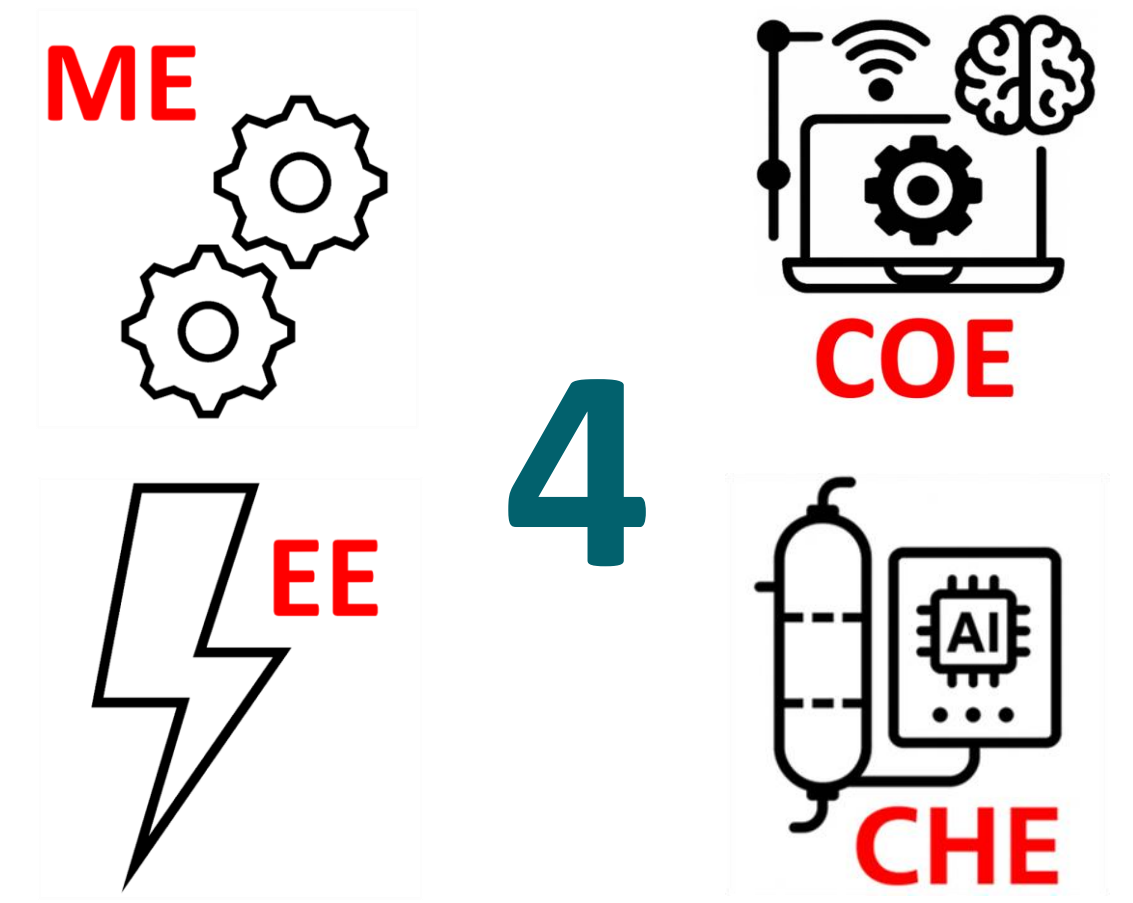


# Smart Modular Chemical Pre-Treatment unit with automated controls

Saud Alshowaiey, Ahmed Alaradi, Abdullah Alduaydi, Ibrahim Alharbi, Magad Suwikh, Majed Alghamdi  
Coach: Dr. Youdong Cheng



## Background

- Treats industrial spent caustic soda to remove toxic pollutants.
- Eliminates H<sub>2</sub>S gas releases that cause safety and operational bottlenecks.
- Integrates an automated scrubber and MOF-based polishing for real-time gas management.

## Problem Statement

- Conventional units are too slow and lack the automation needed for sudden gas surges.
- A modular unit is required to couple liquid neutralization with a fast and highly efficiency gas treatment system.

