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# Kinetic Control of Anaerobic Membrane Bioreactors and its Influence on Operating Parameters

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# Submerged Anaerobic Membrane Bioreactors (SAnMBR) for wastewater treatment

- total biomass retention
  - increase AD efficiency
- high effluent quality
- low sludge production
- potential net energy

- membrane fouling
  - lower flux
  - higher energy demand
- dissolved $CH_4$ in effluent
- high CAPEX and OPEX

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# Research aim

To evaluate the effect of MCRT on membrane fouling, biomass characteristics and overall performance of SAnMBRs when treating low strength wastewater at 20 $^{o}$C

# Experimental method

*Experimental Set-up*

| | |
|---|---|
| No. Reactors | Four gravitational SAnMBR |
| Duration | 242 days |
| Temperature | 20 °C |
| MCRT | 20, 30, 45, 60 and 90 days |
| TMP | Constant but adjusted to match membrane flux in all the reactors and thus OLR<br>TMP range = 1.5 – 9.8 kPa |
| Substrate | Synthetic:<br>• yeast → biosolids<br>• milk and dried blood → protein and fat<br>• sugar → readily utilisable soluble carbon<br>• Urea → organic nitrogen<br><br>Low-to-intermediate strength<br>(COD = 850 mg/L)<br><br>High Solids<br>(TSS ≈ 360 mg $L^{-1}$) |

# Gravitational SAnMBR

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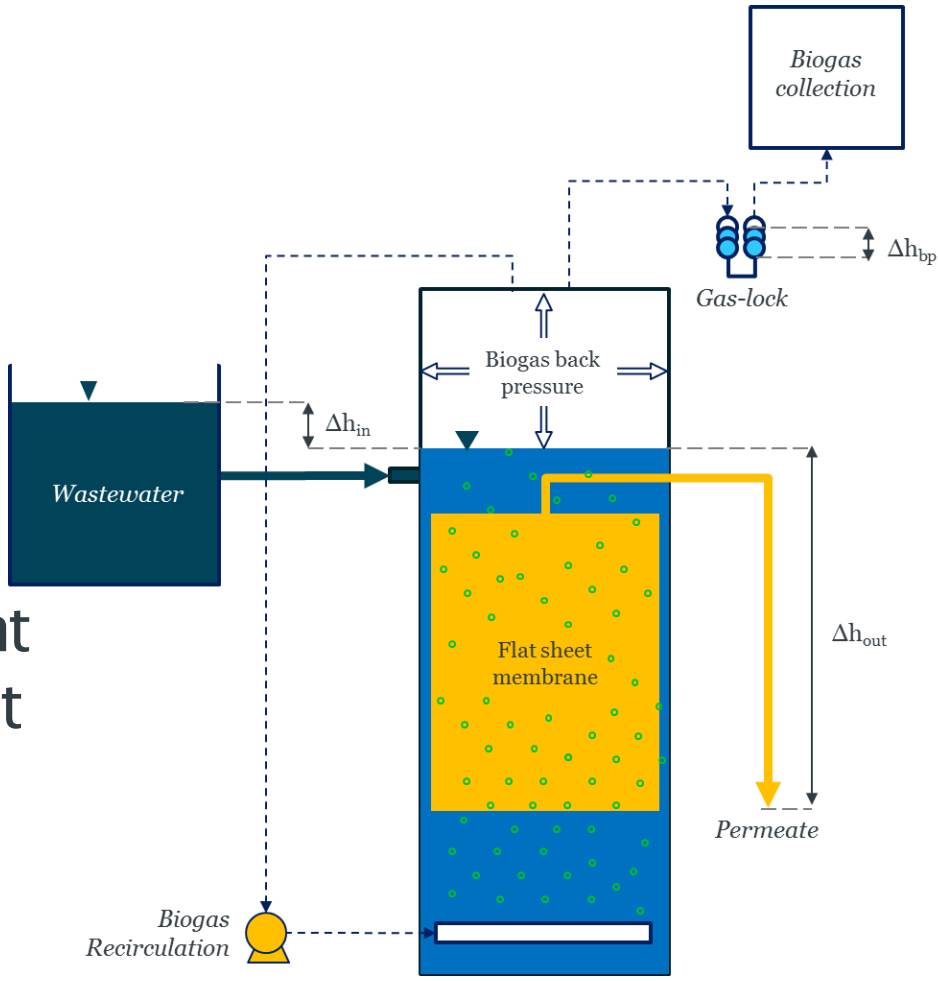
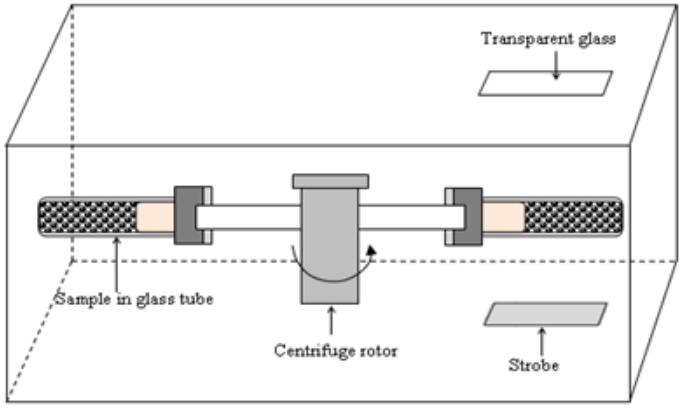
- Alternative to conventional pumped permeation
- Can apply a constant transmembrane pressure (TMP)
- Match the TMP to the target membrane flux
- Allows accurate measurement of membrane flux at constant TMP
- Potentially allows constant OLR by adjustment of hydrostatic head




