Disinfection Residual Effects On Water Distribution Systems Materials

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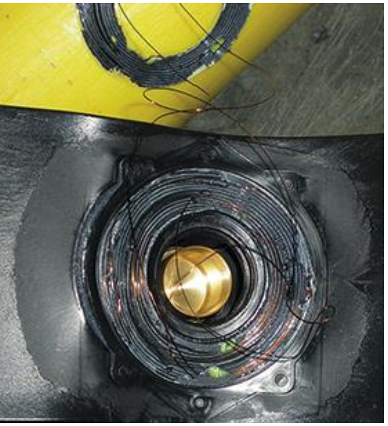
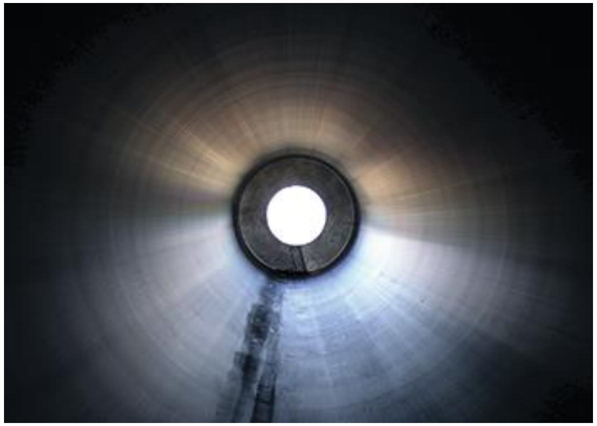
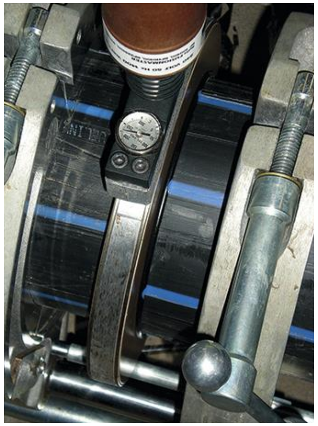
Water New Zealand Conference & Expo 2019


Residual Disinfectants Cause Deterioration To Network Materials

- Complex Reactions
- Depend on Type & Concentrations

Australian and New Zealand Drinking Water Guidelines

Disinfectant Residual Levels Based on Aesthetic and Health Related Issues

Typical Guideline Levels

Free Allowable Chlorine 0.6 mg/L

Typical System Levels 0.2 – 1.5 mg/L

Maximum Allowable Chlorine 5 mg/L

Maximum Allowable Chloramine 3 mg/L

Typical Chlorine Dioxide Levels 1 – 2.5 mg/L

Target Levels pH 6.5 – 8.5

Residual Disinfection Types

- Chlorine
- Chloramine
- Chlorine Dioxide

Chlorination (Gas/Liquid addition)

$$Cl_2 + H_2O \rightarrow HOCl + H^+ + Cl^-$$

HOCl (Hypochlorous acid)

- Weak acid, powerful oxidising agent
- Primary disinfecting agent

Chlorination (Gas/Liquid addition)

Further dissociation

$$HOCl \leftrightarrow H^+ + OCl^-$$

H^+ - Important Hydrogen ions not drop too low

hence pH not too high ≤ 7.5

- Water should be in range 7.0 – 8.0

Chloramination

$$HOCl + NH_3 \leftrightarrow NH_2Cl + H_2O$$

NH_2Cl (Monochloramine)

- Controlled by pH and Chlorine:Ammonia ratio

Chlorine Dioxide (Most common process)

$$2NaClO_2 + Cl_2 \rightarrow 2ClO_2 + 2NaCl$$

ClO_2 (Chlorine Dioxide)

- Effective over wider water pH range
- Decomposed rapidly by sunlight and UV light

Chlorine Dioxide

Reacts with Hydrogen Peroxide (HOOH)

$$2ClO_2 + HOOH \rightarrow 2HClO_2 + O_2 \quad (1)$$

Probably reacts with polymeric hydroperoxides (ROOH)

$$ClO_2 + ROOH \rightarrow RO_2\cdot + HClO_2 \quad (2)$$

- Chain branch reaction as is thermal degradation
- Proposed accelerates polymeric oxidation rate

(Ref Jacobson)