## Constraints

- MEWA/RCJY (pH 6–9)
- sulfide < 5 mg/L)
- Max 2.5 m × 2.5 m footprint
- Analog pH/ORP (0–5V)
- Corrosion/fatigue-resistant materials
- Total cost ≤ 12,000 SAR
- Open-source/Educational license
- ≤ 70% ESP32 Flash/RAM
- Output gas < 5 ppm H<sub>2</sub>S

## Specifications

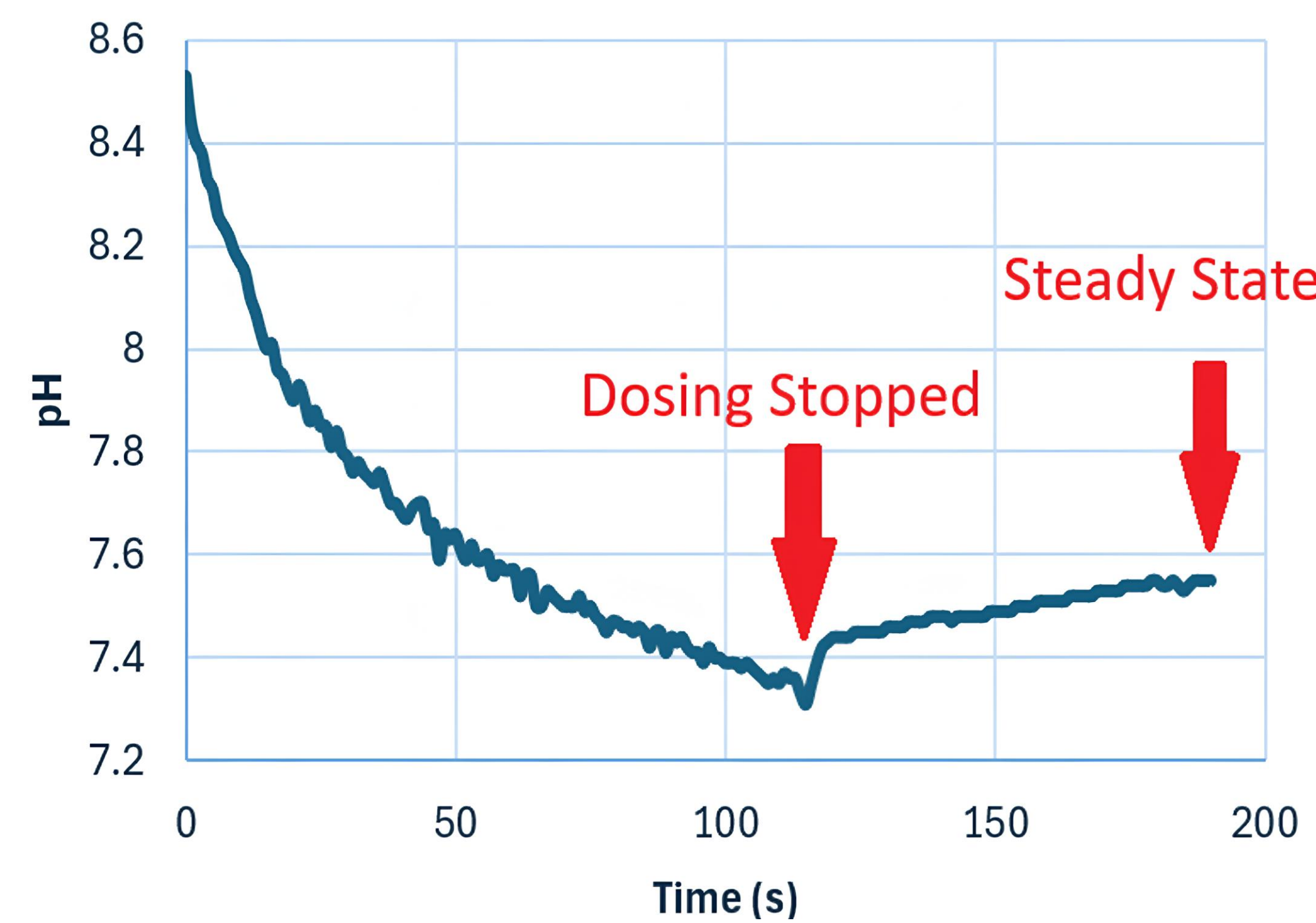
- ≥ 80% removal (100–1000 mg/L)
- 6.0–9.0 pH stable
- Setup/disassembly ≤ 2 hours
- ≤ 40 kg mass , ≤ 80 Wh batch
- ± 0.6 pH ± 30 mV ORP accuracy
- 24-hr+ onboard CSV storage
- Dashboard refresh ≤ 1s , Actions ≤ 1s

## Integrated Specifications

- Signal processing; < 5 s
- Shutdown ≤ 2 s (Gas/pH triggers)
- Watchdog fault recovery ≤ 6 s
- Chemical consumption reduced ≥ 20%

