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Electronic Nose for Reactor Stability Monitoring of an Agricultural Co-digestion Biogas Plant

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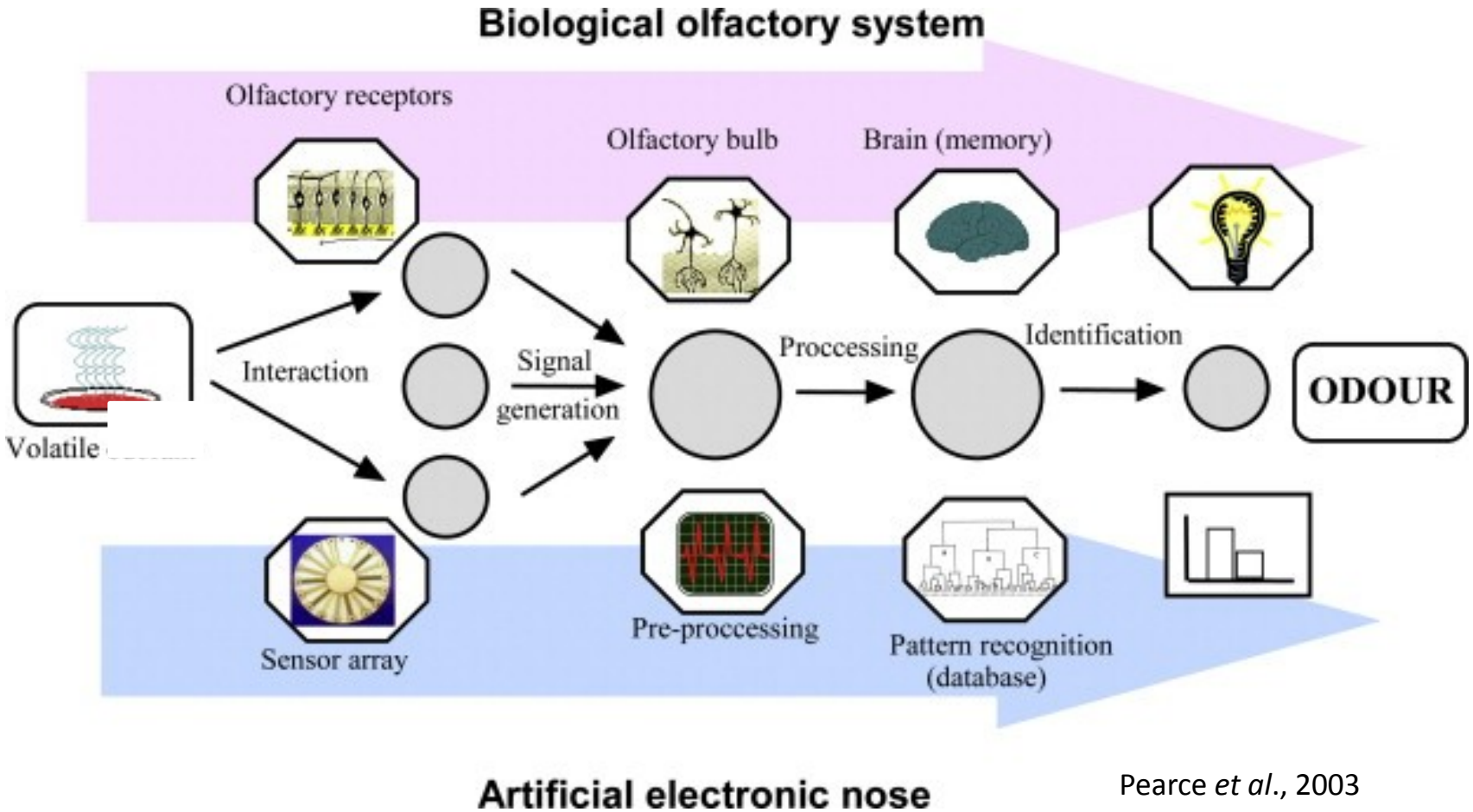
What is an electronic nose (e-nose) ?

It's an array of complementary low-specificity gas sensors

→ increased specificity using sensor array pattern (like a signature)