*Gravitational SAnMBR configuration*

# Parameters monitored

- Membrane flux/TMP
- COD removal rates
- MLSS
- Specific Methane Production
- COD mass balances
- Mixed liquor characteristics:
  - Capillarity suction time (CST)
  - Frozen image centrifugation (FIC)
  - Extracellular polymeric substances*




FIC- Apparatus

CST - Apparatus

# Control of Mean Cell Residence Time (MCRT)

- Simple volumetric control by daily removal of MLSS

Volume of reactor = 10 litres

| MCRT | Daily volume wasted (ml) | % of reactor volume wasted |
|---|---|---|
| 20 | 500 | 5 |
| 30 | 333 | 3.3 |
| 45 | 222 | 2.2 |
| 60 | 166 | 1.67 |
| 90 | 111 | 1.1 |

# Results – *MCRT*

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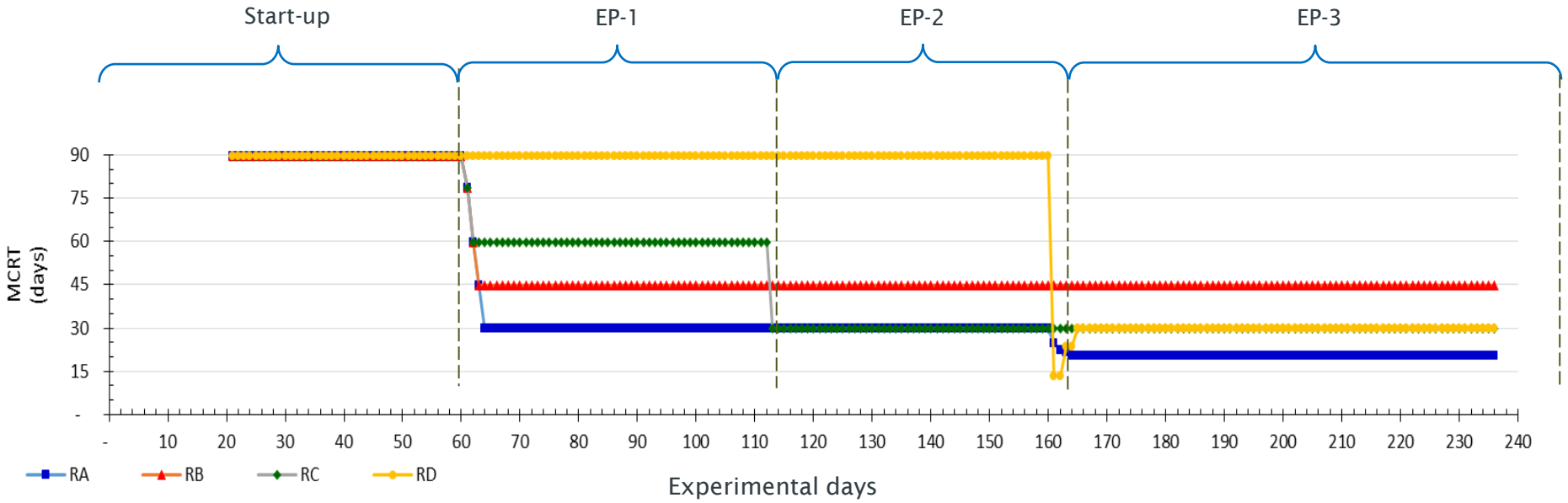


| MCRT (days) | Start-up | EP-1 | EP2 | EP-3 |
|---|---|---|---|---|
| Reactor A | 90 | 30 | 30 | 20 |
| Reactor B | 90 | 45 | 45 | 45 |
| Reactor C | 90 | 60 | 30 | 30 |
| Reactor D | 90 | 90 | 90 | 30 |

| MCRT (days) | Start-up | EP-1 | EP2 | EP-3 |
|---|---|---|---|---|
| Reactor A | 90 | 30 | 30 | 20 |
| Reactor B | 90 | 45 | 45 | 45 |
| Reactor C | 90 | 60 | 30 | 30 |
| Reactor D | 90 | 90 | 90 | 30 |

