

# FIBER REINFORCED PLASTIC (FRP) FORUM & EXPO

Non Metallic Application Challenges and Solutions.

## Rupture of NaOCl FRP Pipe

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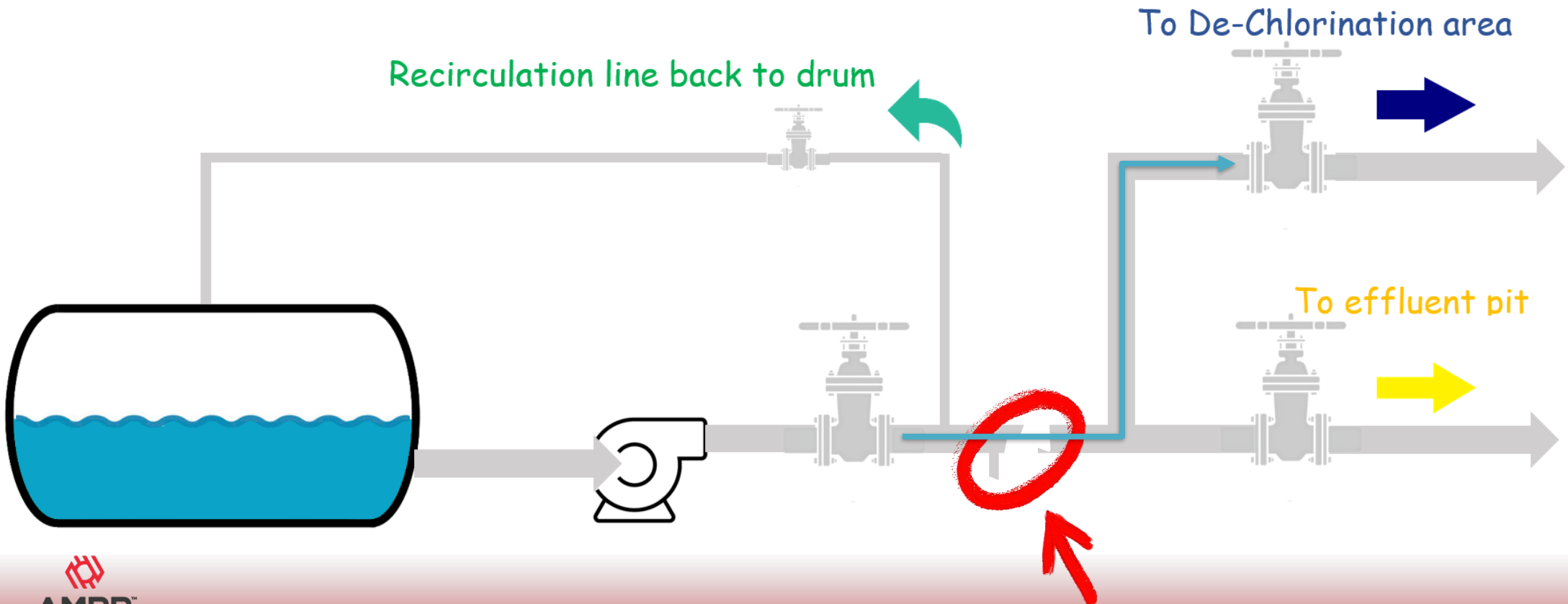
# Introduction

A 3" FRP pipe got ruptured after 10 years of service and while the system was isolated, and the pump in the system was offline. Investigation on the system and comprehensive lab experiments were performed on failed pipe to identify the failure mode and determine the probable causes of such severe damage and decide the forward plan.



## Process Description

- Waste Chlorine gas from all over plant is sucked in header and Chlorine is scrubbed with 18% Caustic Soda solution to neutralize it and this process produced Sodium Hypochlorite (NaOCl).
- As there is no market for Sodium Hypochlorite in KSA, the produced NaOCl is recycled back to Brine by acidifying it to release absorbed Chlorine gas to Chlorine gas header and NaCl to anolyte tank.
- This FRP pipe is designed to transfer Sodium Hypochlorite (NaOCl) solution stored in the drum to Brine de-chlorination area.
- This system is run on a weekly basis, once the drum level exceeds a certain level, the system will run.



# History



The pipe fixed and  
commissioned in  
2013

After 10 years



The rupture happened in May 2023

# Pipe Specification & Parameters

Design specification	
Type of composite	Fiberglass reinforced polymer (FRP)
Manufacturing type	Lamination, fabricated under slight vacuum
Polymer Type	Vinyl ester Resin
Governing Standard	DIN 16965 (UP-GF), Type E