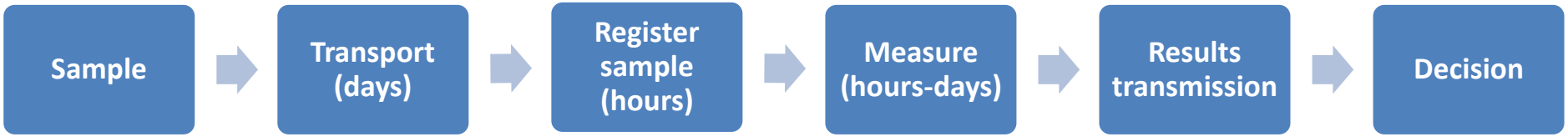


Pearce *et al.*, 2003

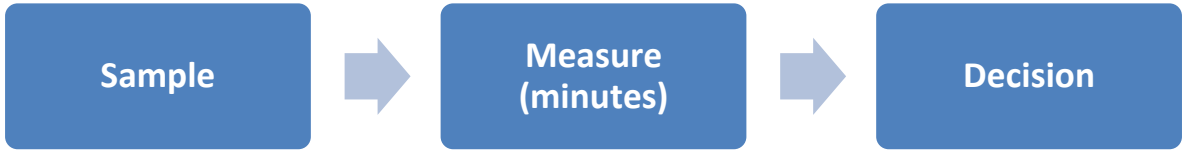
Why e-nose technology?

- Anaerobic digestion process monitoring:
  - Online monitoring: [CH4], [CO2], biogas production, pH
  - Offline analysis: alkalinity, Volatile Fatty Acids (individuals/total), etc.
  - No online tool for early warning of anaerobic digestion process disorders
- E-nose advantages:
  - Online monitoring
  - Gas phase sampling (easier than liquid-phase sampling in anaerobic reactors)
  - Rapid turn-over of gas phase of the reactor (hours)

Actual situation



Ideal situation



Adapted from Holm-Nielsen, 2008

Phase I: 100 L pilot-scale CSTR monitoring

Liquid phase

Total solids [%], volatile solids [%TS]

pH

Alkalinity [ml CO_2]

NH_4^+ [g L^{-3}]

Gas phase

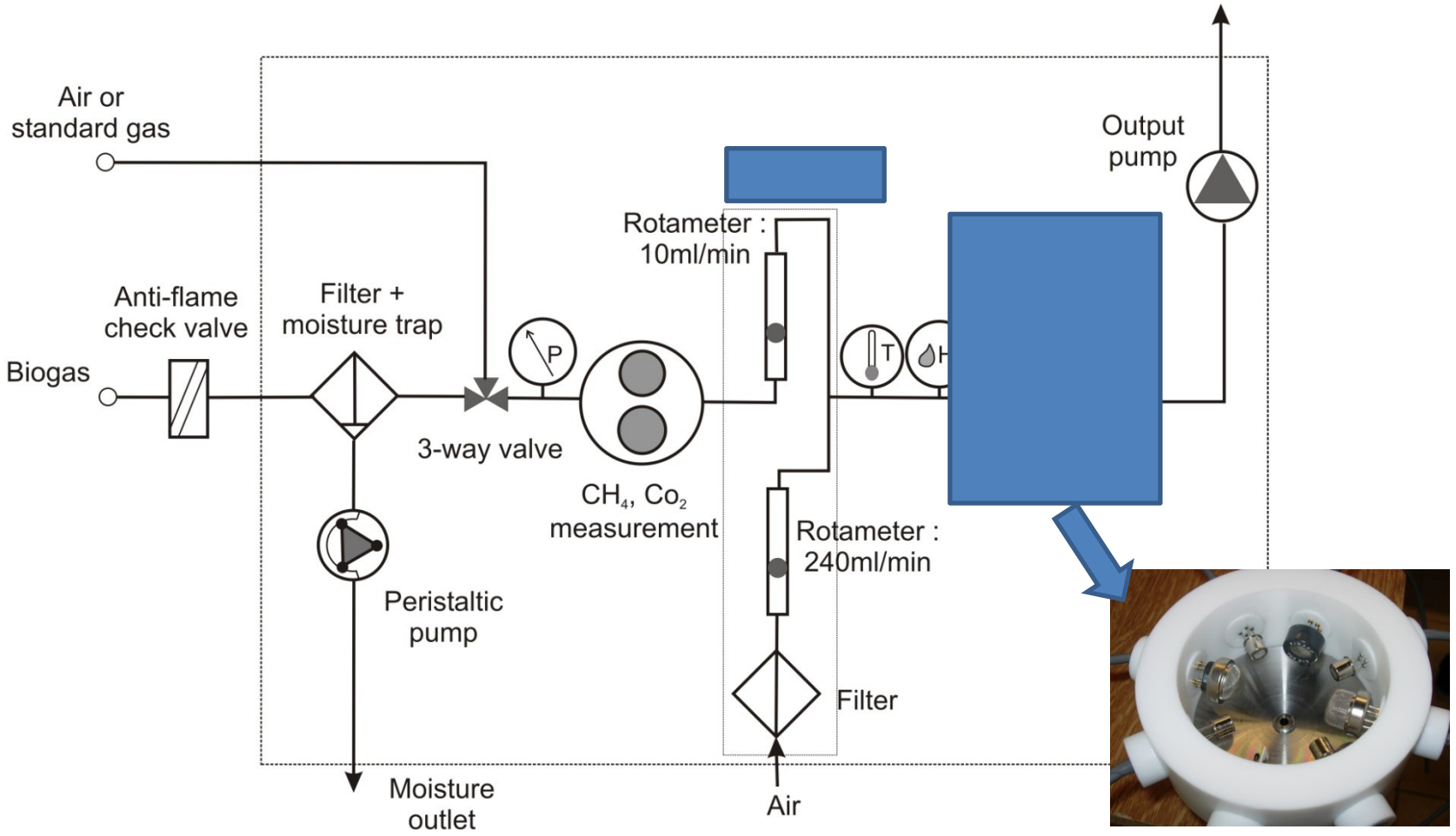
CH_4 [%], CO_2[%], H_2S (ppm), H_2 (ppm)