Disinfection Aggression Differences

Chlorine Dioxide ►Chloramine ►Chlorine

- Chlorine Dioxide most aggressive
- Disinfection method change can result in existing material degradation

Elastomer	Chlorine pH 8.5	Chloramine pH 8.5
Neoprene	Minor crack Surface distort	Moderate crack Minor embrittlement
Nitrile (Sulphur cure)	Minor crack Surface distort	Minor crack
EPDM (Sulphur cure)	Minor crack	Heavy crack Minor embrittlement
Natural Rubber	Moderate crack Moderate embrittlement	Heavy crack Moderate embrittlement

● USA changes from chlorine to chloramine resulted in number of premature elastomer failures (19)

Secondary Disinfection Effects

Copper (Cu)

- Copper corrosion complex, due to more than one influence
- HOCl primary oxidant causing Cu_2O corrosion scale on pipe surface
- ClO_2 and NH_2Cl can cause dissolution of scale releasing Cu^+ ions into the water
- Cause accelerated failures in other materials (PPr) in hot water systems
- Recommendations that ClO_2 not be used as a disinfectant (17)

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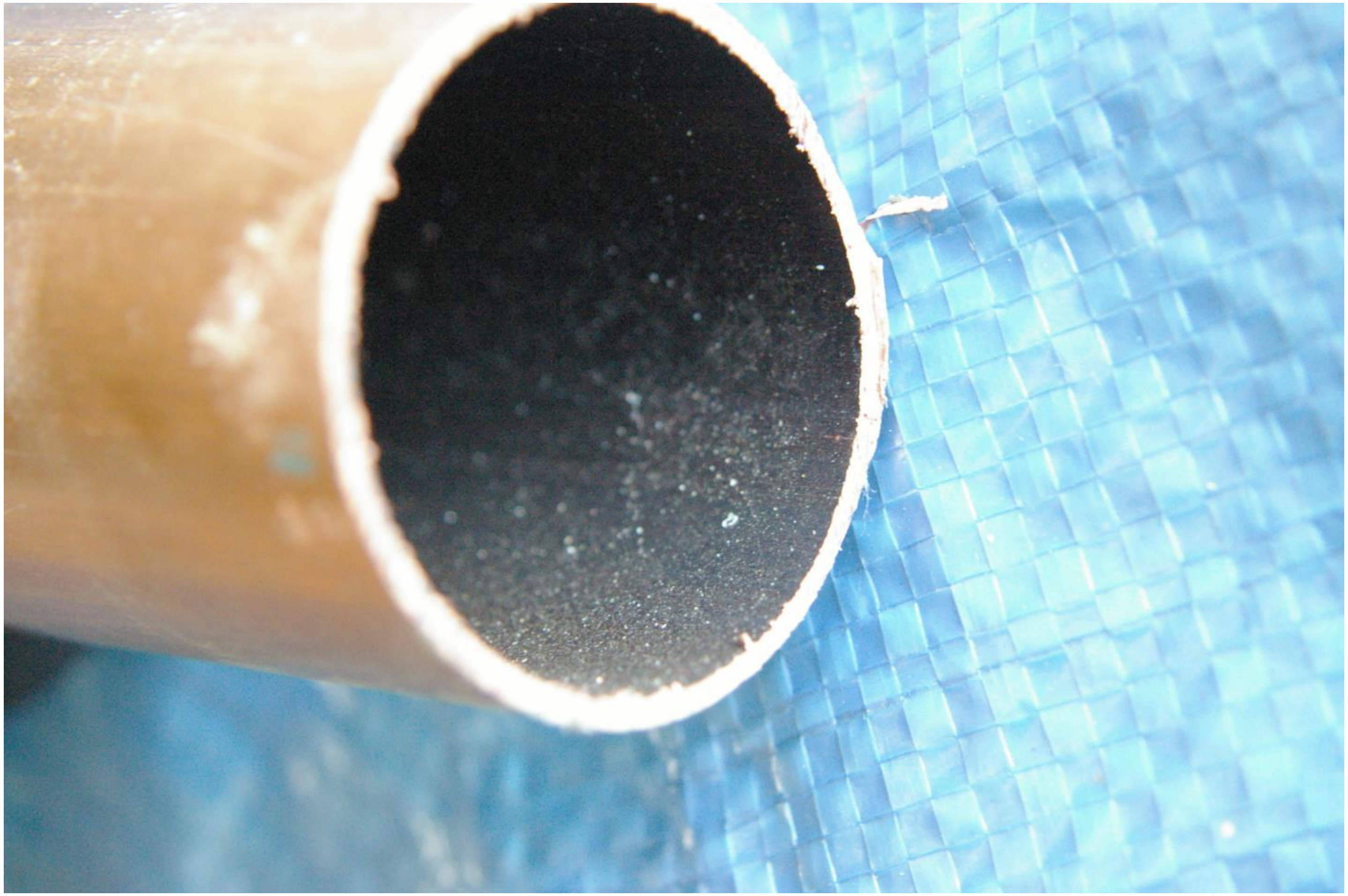
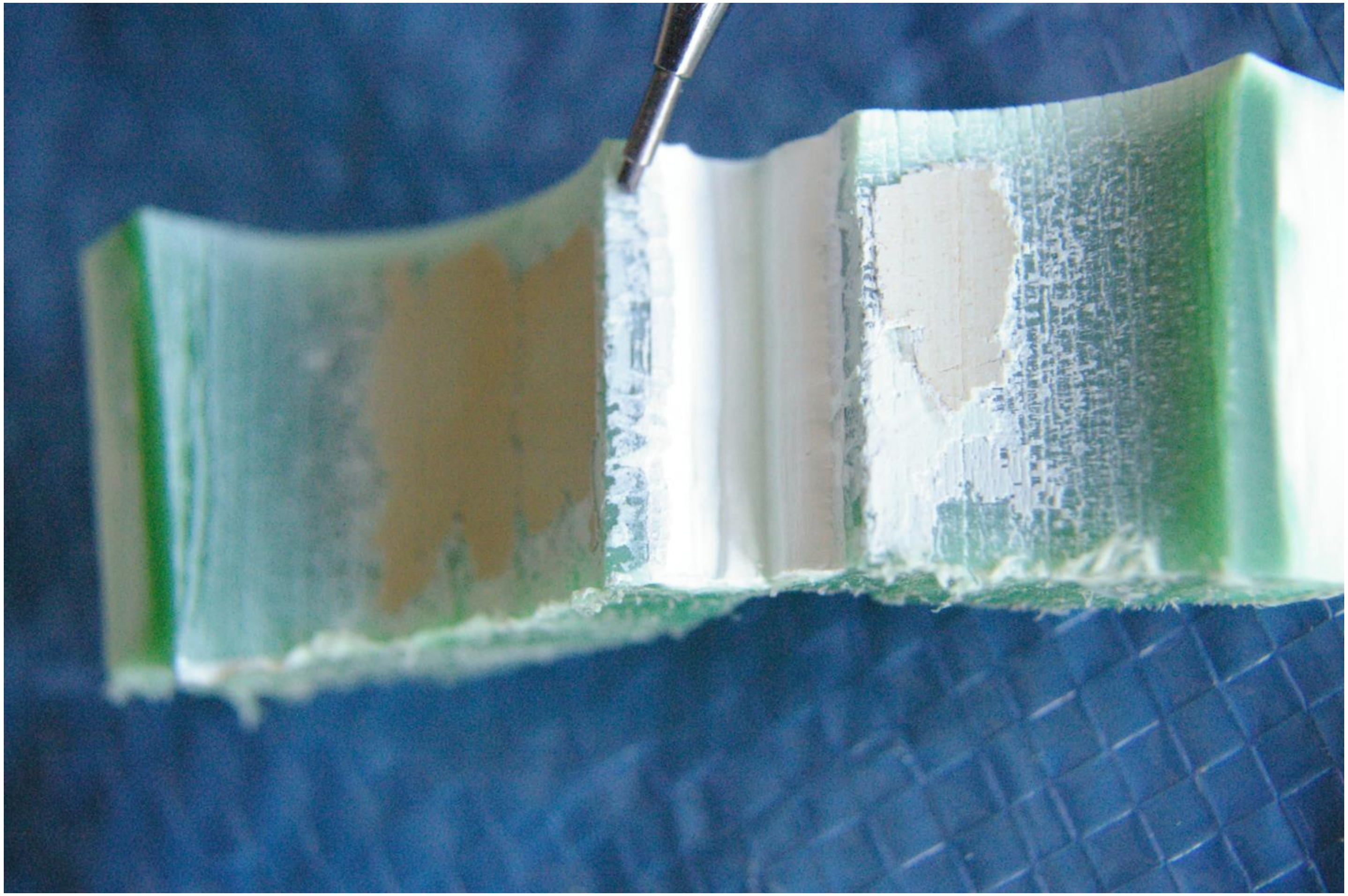
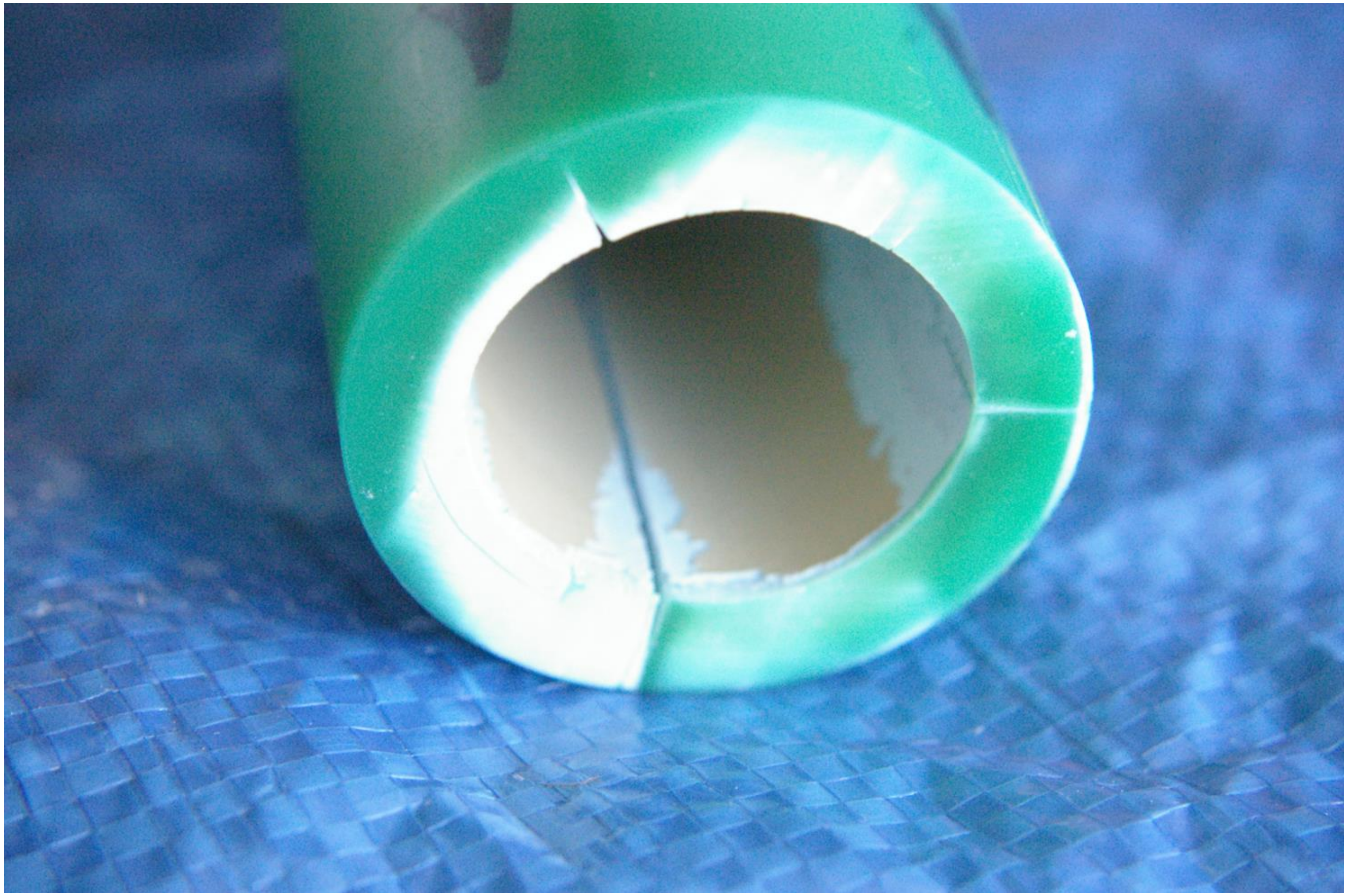
Copper Internal Corrosion Layer



