Treating Intermittent High-Strength Sludge Thickening Emissions Using Catalytic Iron Filtration

A Full-Scale Australian Case Study

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Background

- Melbourne Water's Eastern Treatment Plant (1975)
  - 400 ML/d (Ave) / 1700 ML/d (Peak)
  - 50% of Melbourne's sewage
- Anaerobic Digesters (8 no.) – hydraulic capacity limitations
- Install Rotary Drum Thickeners (RDTs) to increase the hydraulic capacity
- H_2S, reduced sulphur compounds, ammonia, VOCs generated from digestion process
- Intermittent operation: weekdays only, no night-time or weekend operation
- Anaerobic digestion produces very high H_2S and Odour concentrations within the emitted gases
- Odour control facility required to extract and treat these gases from the RDTs

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The Treatment Challenge

- Significant Odour nuisance potential and OHS risks (H_2S)
- Inlet H_2S design basis (based on vent rate):
  - 885 ppm (ave) / 3450 ppm
- OCF discharges had to avoid odour nuisance / OHS impacts:
  - H_2S <0.1 ppm / Odour <500 OU
- Significant challenges to the OCF:
  - Rapid changes in contaminant loading – Not steady state
  - Produces repeated high-load conditions
  - Frequent shutdown & restart cycles

Parameter	Units	Design Basis
Airflow		
Stage 1 Airflow	m^3/h	525
Stage 2 Airflow	m^3/h	700
Inlet		
Average H_2S	ppm	885
Peak H_2S	ppm	3450
Average NH_3	ppm	0.2
Peak NH_3	ppm	0.6
Average VOC	ppm	7.1
Peak VOC	ppm	14.2
Discharge		
H_2S	ppm	<0.1
Odour	OU	<500

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Treatment Options

- Biological treatment
  - Highly variable load limitations / Low removal efficiencies
- Chemical scrubbing
  - High capital & operating cost
  - Hazardous chemicals
- Activated carbon adsorption
  - High operating cost / media replacement
- Thermal combustion
  - SO_2/Sox emissions and significant downstream treatment requirements
- Catalytic Iron Filtration (CIF)
  - Robust bulk H_2S removal / low operating cost / polishing stage required

➢ **Hybrid: CIF & Carbon polishing → Complementary treatment**

Why Catalytic Iron Filtration?

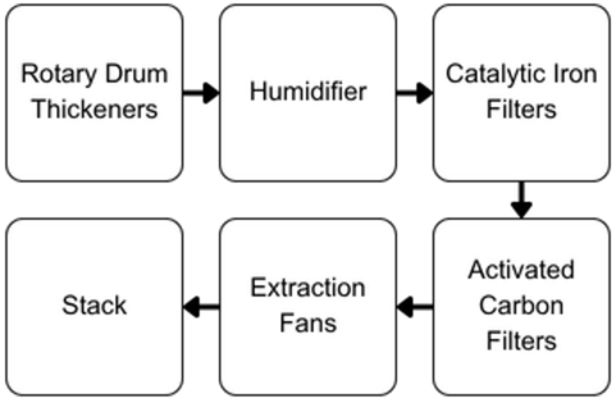
Technology selection was driven by the duty, not by a single contaminant concentration

- Bulk removal of very high H_2S concentrations
- Tolerance of discontinuous operation and rapidly changing loading
- No dependence on maintaining an active biological population
- No continuous chemical dosing or liquid chemical waste stream
- ➢ CIF Limitations (& why carbon based secondary treatment required):
  - CIF primarily targets H_2S – designed for bulk rather than polishing removal
  - Ammonia, VOCs, residual sulphur compounds and other pollutants require additional treatment
  - < 500 OU target to be achieved
- CIF substantially reduces H_2S load to downstream activated carbon polishing

Treatment configuration

A staged system: condition → bulk removal → polish

- Humidification maintains favourable conditions for the catalytic reaction
- Two CIF vessels in series provide bulk H_2S removal
- Pre-heater for relative humidity reduction prior to ACF
- Activated carbon removes residual sulphur compounds and VOCs
- Extraction fans discharge treated air via the stack