E-nose

e-nose = array of 6 low-specificity gas sensors and a dilution system (25x)

Phase II: Full-scale reactor monitoring

Material and methods



E-nose: array of 7 low-specificity commercial gas sensors (Figaro Engineering inc.)

During e-nose monitoring (650 days):
weekly: VFA, VS, TS, VFA/TIC (FOS/TAC)
Every 2 weeks: total ammonia nitrogen (TAN)

Faascht farm (BE)

Co-digestion biogas plant of 750 kW

3 CSTR + two storage tanks + Digestate drying unit

Substrates (18 000 T):

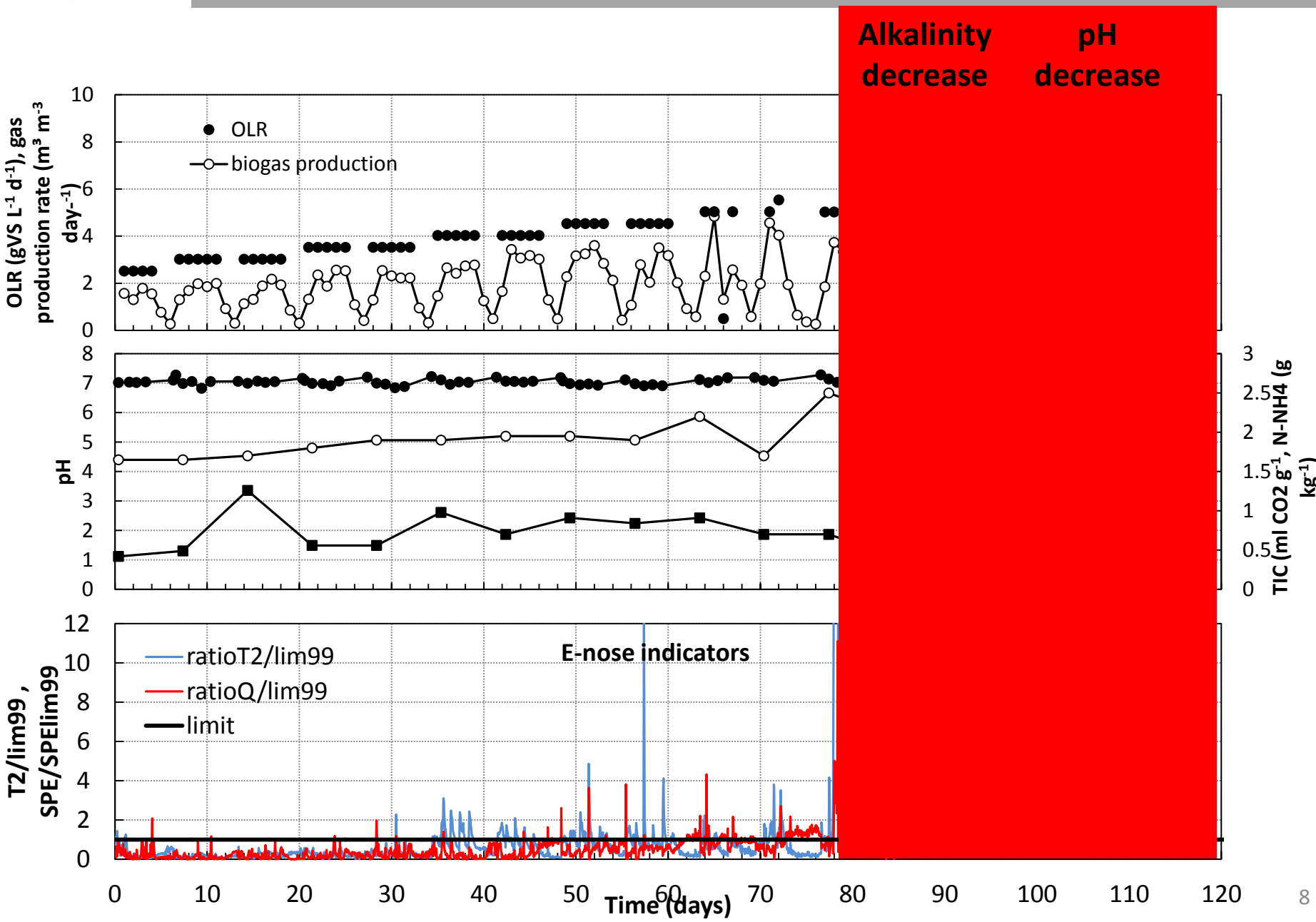
- **Food industry waste (54 %)**
- **Cattle manure/slurry (33 %)**
- **Maize silage (8 %)**