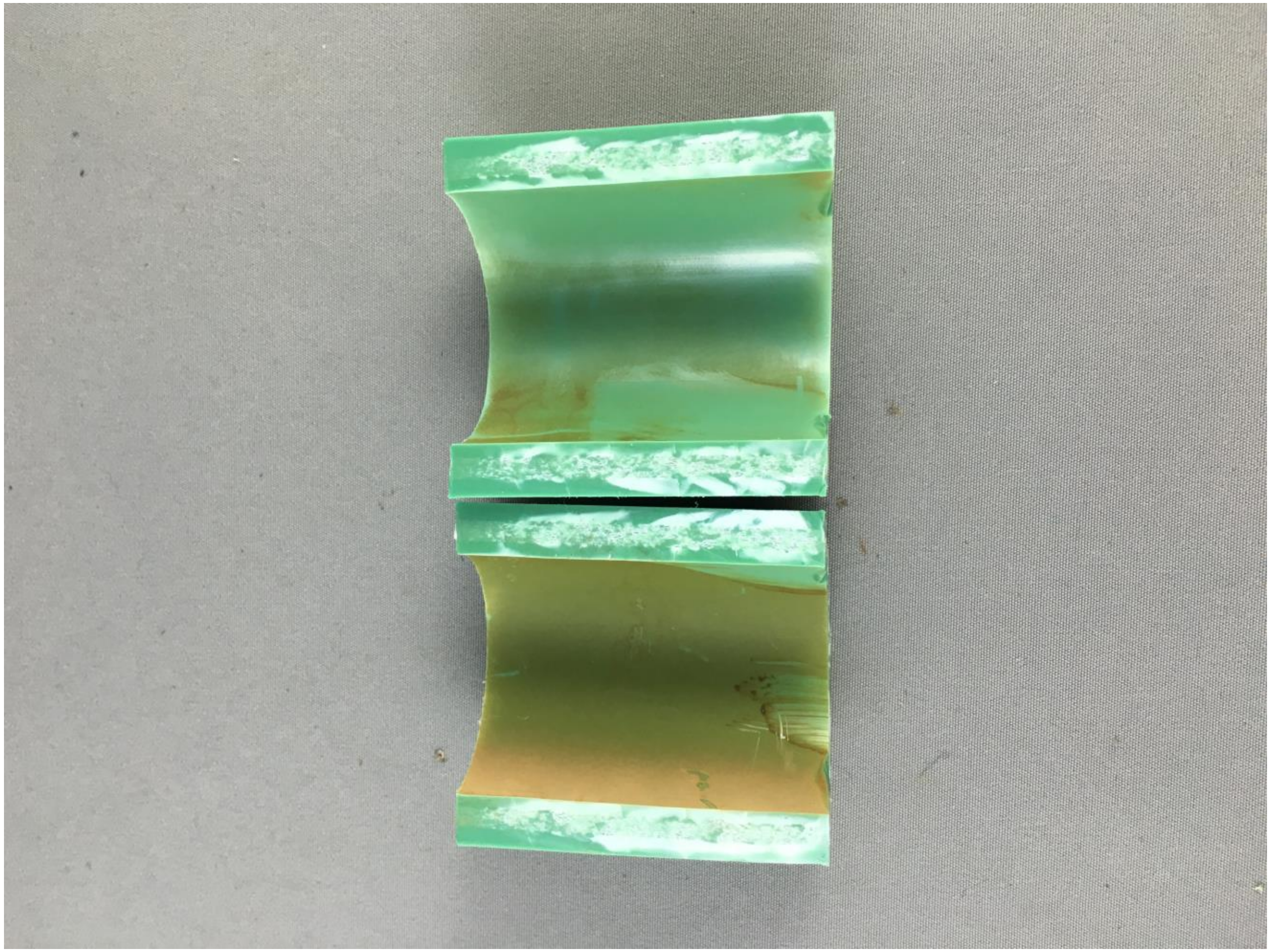
PPr Oxidation Crazing and Partial Initial Fracture – High Cl_2

