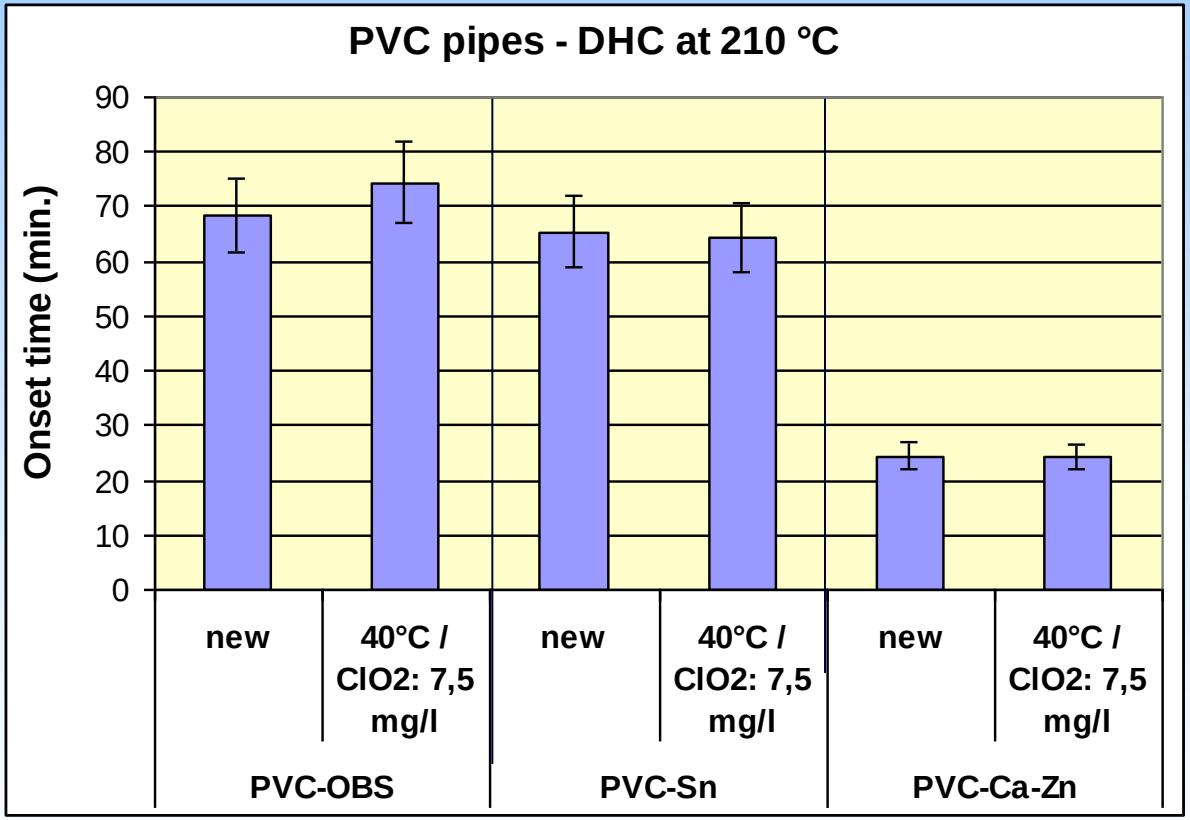
Immersion in disinfectant

- The specimens are immersed in a solution of ClO_2 or NaOCl, in black tanks, at specified testing temperature.