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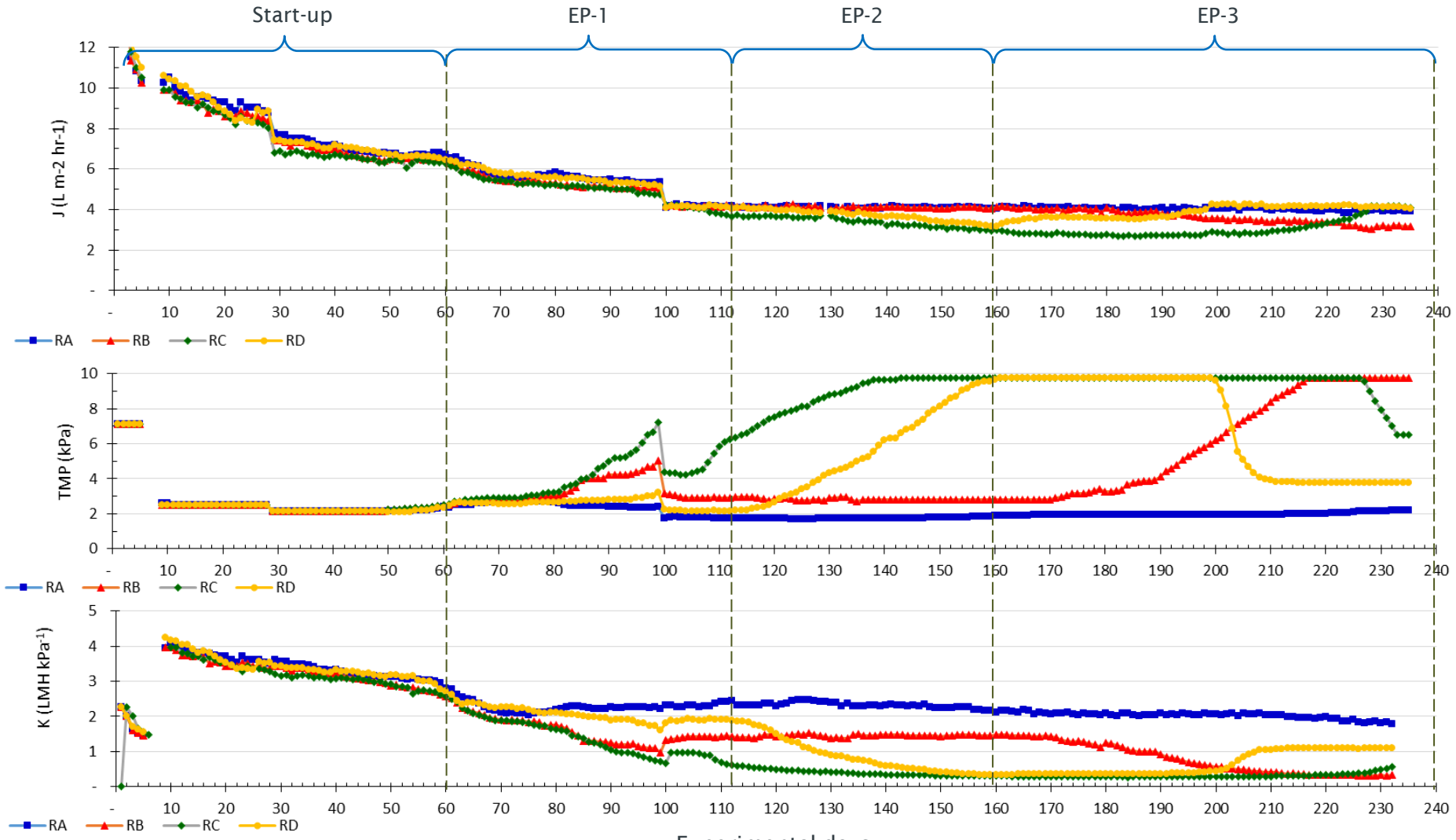
# Results – *Flux, TMP and Permeability*



| MCRT (days) | Start-up | EP-1 | EP2 | EP-3 |
|---|---|---|---|---|
| Reactor A | 90 | 30 | 30 | 20 |
| Reactor B | 90 | 45 | 45 | 45 |
| Reactor C | 90 | 60 | 30 | 30 |
| Reactor D | 90 | 90 | 90 | 30 |