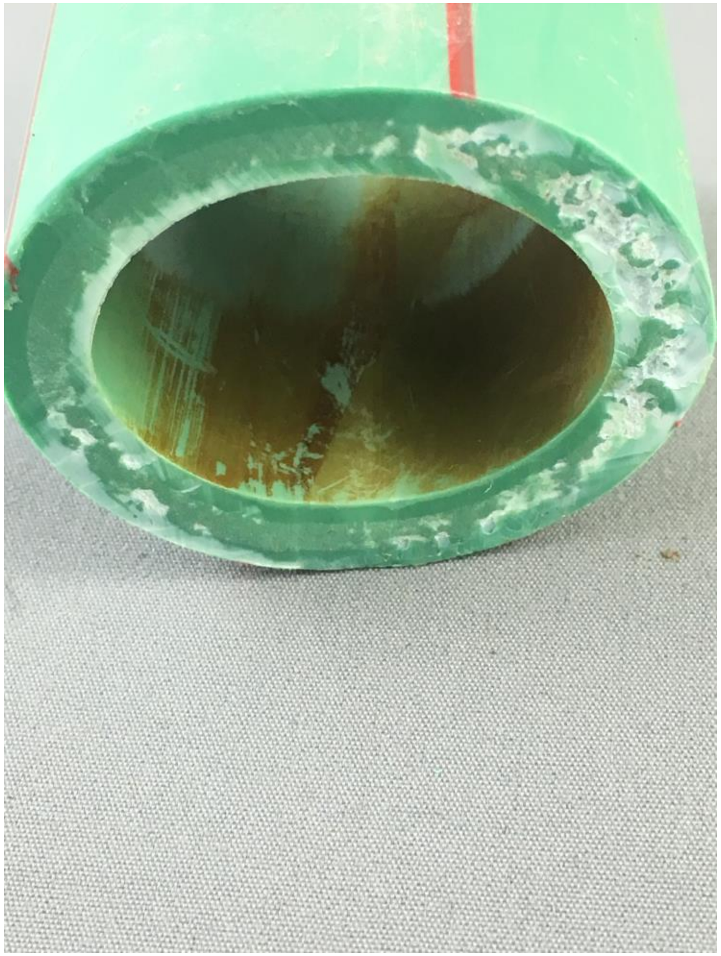


PPr Oxidation Crazing Crush Testing Fracture Propagation



PPr High Cu Content Film – No Oxidation Cracking





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Polyethylene (PE)

- Commonly used water network material
- HDPE (PE63 → PE80 → PE100) Practical use 1955 – 2019 ~ 60 years

Arrhenius **Reaction Rate = $Ae^{-E/RT}$**

E - Activation energy of reaction (50- 150 kJ/mol/K)
T – Absolute Temperature
R – Universal Gas Constant 8.3 J/mol/K

Critical Time l_n (critical time) = A/T + E

Predicts resistance to thermal oxidation

UL (Underwriters Laboratory USA) HDPE 50^{o} C Air 100,000 hours (about 11.4 years)

Rerate to 15^{o} C material temperature Lifetime → 119.7 years

Polyethylene (PE)

- Oxidation damage shows up as fine cracking/crazing on inside diameter of pipe
- Propagation of fine cracks through the pipe wall until burst occurs
- Shows up as brittle rupture several small cracks
- ISO 9080 long term stress/time regression curve point Stage III onset