Physical evaluation

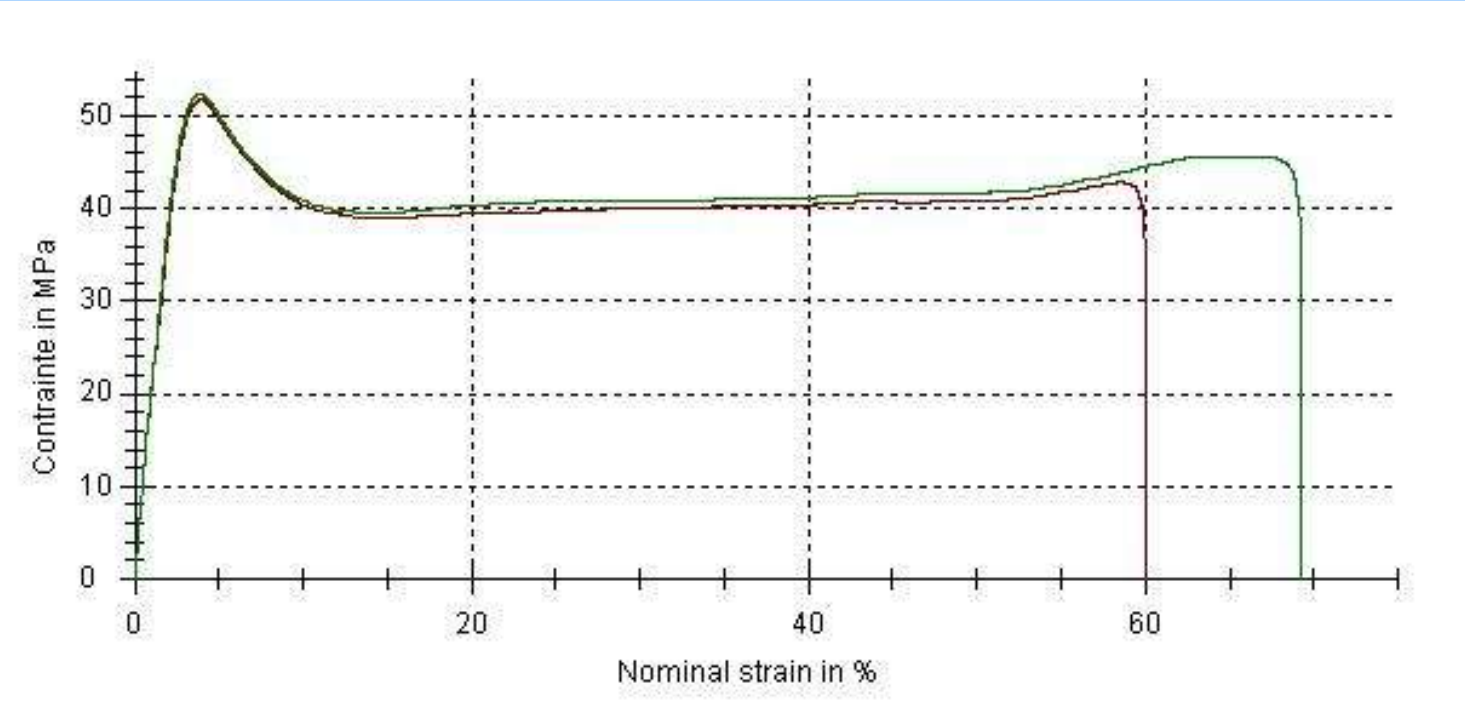
Residual stability of samples after exposure to ClO_2:



- For PVC : Thermal stability is depending on the stabiliser system but shows no loss of thermal stability with exposure