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How CIF works

Iron oxide-coated metallic Pall rings provide a regenerable reaction surface

- Under humid conditions, H_2S reacts with iron oxide to form iron sulphide and elemental sulphur
- In the presence of oxygen, iron sulphide is oxidised back towards iron oxide
- The catalytic surface is therefore regenerated during operation
- Sulphur accumulation ultimately limits media life, so periodic inspection and eventual media replacement remain necessary

How CIF works

Iron oxide-coated metallic Pall rings provide a regenerable reaction surface

1. Primary H_2S reaction

$Fe_2O_3{\cdot}xH_2O_{(s)} + 3H_2S_{(g)} \rightarrow 2FeS_{(s)} + 3H_2O_{(l)} + S_{(s)}$

2. Alternative Fe_2S_3 pathway

$Fe_2O_3{\cdot}xH_2O_{(s)} + 3H_2S_{(g)} \rightarrow Fe_2S_{3(s)} + 3H_2O_{(l)}$

$Fe_2S_{3(s)} \rightarrow 2FeS_{(s)} + S_{(s)}$

3. Oxidative regeneration

$4FeS_{(s)} + 3O_{2(g)} \rightarrow 2Fe_2O_{3(s)} + 4S_{(s)}$ + heat

$4FeS_{(s)} + 7O_{2(g)} \rightarrow 2Fe_2O_{3(s)} + 4SO_{2(g)}$ + heat (alternative oxidation pathway)

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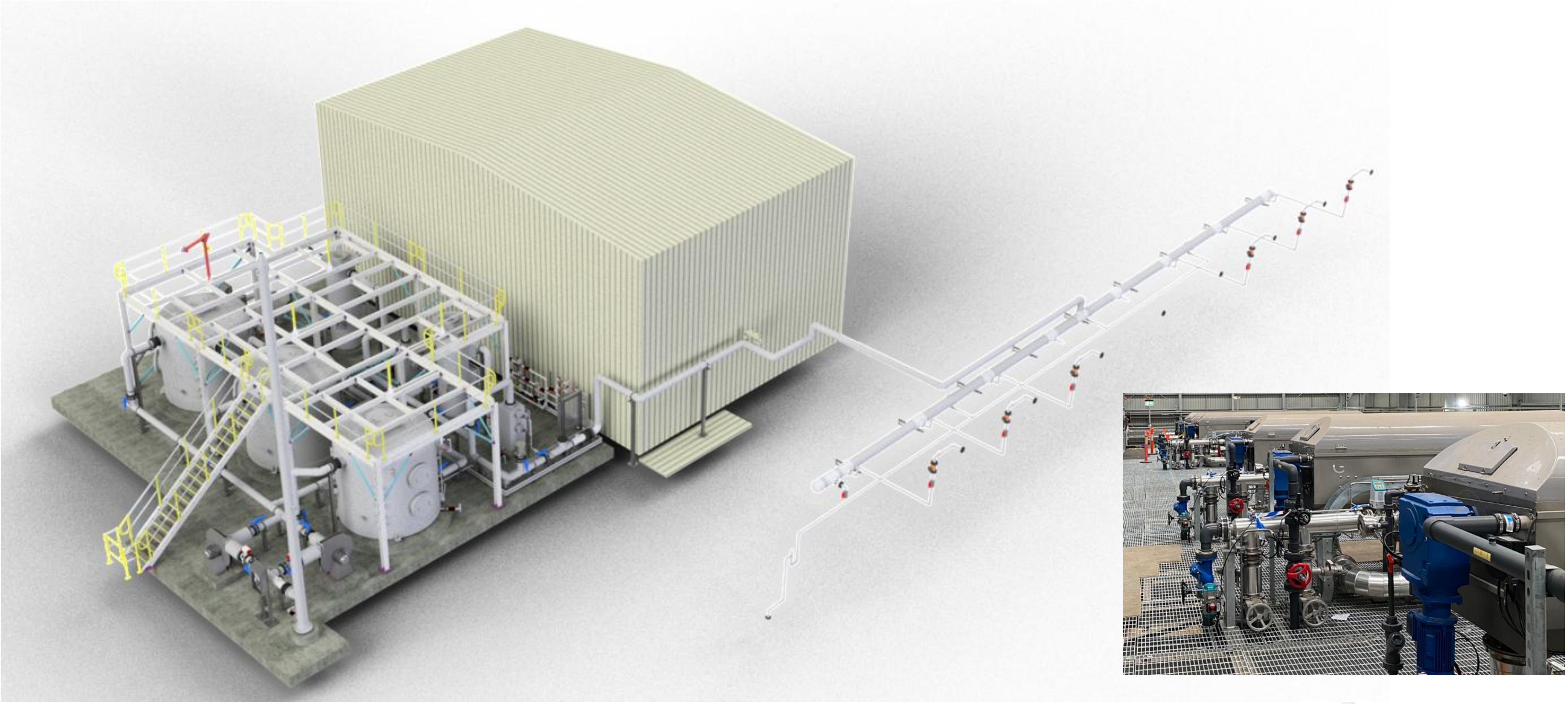