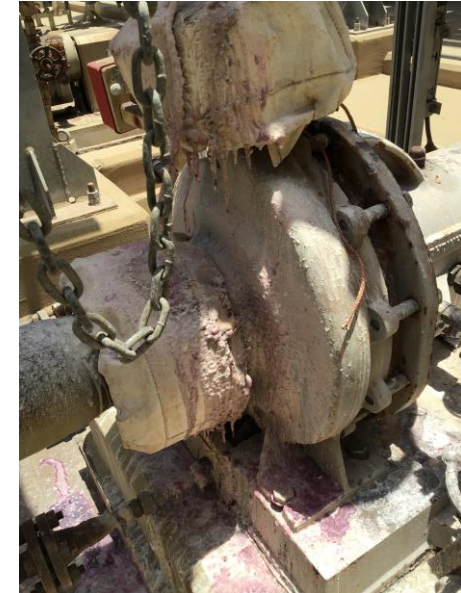
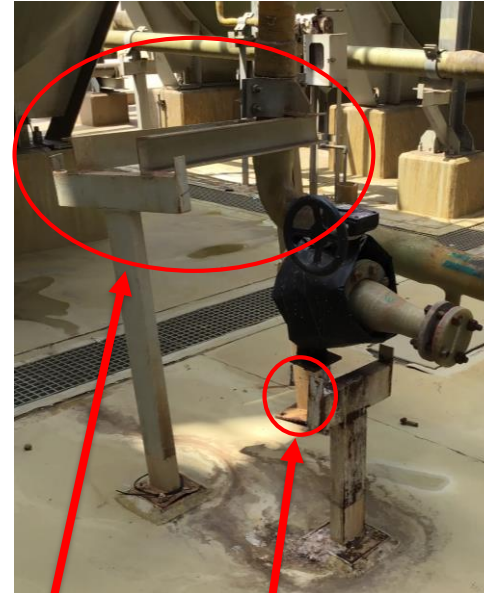
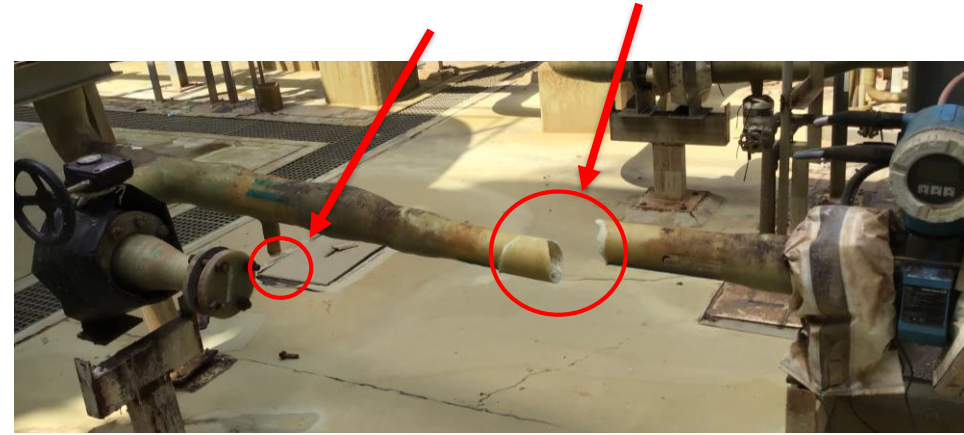
Process parameters		
Design	Pressure	9 bar
	temperature	70 C
Operating	Pressure	4-6 bar
	temperature	20 C
Process flow	Naocl + H <sub>2</sub> O	



# Initial Inspection Findings

## Inspection Findings:

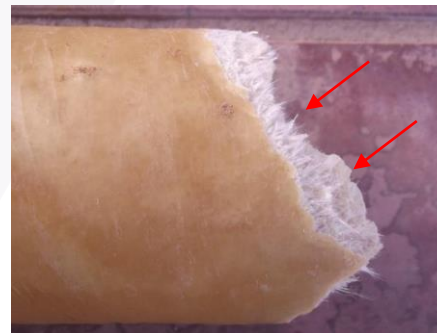
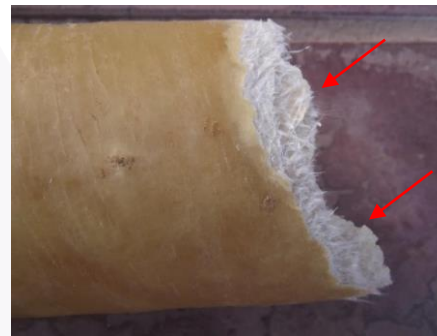
- The main 3" FRP pipe was found de attached.
- The LPD valve was broken from the drain nipple.
- The pipe and support were found dislocated from its position.
- Pipe shoe supports were dislocation from original place on pipe rake.



# Lap Analysis - Visual Examination

## Observations:

- Swelling of the pipe visually apparent.
- fracture face exhibited exposed fibers.
- White and brown scales were observed in the ID surface in 6 clock direction.