Evaluation of mechanical properties

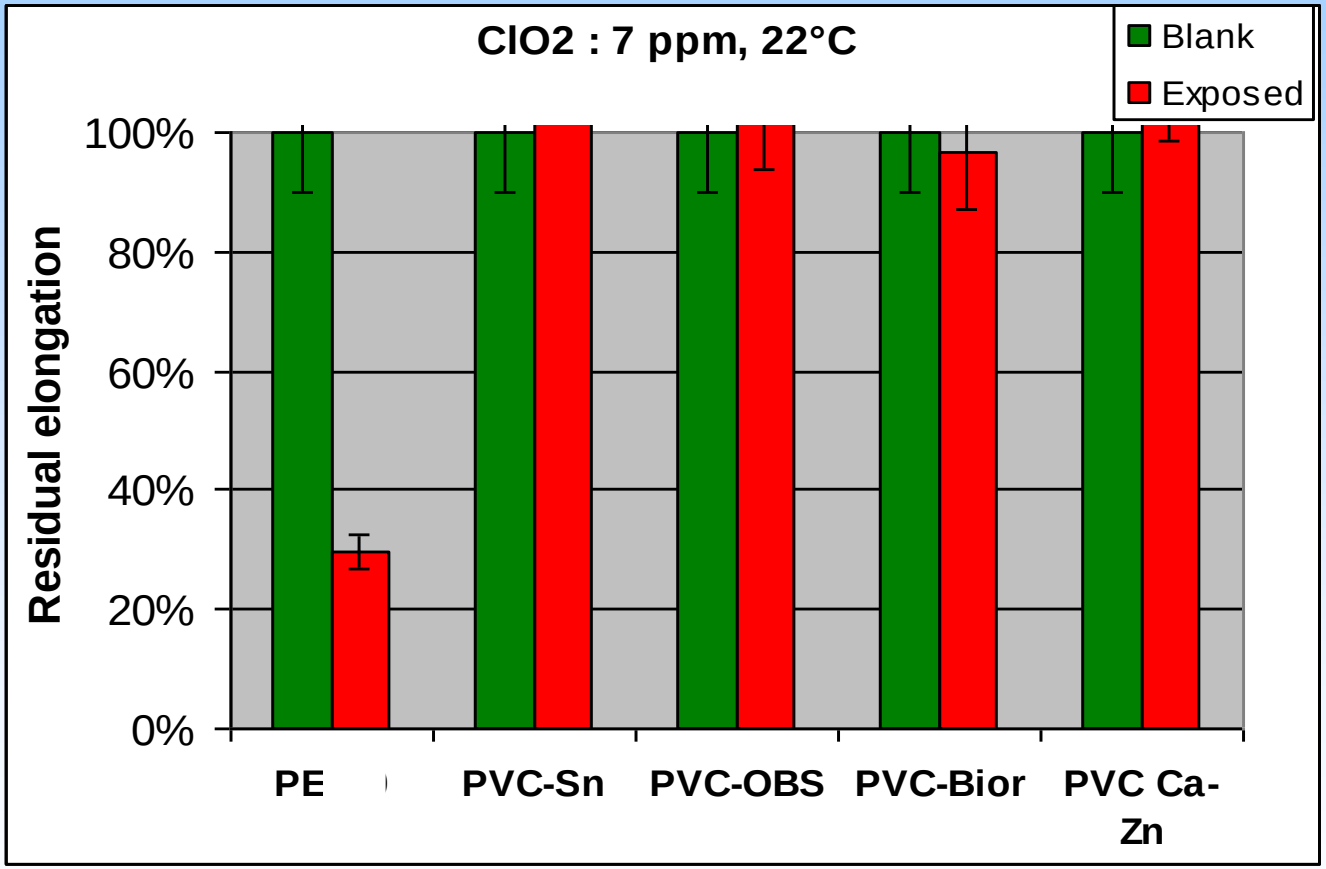
- Tensile test for elongation criteria



Stress at rupture is compared for the different conditions

Results of the study with ClO_2

Residual elongation at break after exposure :