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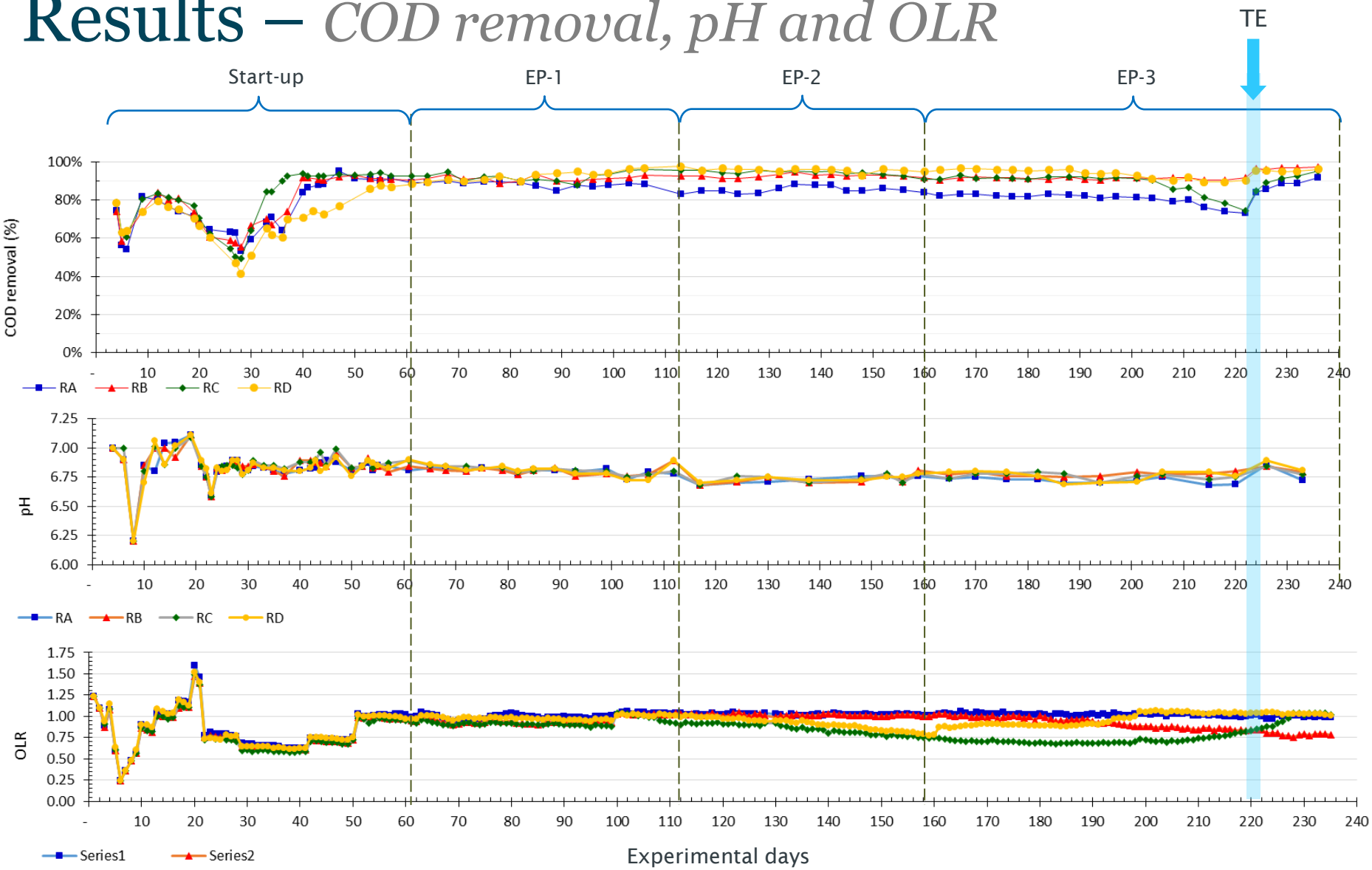
# Results – *COD removal, pH and OLR*



| MCRT (days) | Start-up | EP-1 | EP2 | EP-3 |
|---|---|---|---|---|
| Reactor A | 90 | 30 | 30 | 20 |
| Reactor B | 90 | 45 | 45 | 45 |
| Reactor C | 90 | 60 | 30 | 30 |
| Reactor D | 90 | 90 | 90 | 30 |