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Performance testing

Measured at inlet, CIF interstage and final discharge

- Calibrated H_2S instrumentation used across the treatment train
- NATA-accredited discrete H_2S and odour sampling
- Additional operational monitoring captured the variable RDT loading profile
- Testing assessed both contractual compliance and behaviour under cyclic operation

525 m^3/h
Average operating airflow

993 m^3/h
Maximum observed airflow

90–1,225 ppm
Operational inlet H_2S

Hydrogen Sulphide Performance

Bulk CIF removal followed by very high-efficiency polishing

54.6–74.1%	>99.99%	0.004–0.006 ppm
CIF removal during formal testing	Overall H_2S removal	Final outlet H_2S

- CIF exceeded the contractual ≥50% H_2S removal requirement
- The bulk removal stage substantially reduced loading to the activated carbon
- Final discharge performance remained well below the <0.1 ppm requirement

Odour performance

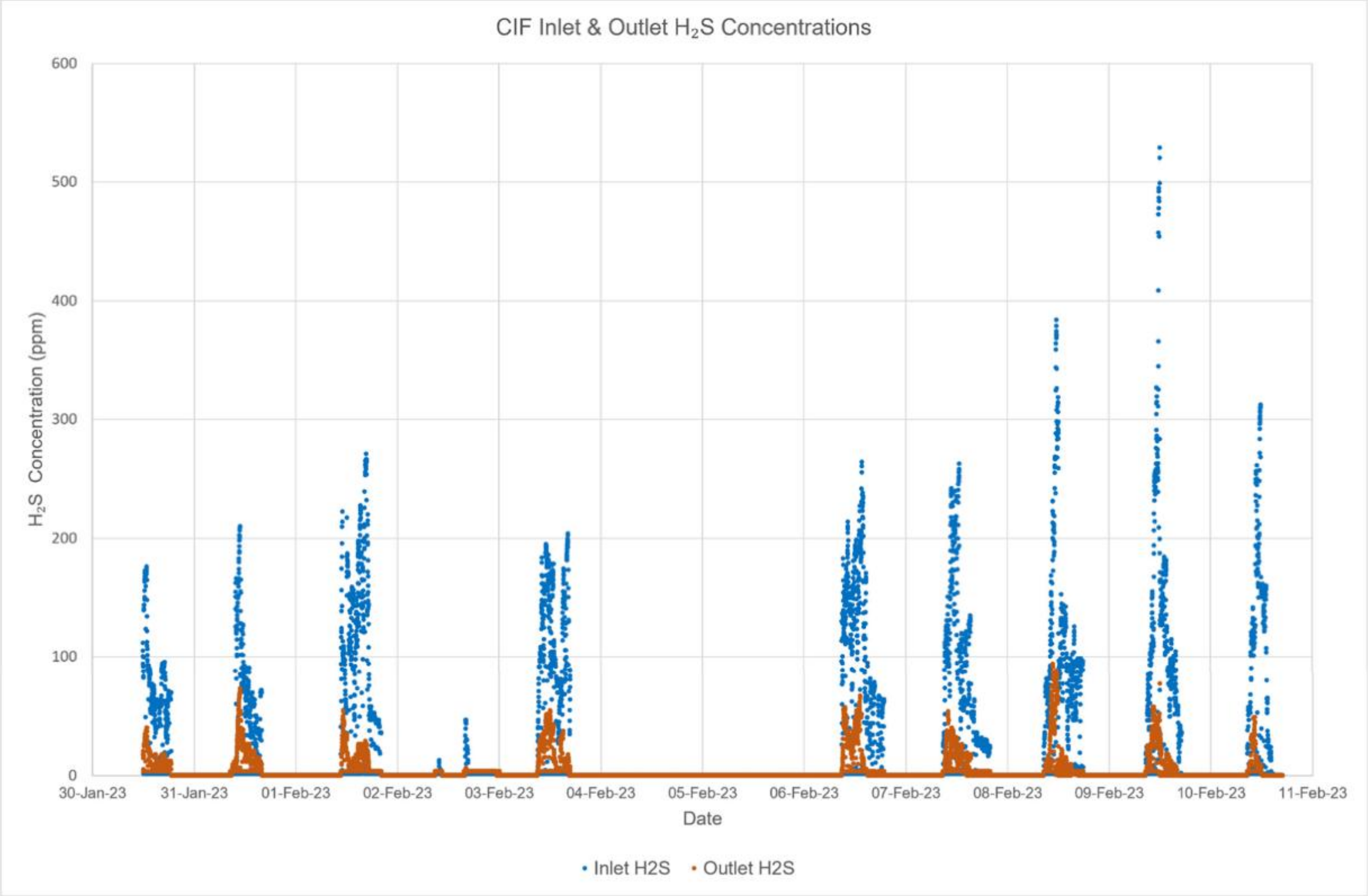
High inlet odour concentrations were reduced to near detection limits