No reduction of elongation at break for PVC

Observations for ClO_2 exposure

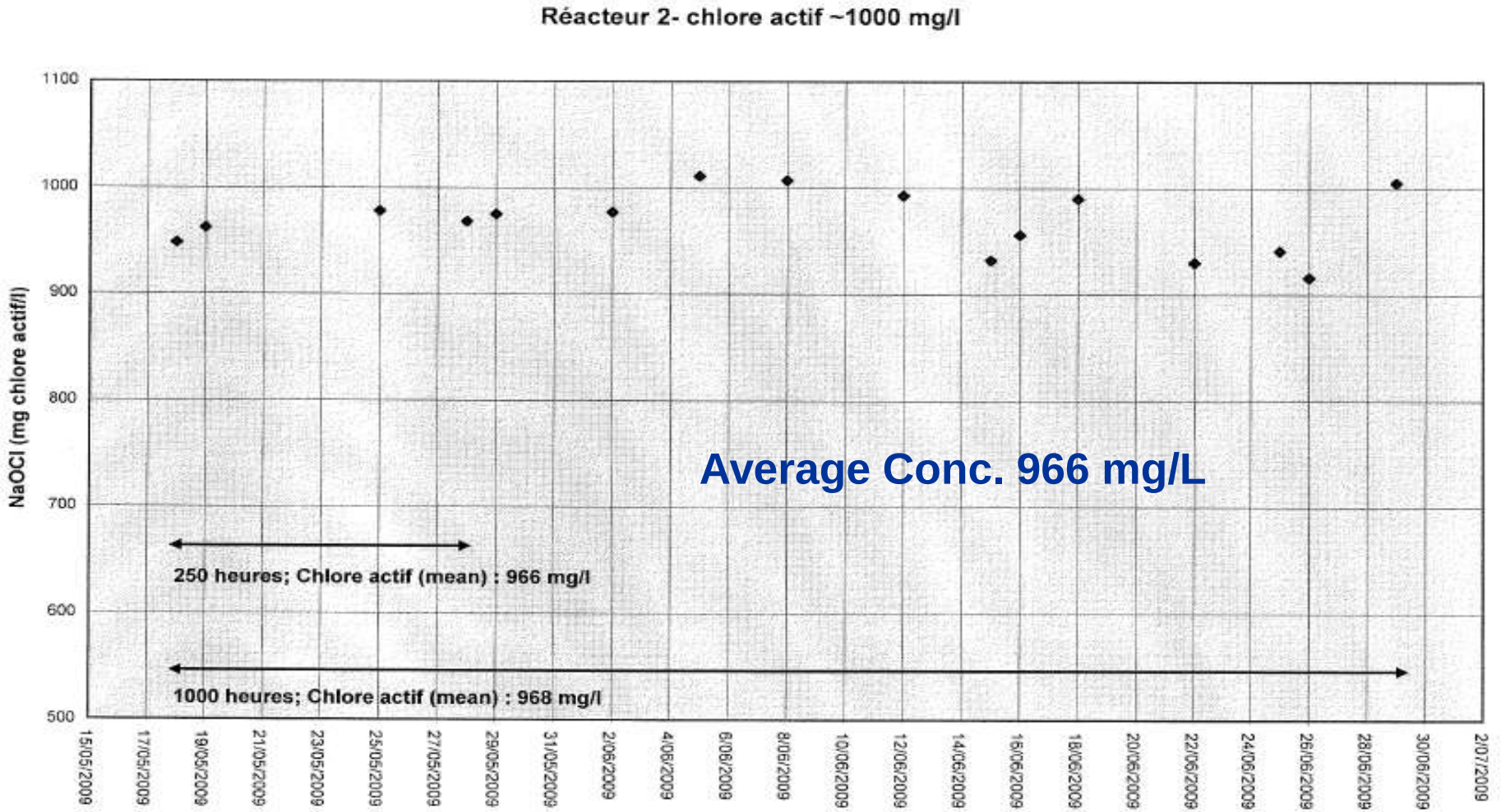
- With normal temperature and concentrations conditions, no attack of the PVC pipe was registered with ClO_2.
- In very hard and unrealistic conditions : (Temp = 40°C, high concentrations, ...) we could only induce a limited attack of the PVC surface.
- This limited attack is far beyond the levels required for non acceptance of a pipe material (ISO 4433)

Resistance to NaOCl

- An assessment was also realised with industrial concentrations of NaOCl
- Same experimental procedure
- Samples :
  - ★**1 PVC Ca-Zn stabilised**
  - ★**1 PVC OBS stab**
  - ★**1 PVC Tin stab**
  - ★**1 PVC molecularly bioriented**
- Concentrations : 10 and 1000 ppm NaOCl

Resistance to NaOCl

- Active chlorine was kept constant by automatic adjustment



Resistance to NaOCl

- After exposure to the different conditions :