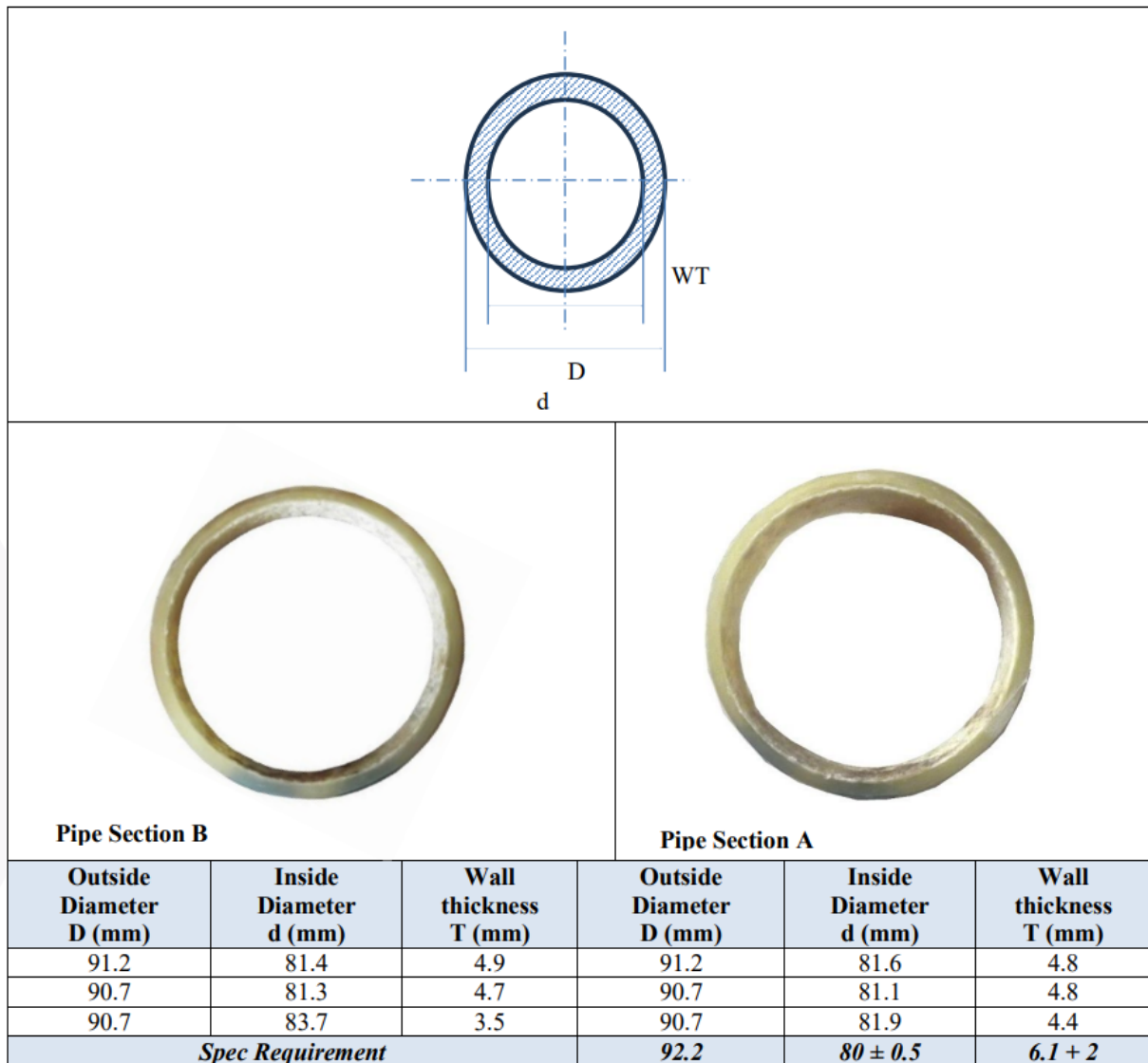
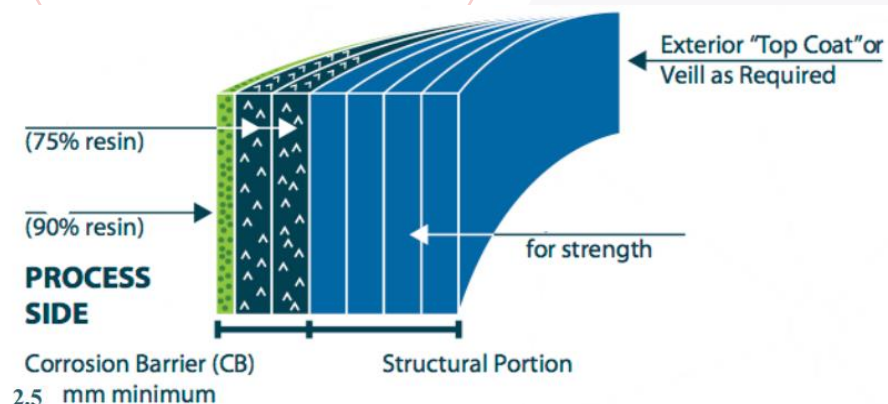




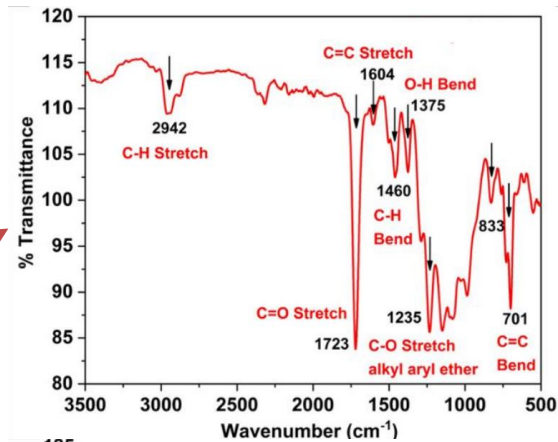
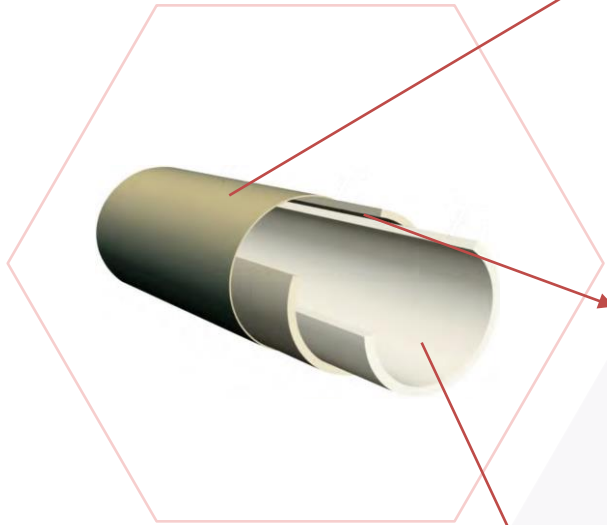
# Lap Analysis - Dimensional Measurements