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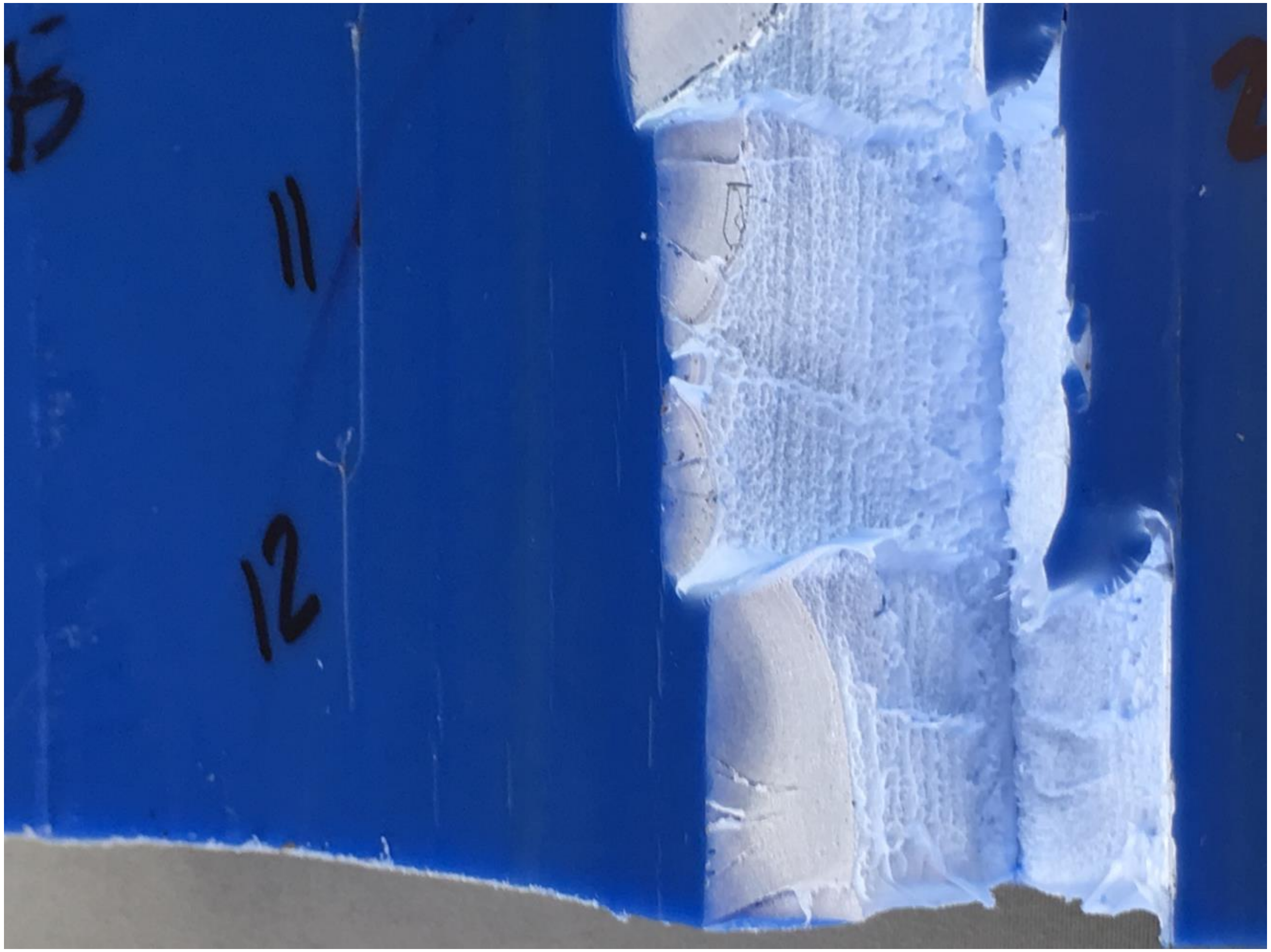
Polyethylene (PE)



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Polyethylene (PE)

- **Sporadic failures reported in water services**

- France – Change from Chlorine to Chlorine Dioxide Disinfection

- North Africa – High temperature, Uncertain pipe quality, Uncertain disinfection levels

- North West Australia/Far North Queensland – High soil temperatures, High water temperatures, Uncertain disinfection levels, Uncertain installation practices, Small diameter thin wall pipes

All These Factors Reduce Nominal Pipe Lifetimes

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Polyethylene (PE) Soil Temperatures

Location	Soil Temperature °C 0.3 – 1.0 metre depth Annual average BOM
Adelaide/Perth/Melbourne Sydney/Brisbane	< 21
Mt Isa/Katherine/Tennant Ck	27 – 30
Port Headland*	30 – 33

- **Reported failures (all causes) > 20 bursts(leaks)/100 Km pipe***
- **No reported failures**

* CEED Seminar 2017

Location	Soil Temperature 100 mm NIWA Mean monthly ºC	Soil Temperature 100 mm NIWA Year average ºC
Dunedin	10 – 20	10.0
Christchurch	4 – 18	10.6
Palmerston North	7 – 18	12.8
Auckland	10 – 20	15.1
Kaitia	11 - 20	15.2

Anticipated that the 2020 Revision of AS/NZS 2033 – Installation of PE Pipeline Systems; will include Temperature/Lifetime values for PE80 and PE 100 materials

Disinfection/Oxidation Stabilisation

- 2 types of anti-oxidation stabilisation

 * High temperature (200 ^{o}C) for short term processing

* Lower temperature for long term leaching/depletion during service lifetime

Disinfection Stabilisation USA Approach

Immerse PE Pipe Specimens in recirculating water at 20°C with replenished Chlorine level at 4 mg/l and ORP of 800 mV.