  10 ppm - 1000 ppm
  250 h - 1000 h

- Samples weighing : all weight changes < + 0.2%

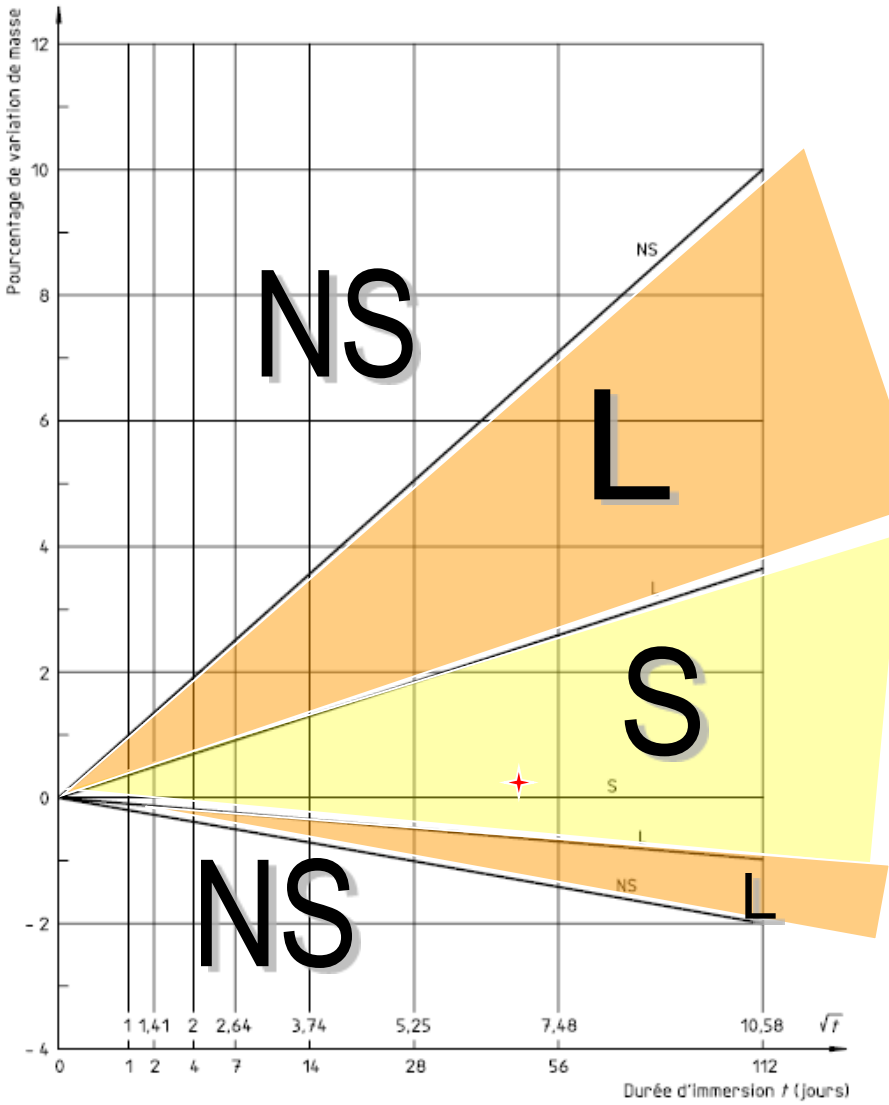
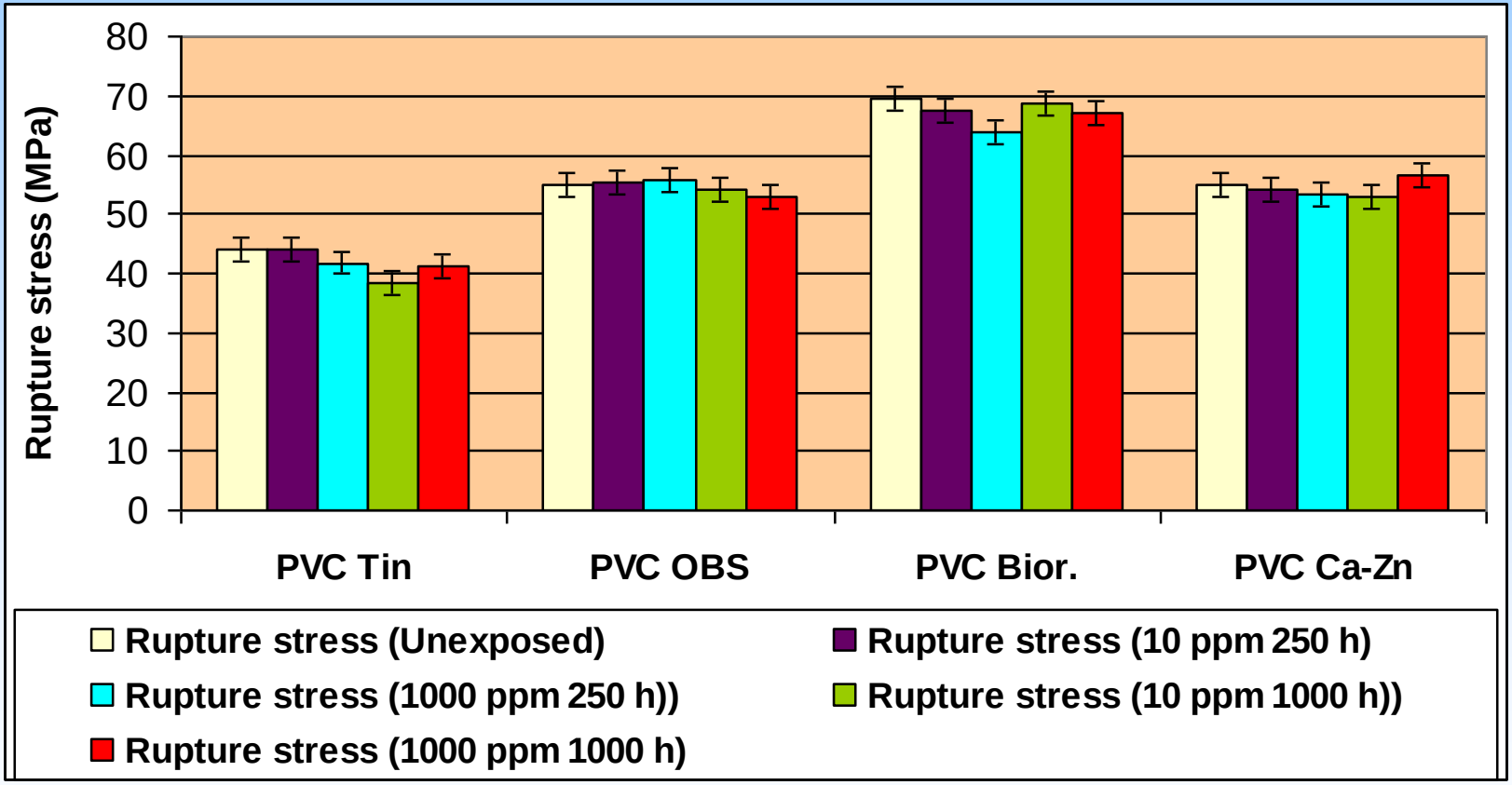