## Findings:

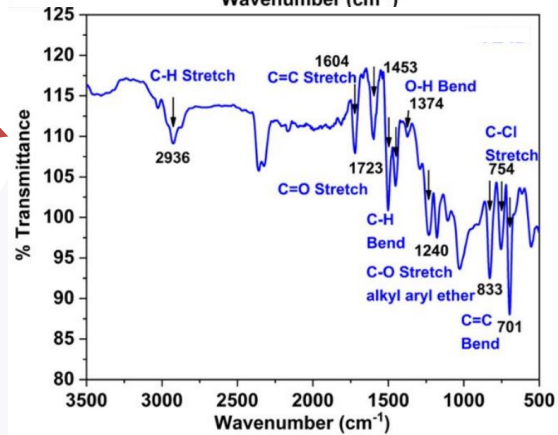
- A significant thickness reduction from the pipe interior.
- DIN-16965-5 specifies minimum thickness of internal corrosion barrier to be 2.5mm.
- The thickness reduction of 2.6mm implied that the corrosion barrier was compromised in the failed pipe sample.



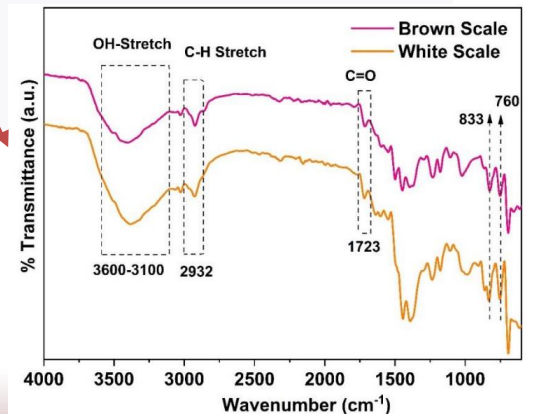
# Lap Analysis - Fourier Transformation Infrared Spectroscopy (FTIR)