150,000–360,000 OU Measured inlet odour	**<30–48 OU** Discharge odour	**99.98–99.99%** Overall odour removal

- Performance substantially exceeded the discharge criterion of <500 OU
- Results confirmed that the staged configuration addressed both H_2S and broader odour impacts

The Key Result: Resilience under Cyclic Loading

Repeated shutdown and restart without an observable recovery period



- Each cluster represents an RDT operating period
- Gaps represent shutdown/offline periods
- Inlet H_2S rises rapidly after restart
- CIF resumes effective removal immediately – no observable conditioning period

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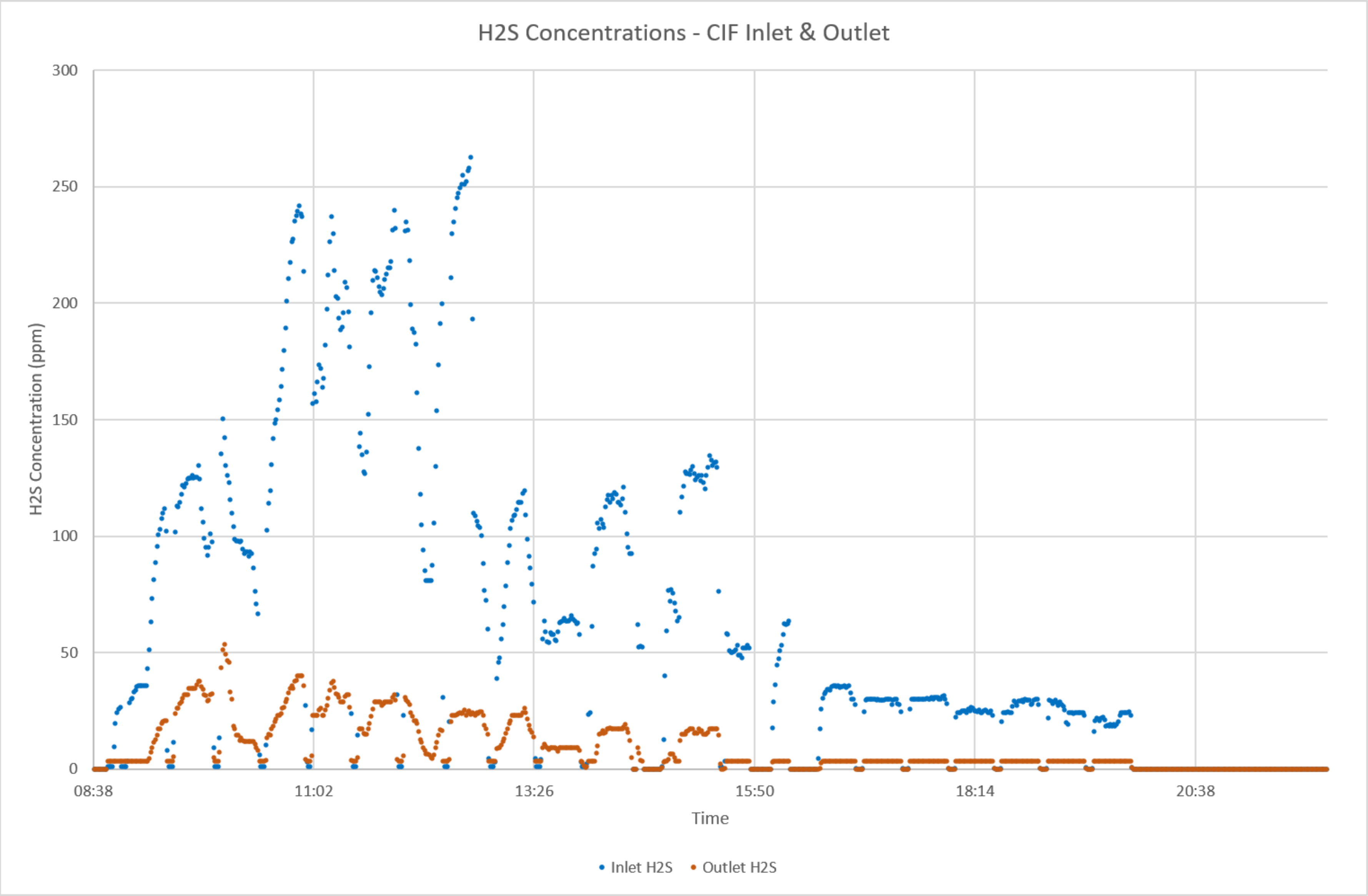