Figure 1 — Diagramme de classification des tubes en PVC-U, PVC-choc et PVC-C basée sur les variations de masse

Resistance to NaOCl

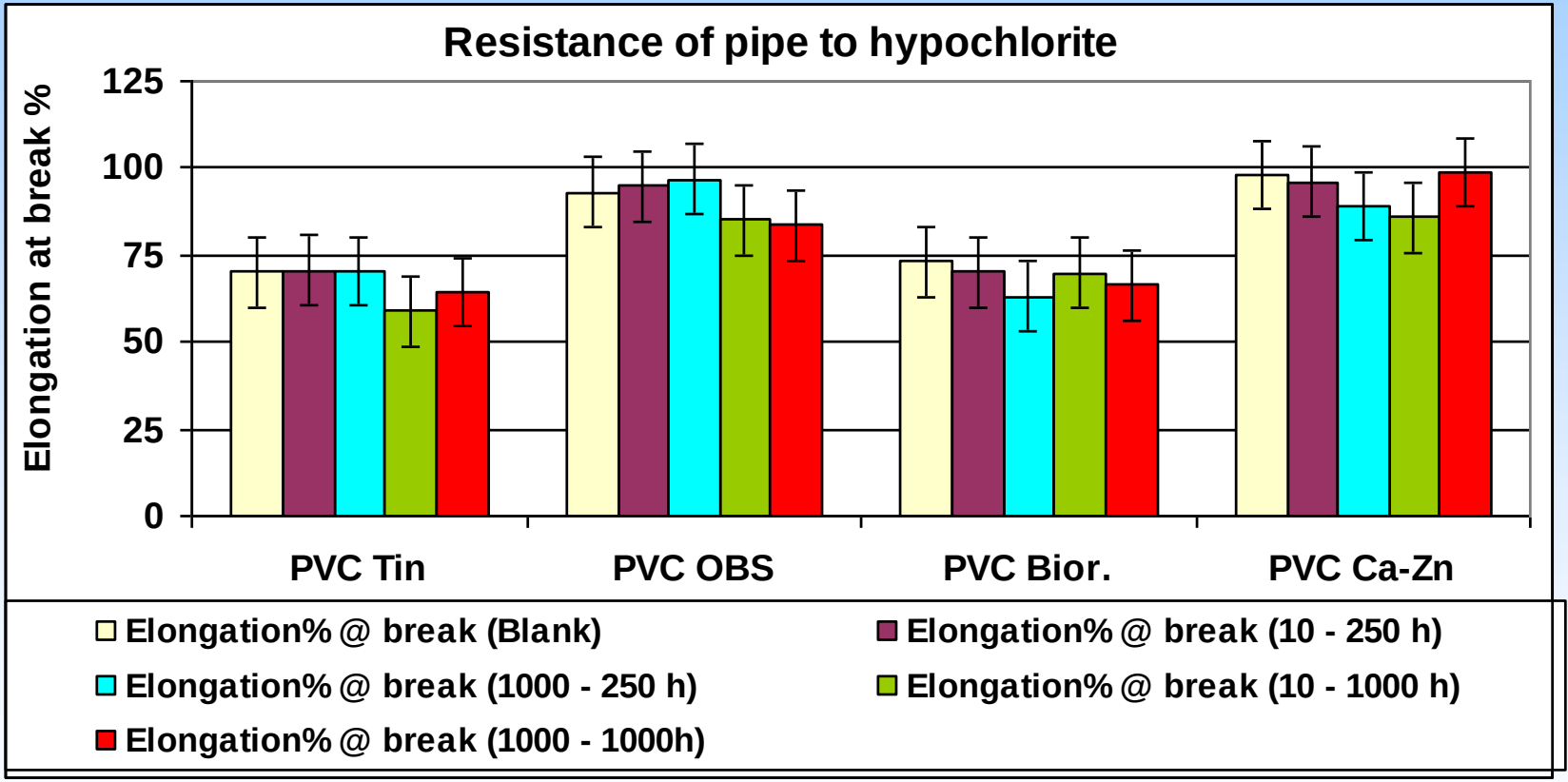
- Stress at rupture



- No significant influence of the oxidising solution
- Confirmation of the high performance of bioriented PVC