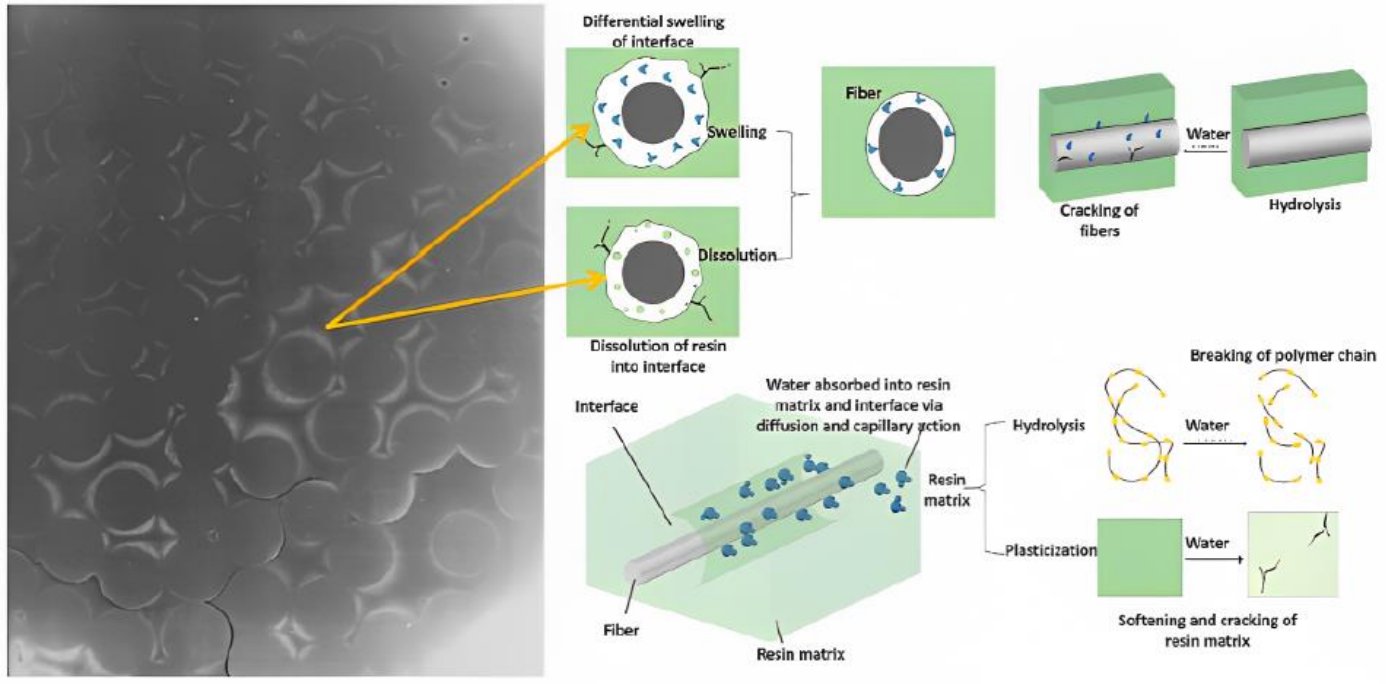
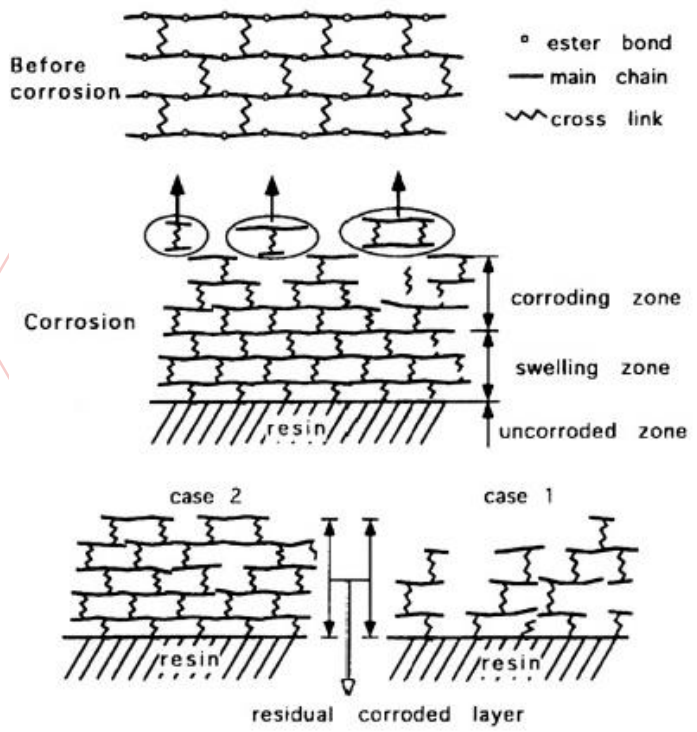
Pipe OD		
Functional Group	Wavenumber (cm <sup>-1</sup> )	Transmittance (%)
C-H Stretch	2942	109
C=O Stretch	1723	83
C=C Stretch	1604	108
C-H Bend	1460	102
O-H Bend	1375	103
C-O Stretch Alkyl aryl ether	1235	85
C=C Bend	701	88
C-Cl Stretch	-	-



Pipe ID		
Functional Group	Wavenumber (cm <sup>-1</sup> )	Transmittance (%)
C-H Stretch	2936	109
C=O Stretch	1723	107
C=C Stretch	1604	110
C-H Bend	1453	104
O-H Bend	1374	109
C-O Stretch Alkyl aryl ether	1240	98
C=C Bend	701	93
C-Cl Stretch	754	96



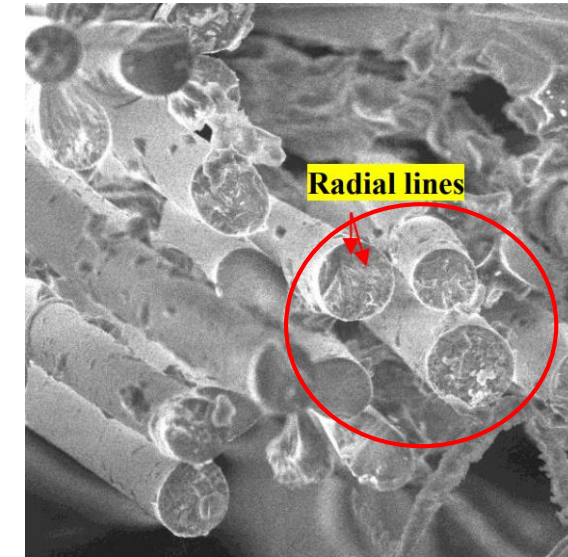
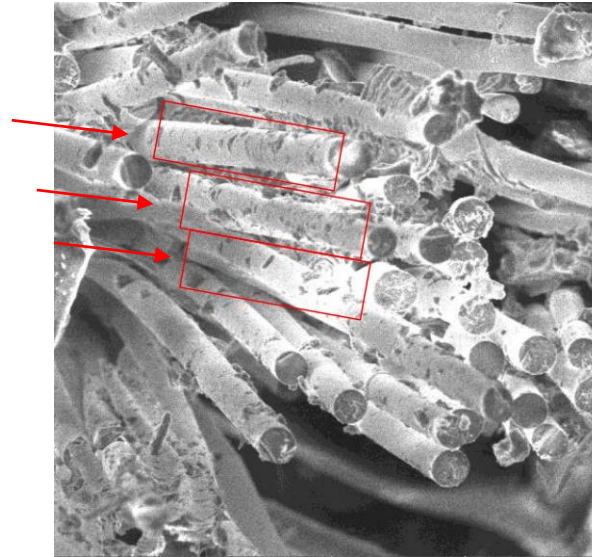
# Lap Analysis - Corrosion and Degradation Process