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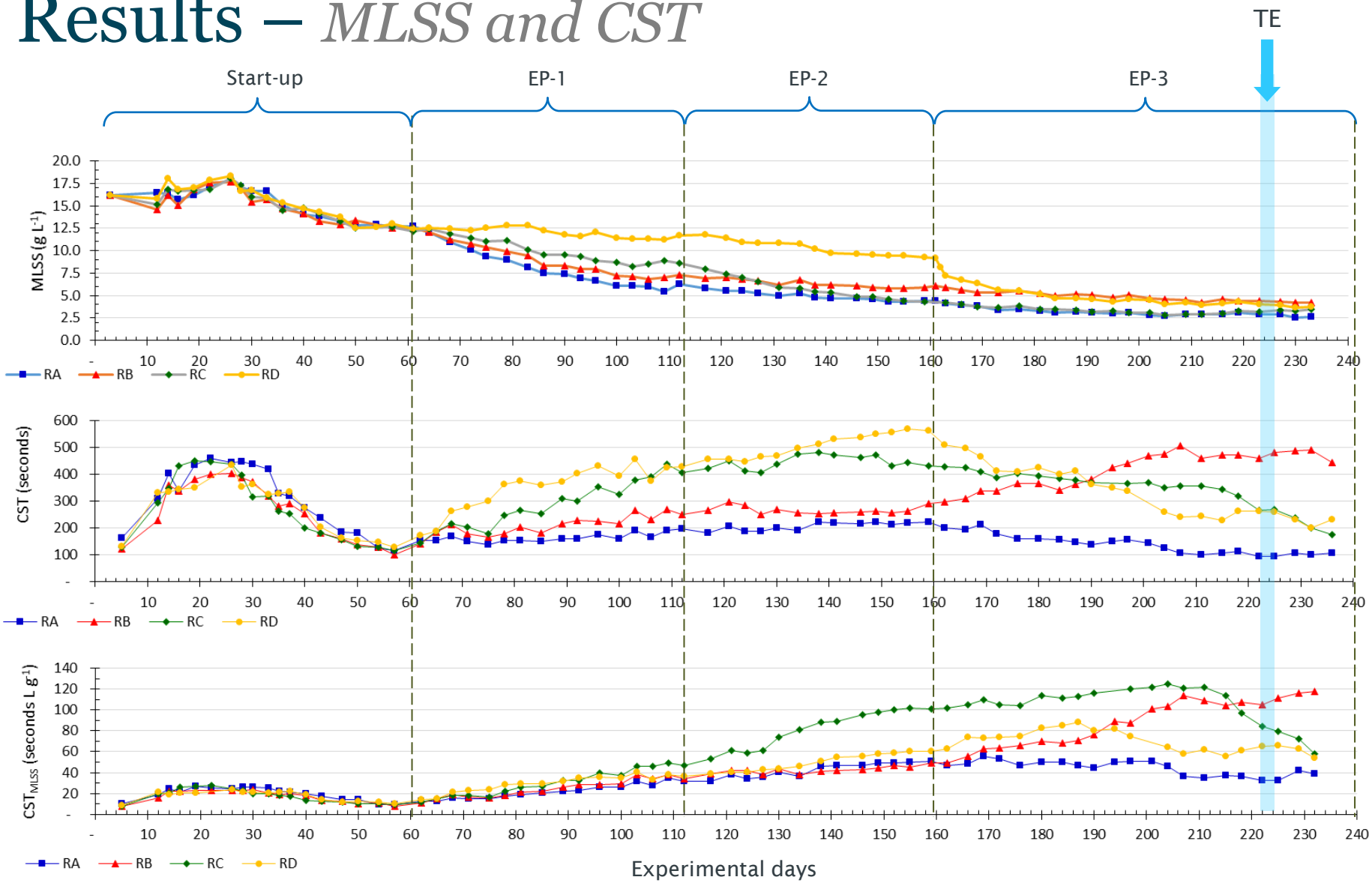
# Results – *MLSS and CST*



| MCRT (days) | Start-up | EP-1 | EP2 | EP-3 |
|---|---|---|---|---|
| Reactor A | 90 | 30 | 30 | 20 |
| Reactor B | 90 | 45 | 45 | 45 |
| Reactor C | 90 | 60 | 30 | 30 |
| Reactor D | 90 | 90 | 90 | 30 |