Other Compounds

Compound	CIF Inlet (mg/m^3)	CIF Outlet (mg/m^3)	CIF Removal Efficiency	Final OCF Outlet (mg/m^3)	Whole-Facility Removal
Methyl mercaptan	0.076 - 0.180	0.078 - 0.100	0% - 49.4%	<0.002	Below Detection
Ethyl mercaptan	0.016 - 0.034	0.014 - 0.018	0% - 58.8%	<0.003	Below Detection
Dimethyl sulphide	0.025 - 1.000	0.0030 - 0.0032	88% - 99.7%	<0.003	Below Detection
Total VOCs	5.2 - 8.9	4.9 - 8.0	5.8% - 10.1%	<0.3	Below Detection

Operational Insights

What changed once the system was operating

- Humidification:
    - Moisture entrained in the foul air reduced supplementary water demand
    - Too much moisture detrimental to H_2S removal process
- Activated carbon filter media protection:
    - CIF removed substantial H_2S load to carbon media
    - Carbon media design life was 6 months (worst case), but now significantly extended
- CIF media life:
    - Design life: 3.0 years first CIF vessel; 5.9 years second CIF
- Maintenance:
    - Monitor humidity
    - Pressure drop and sulphur/fouling
    - **Currently**: No CIF or carbon media replacement required after 3.5 years

Whole-of-life Operational Benefit

The staged configuration has reduced consumables and maintenance intervention

- First CIF vessel has exceeded its 3.0-year theoretical design life and remains in service
- Activated carbon had a nominal six-month design replacement interval; no replacement has been required to date
- Required outlet H_2S performance continues to be achieved
- **Result**: substantially reduced media replacement and maintenance requirements for Melbourne Water

>3.5 years
CIF 1 media still performing

>3.5 years
AC in service vs 6-month nominal

<0.1 ppm
Required outlet H_2S maintained

Conclusions

Three take-home messages

1. **Performance**
   CIF + activated carbon achieved >99.99% overall H_2S removal and very low final discharge concentrations.

2. **Resilience**
   CIF maintained effective treatment through repeated shutdown/restart cycles and highly variable H_2S loading.

3. **Whole-of-life value**
   Extended media service and low consumable requirements have delivered substantial operational benefits.

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Questions?

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