# Lap Analysis - SEM/EDS Analysis

## Scanning electron microscope (SEM) of the fracture face

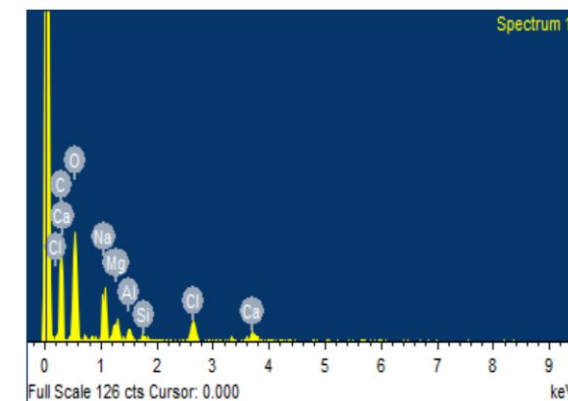
- Remnants of polymer matrix on the fiber surface.
- The presence of radial marks suggested a failure in tension.
- It appears that fibril like failure occurred.



## Energy Dispersive Spectroscopy (EDS) of the scales deposit noted on the inner surface

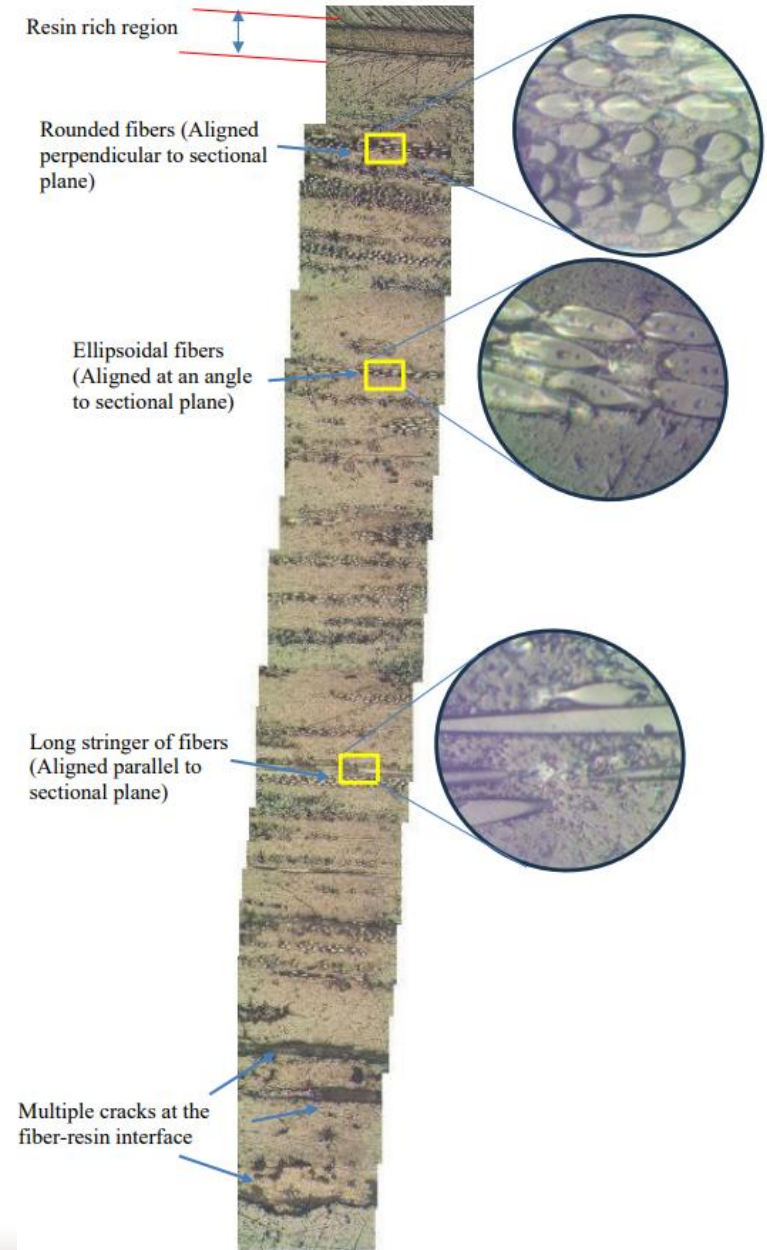
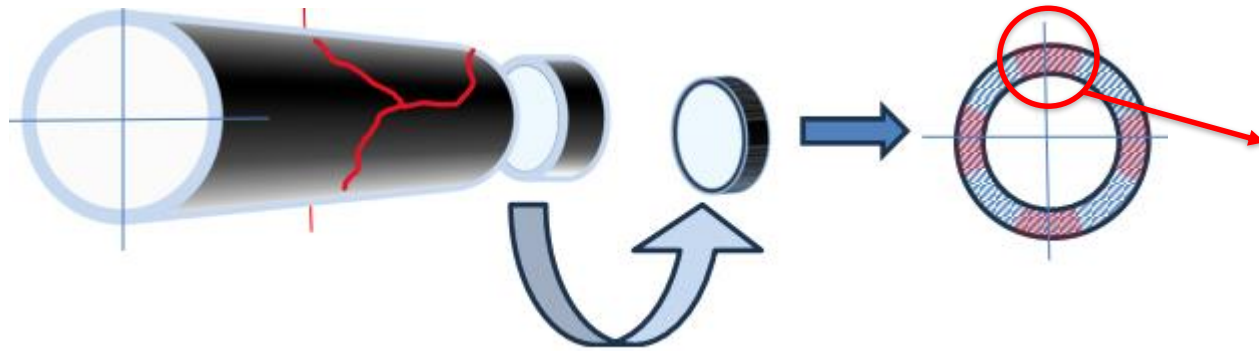
- Carbon (C) and Oxygen (O) as the major constituents of the scale which confirms the organic nature of the scale.
- Calcium (Ca), Magnesium (Mg) are most likely due to presence of dissolved salts within the water in sodium hypochlorite solution.