## Testing & Validation

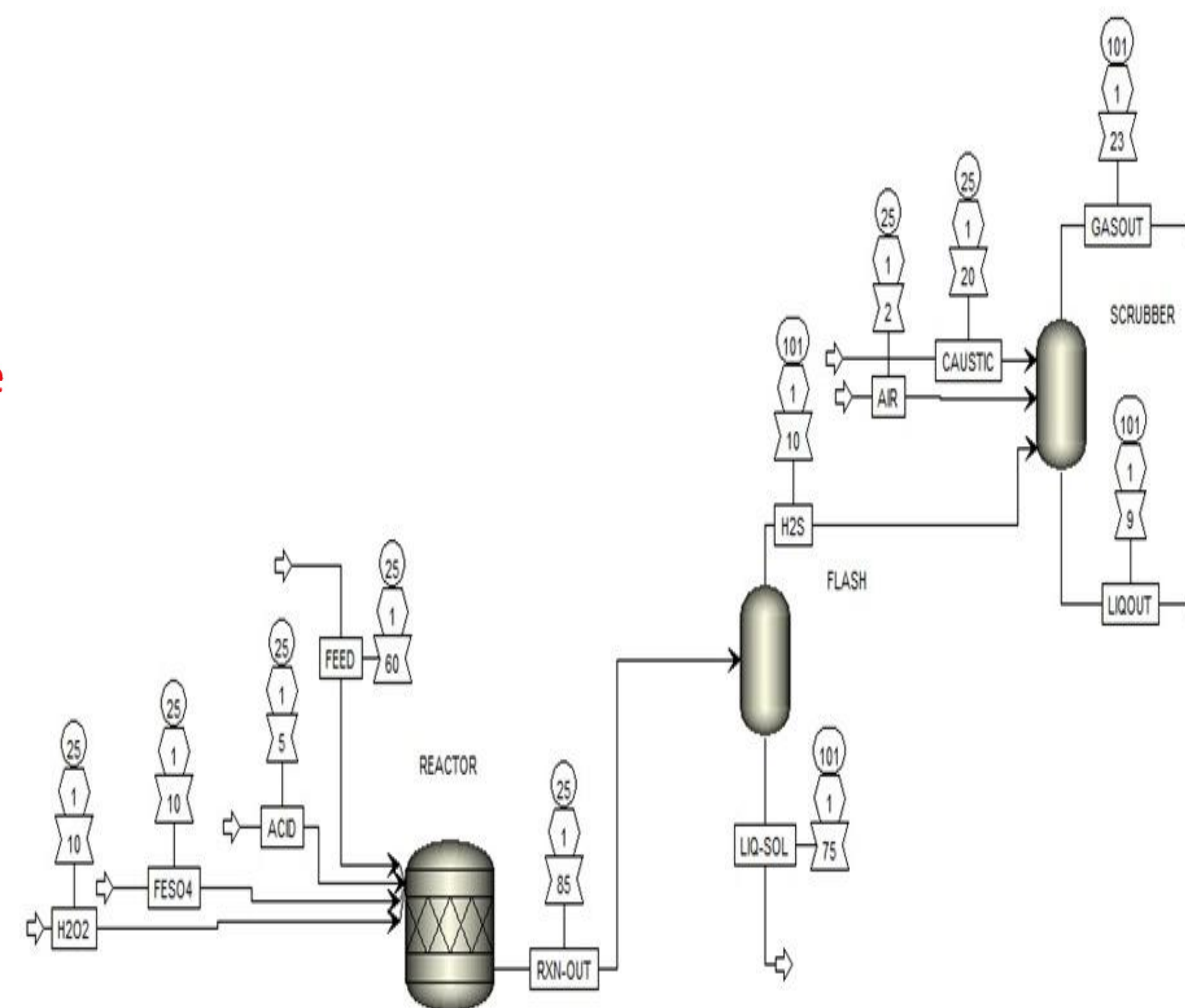
pH vs Time



## System Concept



## Flow Diagram



## Conclusion

- Met all effluent standards by maintaining pH 6–9 and sulfide < 5 mg/L.
- Ensured outlet H<sub>2</sub>S remained below 5 ppm assisted by the MOF-polishing stage.
- Reduced chemical consumption compared to manual systems through automated dosing.
- Validated a portable, automated solution for treating high-caustic industrial wastewater.

## Innovation

### TPMS-Based Structured Polishing Scaffold for H<sub>2</sub>S Vent Control

- PETG gyroid TPMS**: 3D-printed cylindrical insert
- High connectivity**: Continuous interconnected channels. Improves distribution and gas-surface contact.
- CFD-based flow performance**: V<sub>sup</sub> = 1.63 m/s, V<sub>int</sub> = 3.18 m/s, ΔP ≈ 0.34 kPa. Low pressure penalty with distributed gas passage.
- Mechanical suitability**: E = 46.72 MPa, G = 17.84 MPa, K = 31.73 MPa. Supports handling and prototype mounting.
- Thermal suitability**: PETG suitable for ambient to mildly elevated operation. Appropriate for prototype scrubber-top integration.
- Near-isotropic response**: Z = 0.958, AU = 0.0336. Indicates uniform structural response.
- Residence-time limitation**: τ ≈ 0.0126 s. Best used as a polishing scaffold rather than a standalone capture bed.

Used as a structured polishing scaffold within the CPT vent-treatment path, complementing the modular gas-capture concept.