Advantages of PVC chemical resistance for pressure pipes
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: ClO₂
  - 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 (≥ 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

<table>
<thead>
<tr>
<th>Chemicals</th>
<th>Potential (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MnO$_4^-$ $\leftrightarrow$ Mn$^{2+}$</td>
<td>1.49</td>
</tr>
<tr>
<td>Cl$_2$ $\leftrightarrow$ 2 Cl$^-$</td>
<td>1.36</td>
</tr>
<tr>
<td>O$_3$ $\leftrightarrow$ O$_2$</td>
<td>1.24</td>
</tr>
<tr>
<td>ClO$_2$ $\leftrightarrow$ ClO$_2^-$</td>
<td>0.95</td>
</tr>
<tr>
<td>ClO$^-$ $\leftrightarrow$ Cl$^-$</td>
<td>0.90</td>
</tr>
<tr>
<td>I$_2$ $\leftrightarrow$ 2 I$^-$</td>
<td>0.54</td>
</tr>
<tr>
<td>O$_2$ $\leftrightarrow$ 4 OH$^-$</td>
<td>0.40</td>
</tr>
</tbody>
</table>

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

Results reported in this ISO/TR are based on 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**:

<table>
<thead>
<tr>
<th>Pipe material</th>
<th>Residual property</th>
<th>Satisfactory if</th>
<th>Limited if</th>
<th>non-satisfactory if</th>
</tr>
</thead>
<tbody>
<tr>
<td>PE, PE-X, PP</td>
<td>E_modulus</td>
<td>$Q_E \geq 38%$</td>
<td>$38% \geq Q_E \geq 31%$</td>
<td>$Q_E &lt; 31%$</td>
</tr>
<tr>
<td></td>
<td>Elong @ rupture</td>
<td>$200% \geq Q_R \geq 50%$</td>
<td>$50% \geq Q_R \geq 30%$</td>
<td>$Q_R &lt; 30%$</td>
</tr>
<tr>
<td>PVC</td>
<td>E_modulus</td>
<td>$Q_E \geq 83%$</td>
<td>$83% \geq Q_E \geq 46%$</td>
<td>$Q_E &lt; 46%$</td>
</tr>
<tr>
<td></td>
<td>Elong @ rupture</td>
<td>$125% \geq Q_R \geq 50%$</td>
<td>$50% \geq Q_R \geq 30%$</td>
<td>$Q_R &lt; 30%$</td>
</tr>
</tbody>
</table>
Testing method and samples

- 1st study with ClO\textsubscript{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).
**ClO₂ Disinfectant**

- ClO₂ disinfectant is not stable and can not be purchased as such

  - $2 \text{NaClO}_2 + \text{NaOCl} + 2 \text{HCl} \rightarrow 2 \text{ClO}_2 + 3 \text{NaCl} + \text{H}_2\text{O}$

- ClO₂ Disinfectant was introduced using a commercial kit (Accepta ® )
The concentration of ClO₂ was decreasing with time (decay of ClO₂) 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 ClO₂

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
Active chlorine was kept constant by automatic adjustment.

Average Conc. 966 mg/L
After exposure to the different conditions:
10 ppm - 1000 ppm
250 h - 1000 h

Samples weighing:
all weight changes < + 0.2%
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

![Graph showing resistance to hypochlorite for different PVC types](chart)

**Resistance of pipe to hypochlorite**

- PVC Tin
- PVC OBS
- PVC Bior.
- PVC Ca-Zn

**Elongation at break %**

- Elongation% @ break (Blank)
- Elongation% @ break (10 - 250 h)
- Elongation% @ break (1000 - 250 h)
- Elongation% @ break (1000 - 1000h)
- Elongation% @ break (10 - 1000 h)
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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