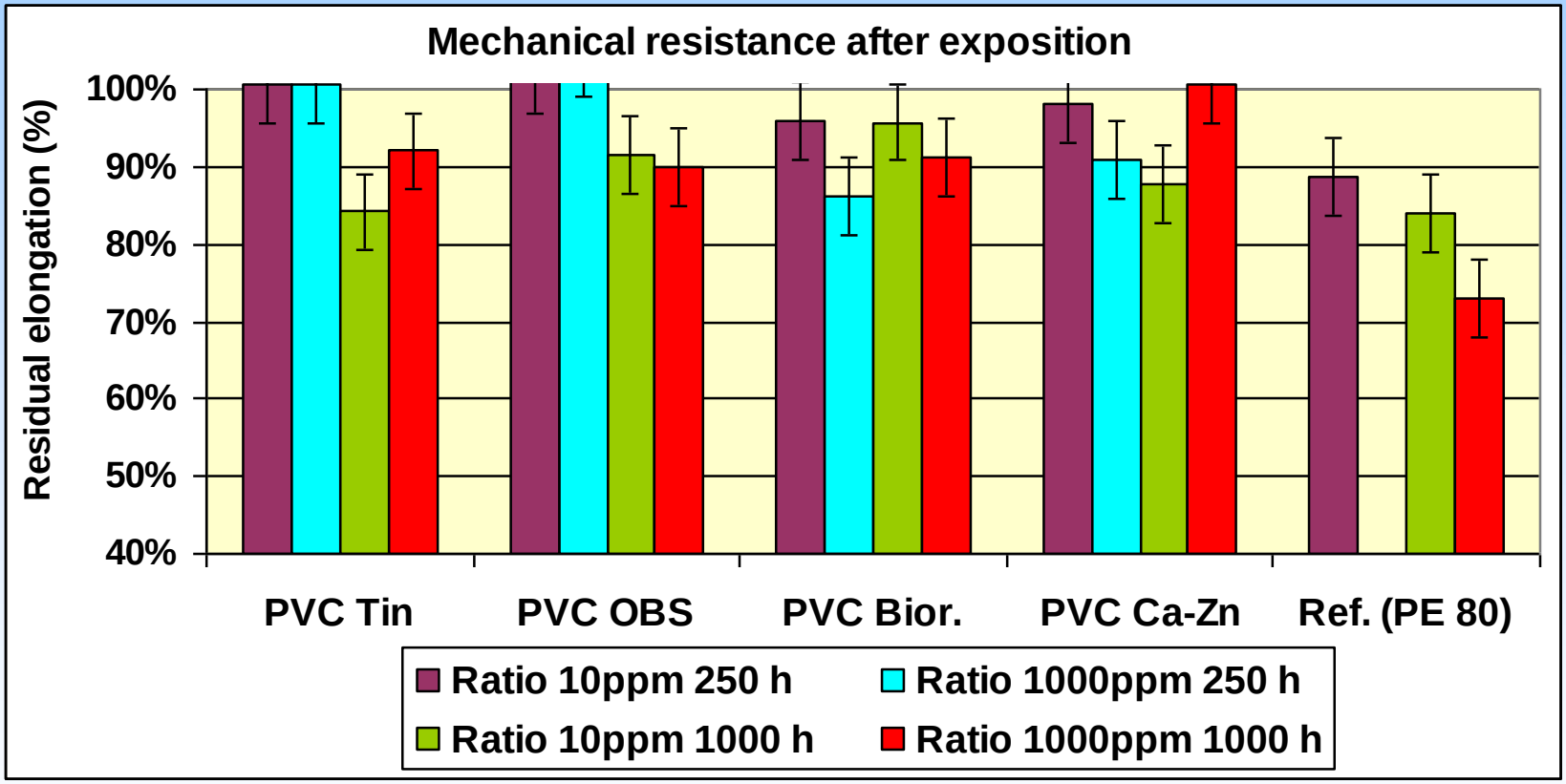
Resistance to NaOCl

- Elongation at break



Resistance to NaOCl

- Residual elongation after exposure to oxidant



According to ISO 4433 the PVC shows
no significant reduction of properties

Conclusions

- PVC pipes can withstand concentrations of 1000 ppm of NaOCl without adverse effect
- All major PVC formulations types show a similar behaviour
- Bioriented PVC is also convenient for this application
- We could confirm that PVC :
  - shows very low sensitivity to strong oxidising media
  - is a cost effective material for the transport of oxidant solutions.

Thank you !

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