Element	Weight (%)	Atomic (%)
C	37.95	49.52
O	37.97	37.19
Na	9.02	6.15
Mg	2.06	1.33
Al	1.88	1.09
Si	0.41	0.23
Cl	6.01	2.66
Ca	4.70	1.84
<b>Total</b>	<b>100</b>	





# Lap Analysis - Micro Examination



Process side

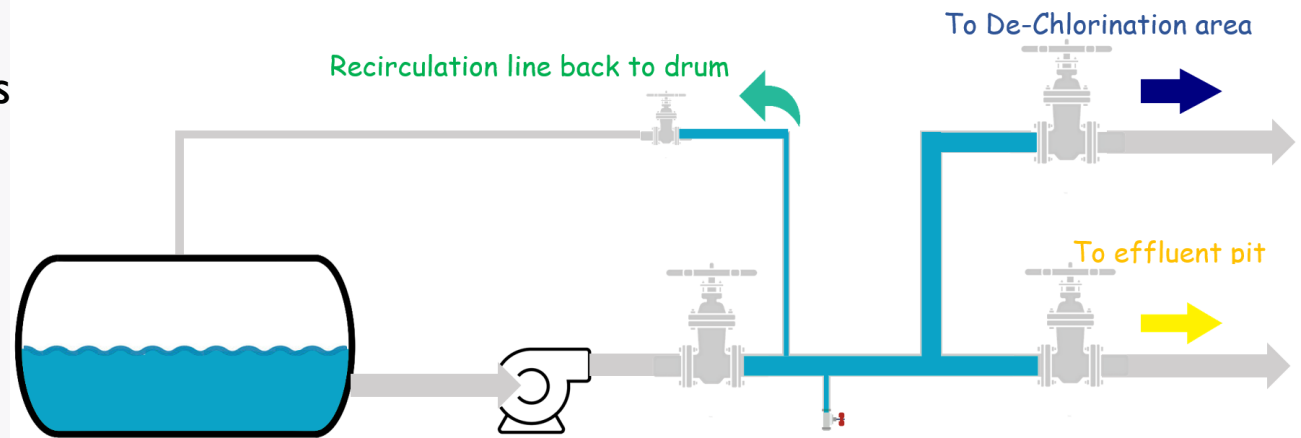
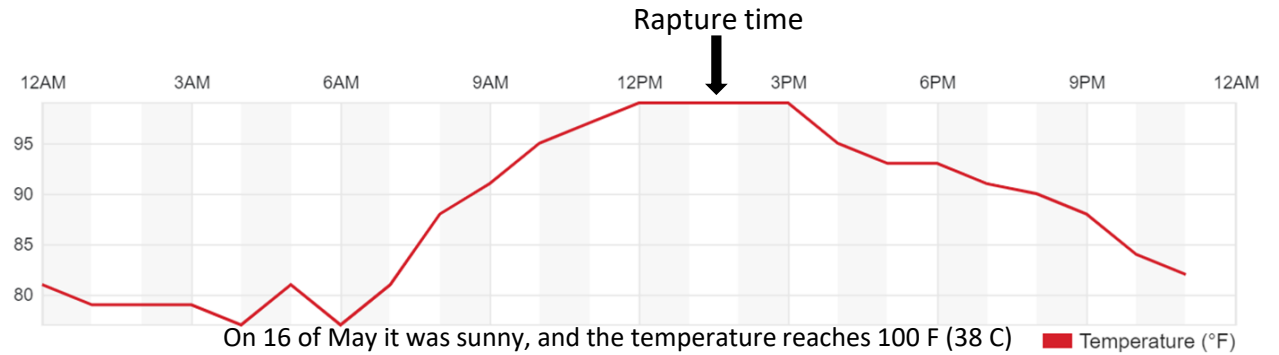
# The Investigation

## Process Findings:

- Sodium Hypochlorite solution is pressurized and releases chlorine gas when heated above 35C.
- The temperature in the day of accident was 38C

## Operational Findings:

- The system was offline while process residues kept without flushing.
- All the valves in the system were kept in closed condition even the recirculation line valve.



The process was kept in the system without venting!