ASTM F 2263:2014 Method of Test

Establishes rupture stress/time points to categorise materials

Test results classified against ASTM D3350:2014 – Standard Specification for PE Plastics Pipes and Fittings Materials

Class CC1 Base resin (existing PE100 AS/NZS 4131)

Class CC2 Higher oxidative resistance

Class CC3 Highest oxidative resistance

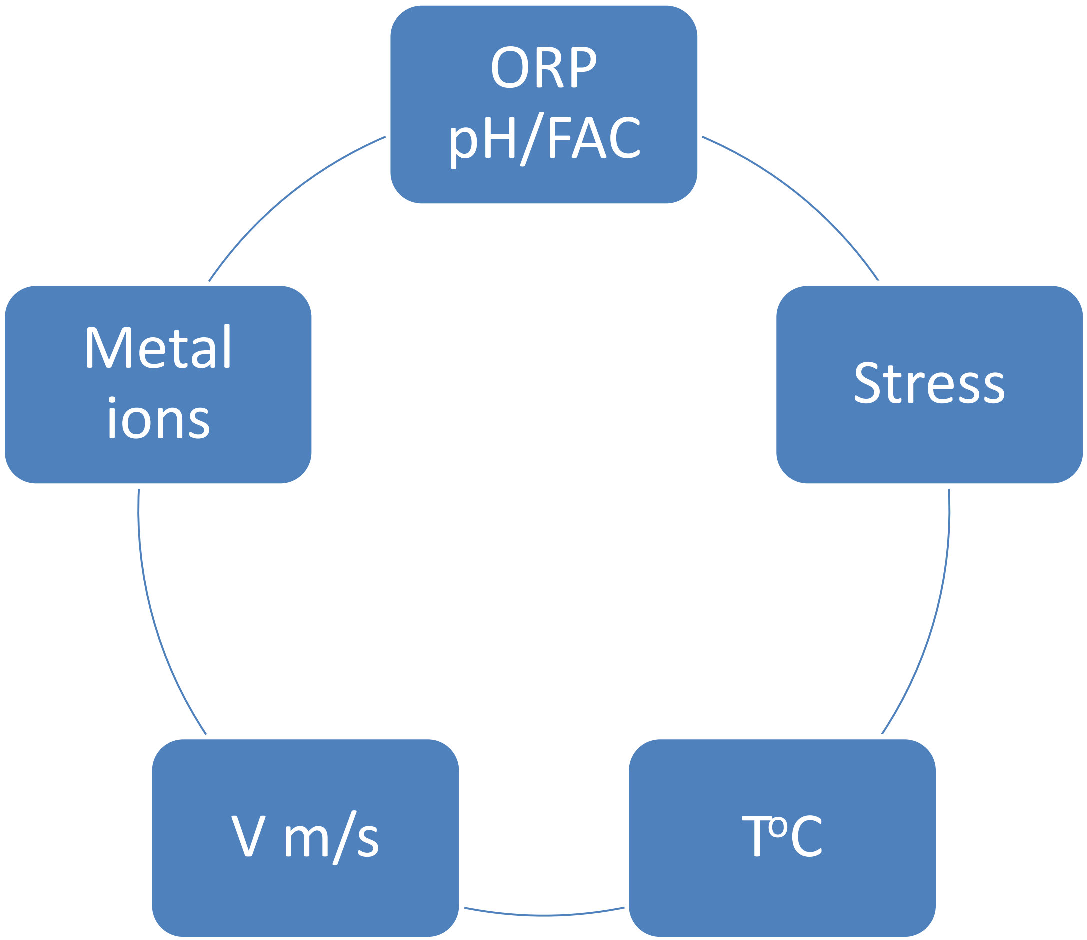
Designed for small diameter/thin wall pipes operating in high temperature/high disinfection (Chlorine/Chloramine) content applications

Debate exists as to Chlorine Dioxide application due to possible damage to polymer chains

Recommendations PIPA/PPI USA to not use Chlorine Dioxide as a disinfectant*

***PIPA POP 018, PPI TN44 - 2015**

Oxidative performance needs combination of all inputs



Thank you

Welcome any questions

Will be at Stand 165 over Expo