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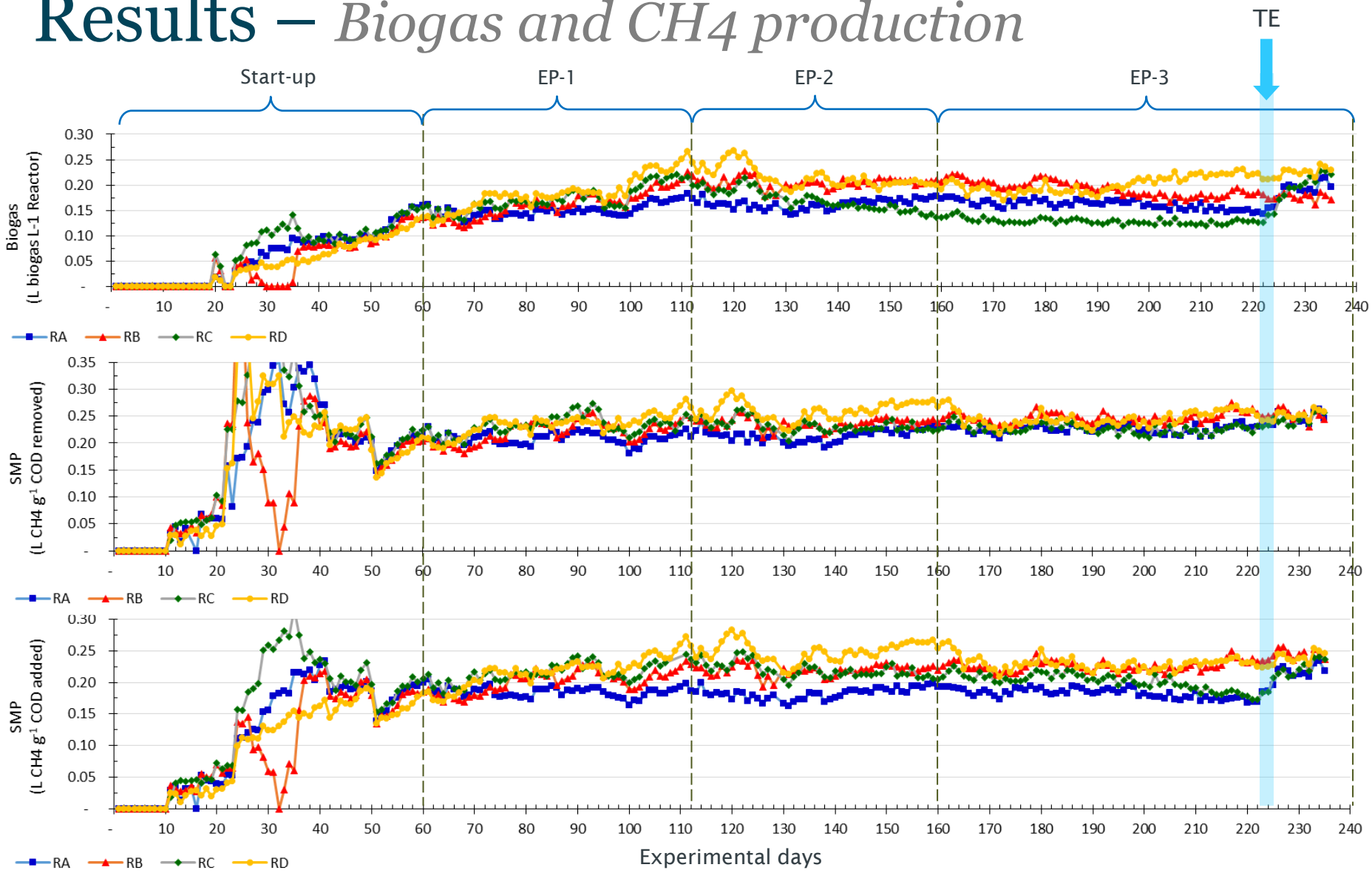
# Results – *Biogas and CH4 production*



| MCRT (days) | Start-up | EP-1 | EP2 | EP-3 |
|---|---|---|---|---|
| Reactor A | 90 | 30 | 30 | 20 |
| Reactor B | 90 | 45 | 45 | 45 |
| Reactor C | 90 | 60 | 30 | 30 |
| Reactor D | 90 | 90 | 90 | 30 |

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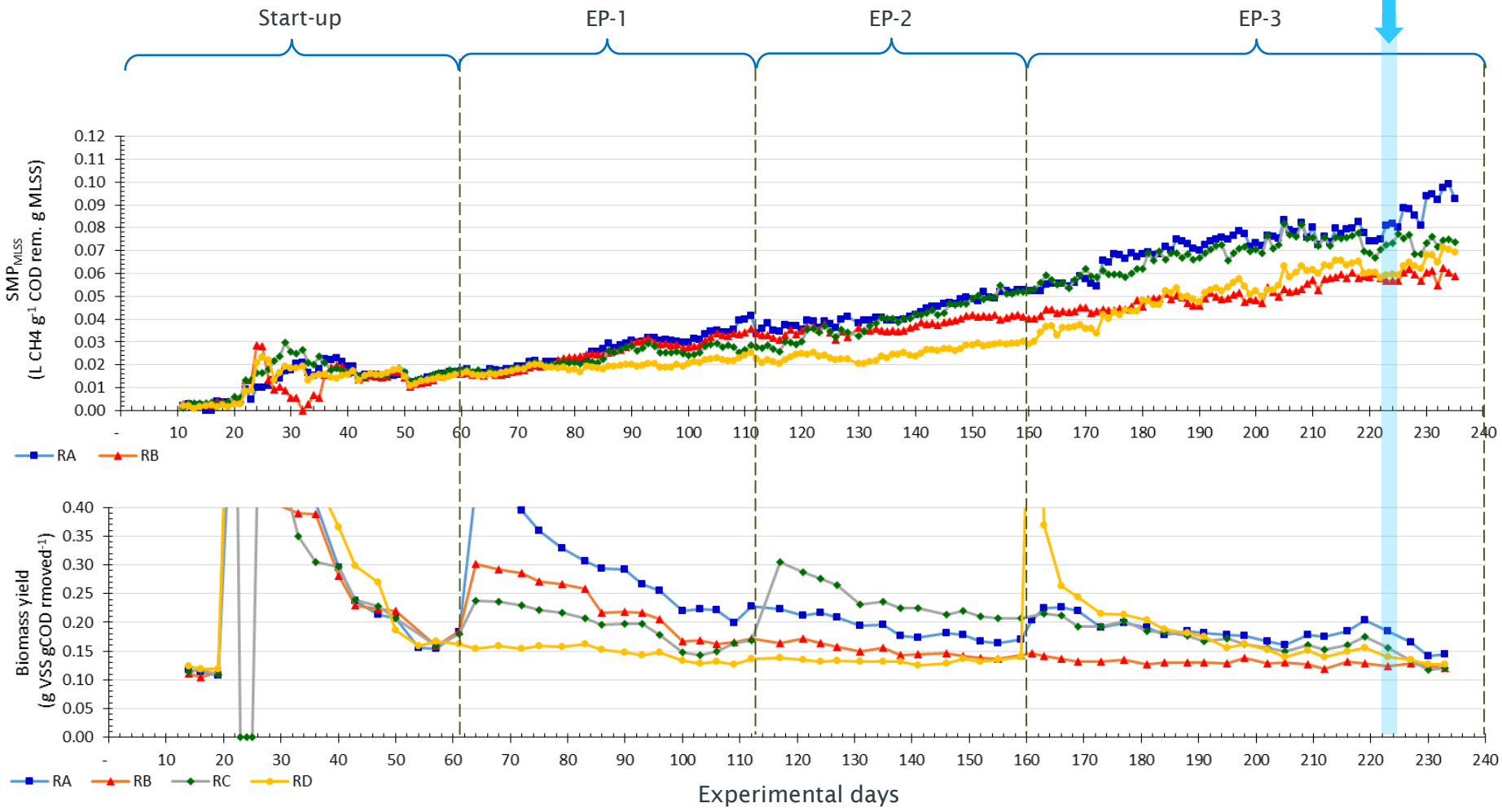
# Results – *CH4 production$_{MLSS}$ and growth yield*$^{TE}$