# The Investigation

## Investigation outcomes:

### Direct cause

- **Keeping the recirculation line valve in close condition (without venting).**

### Root cause

- **SOP doesn't designate keeping the system venting in idle condition.**

### Contributing cause

- **No integrity management program for the piping in the unit.**

## Discussion

### The Investigation on the System

- The process pressurized and releases cl gas when heated above 35C, and the temperature on the day of rupture reaches 38C.
- Recirculation line valve was in close condition.

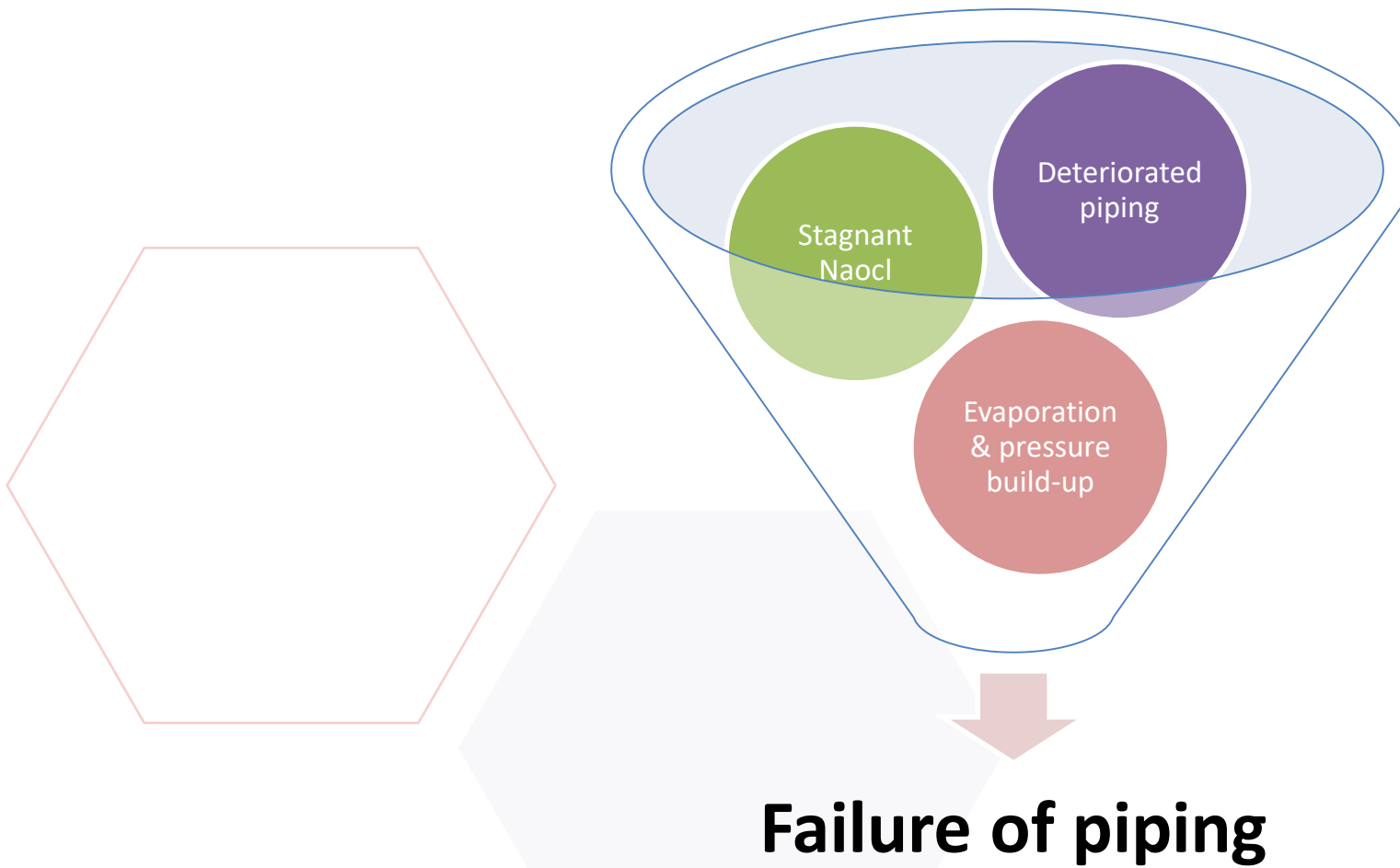
### Lap Analysis Results

- **Visual Examination:** High absorption of water.
- **Dimensional Measurements:** Reduction of the pipe thickness.
- **FTIR:** Pipe ID got deteriorated.
- **EDS:** The organic nature of the scale.
- **SEM:** The failure happened in brittle fracture.
- **Micro Examination:** Multiple cracks in the resin matrix.

Failure



# Conclusion



## Failure of piping

Sodium hypochlorite solution is high corrosive process and it's pressurized when heated. And the process was kept in the system without venting while the weather temperature heating the process, so the pressure bulled up, and the failure happened. And since the corrosion barrier was compromised in the pipe with the time, so that accelerate the failure.

# Mitigations

- Revise the SOP to include a clause that ensures venting the system in Idle condition.
- Adding a line to the system and include PSV with a rupture disk as a safety precaution.
- Establish PM for the unit piping for integrity management.
- Developing Ultrasonic based NDT techniques to assess the condition of internal corrosion barrier for the piping.