# Results – *COD balance*

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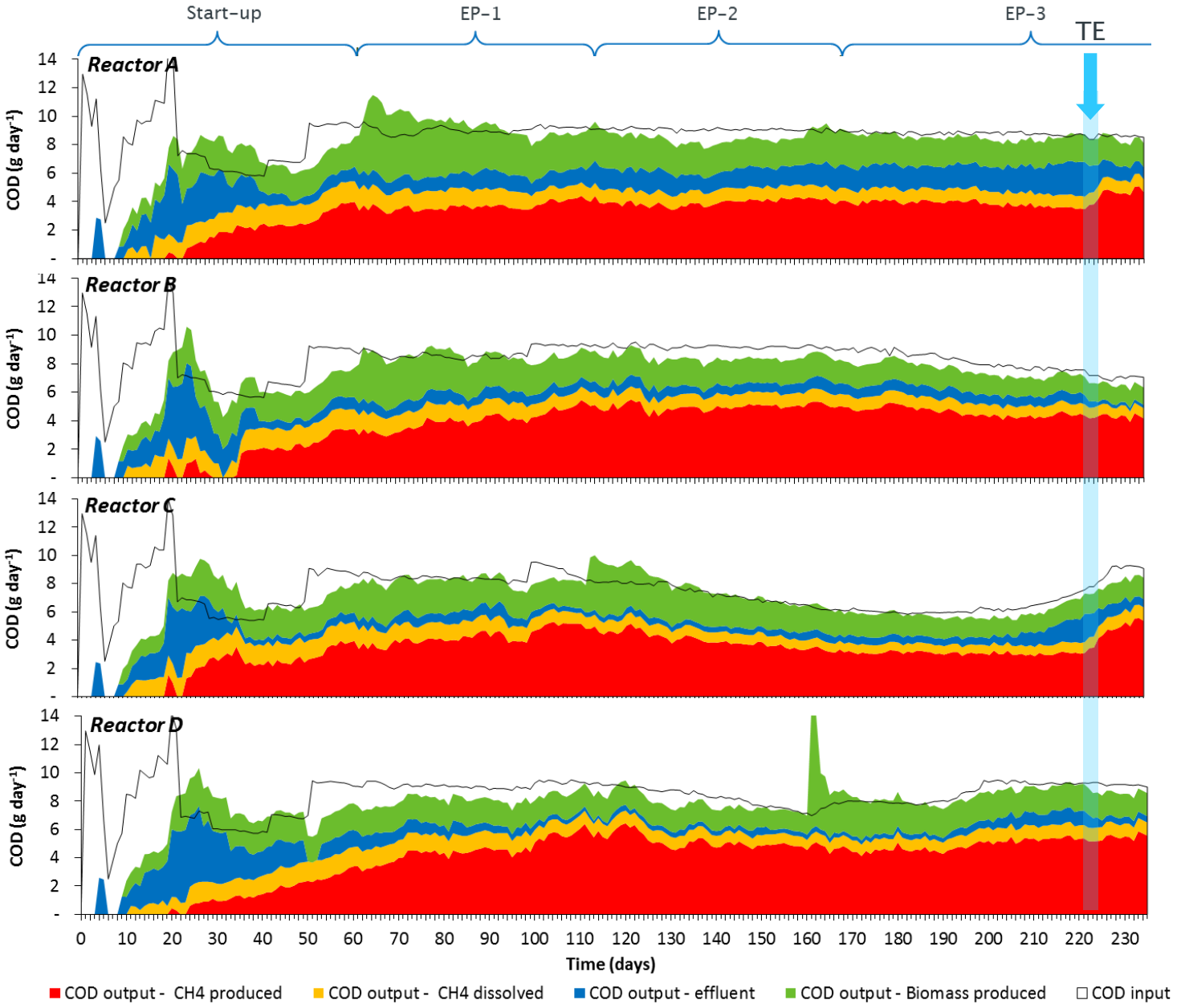

# Results – *FIC*

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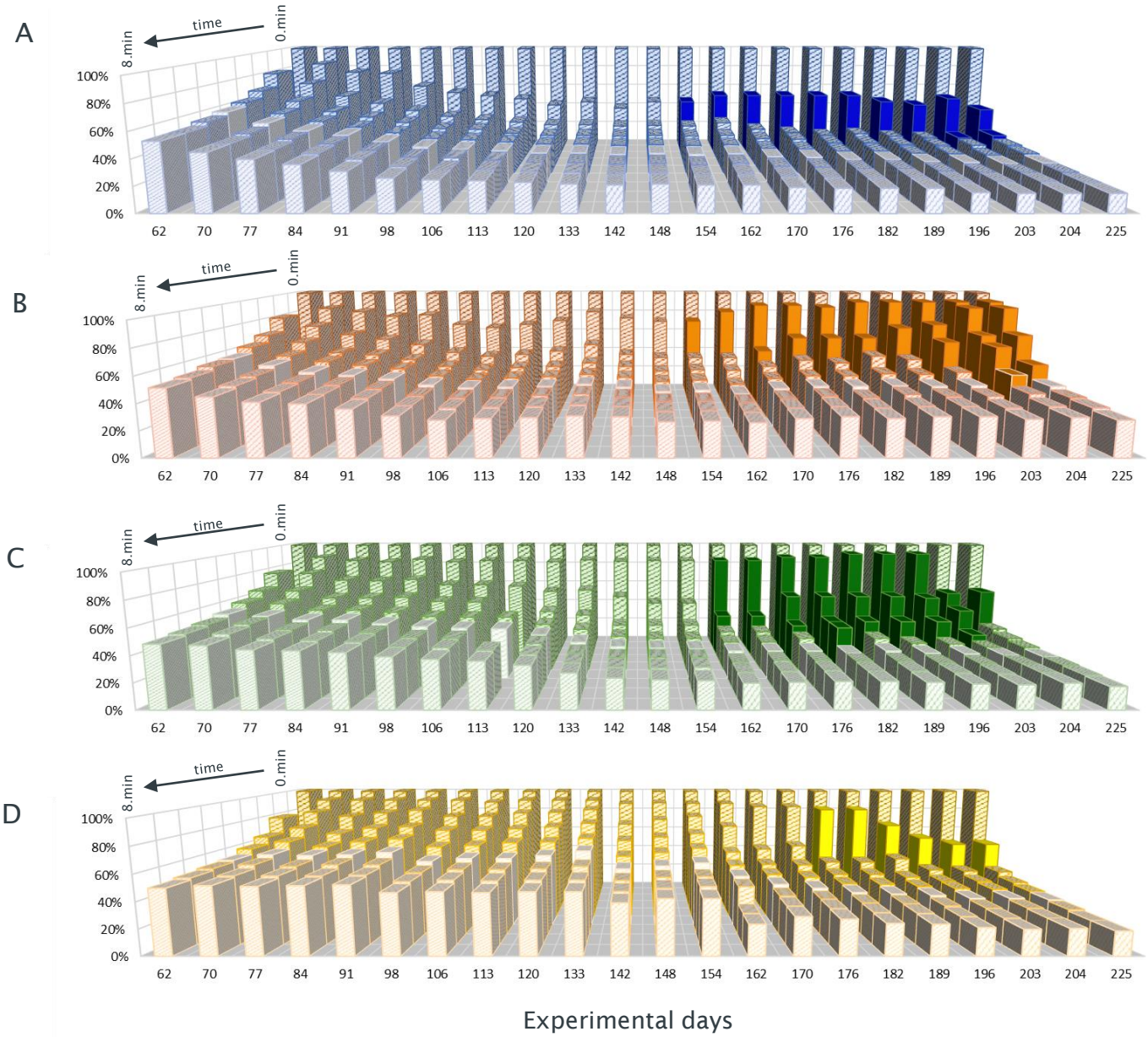


Solid bars
=
three phases

# Conclusions

- MCRT affected Membrane flux
  - Shorter MCRTs showed the best membrane performance
  - Clear evidence of fouling at MCRT ≥ 45 days, with 60 days giving the worst membrane performance
  - No advantage on operating < 30 days MCRT observed
  - Recovery from fouling observed when MCRT reduced to 30 days
  - CST and FIC confirm biomass characteristics affected by MCRT
  - EPC tests still in progress
- COD removal performance could be directly related to TE availability

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# Thank you

*Research sponsored by:*

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