Limited process monitoring capabilities:

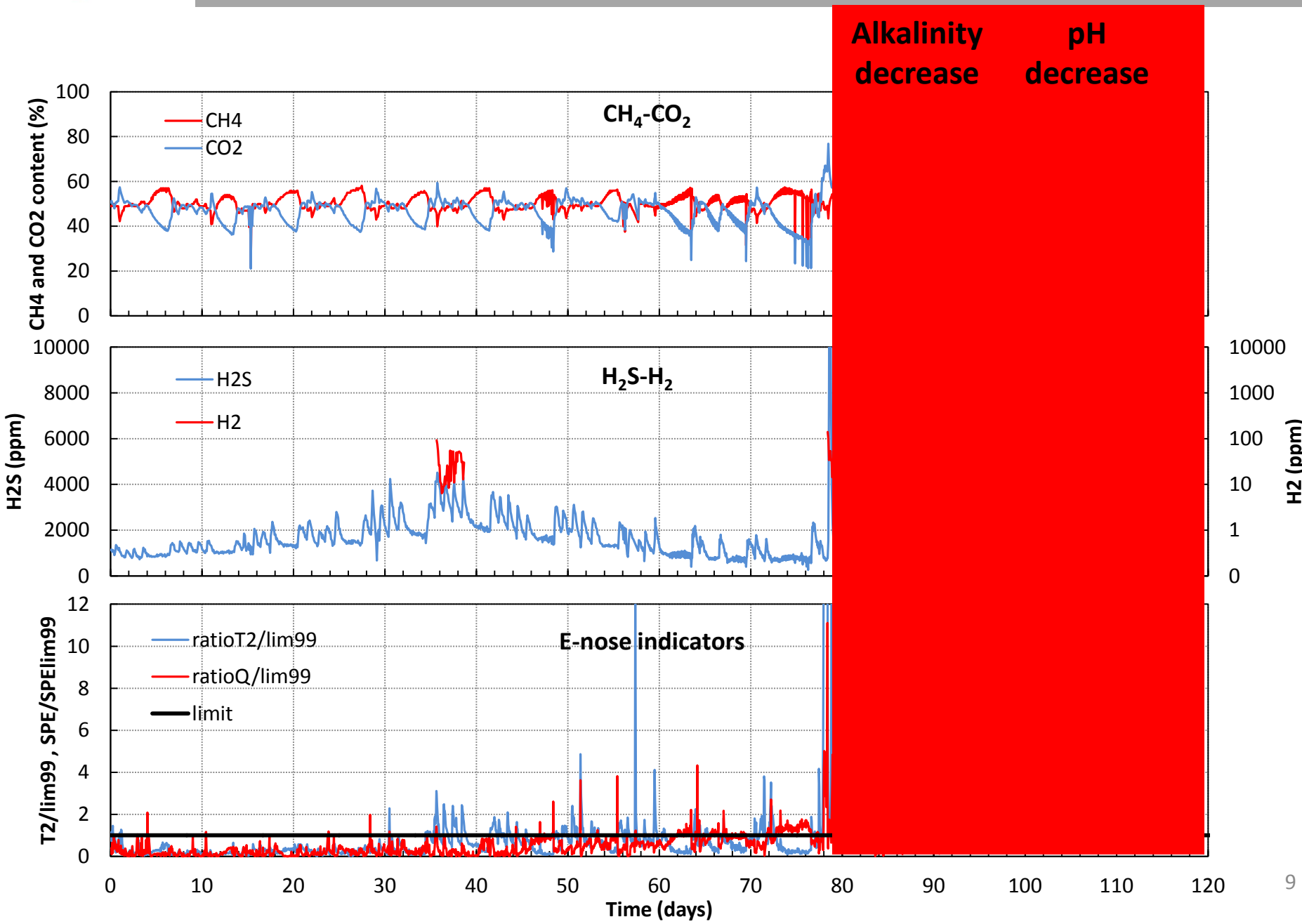
On-line: CH_4, CO_2, H_2S and O_2 (prior to CHP)

When low gas quality/production: VFA, N-NH_4^+ in the sludge

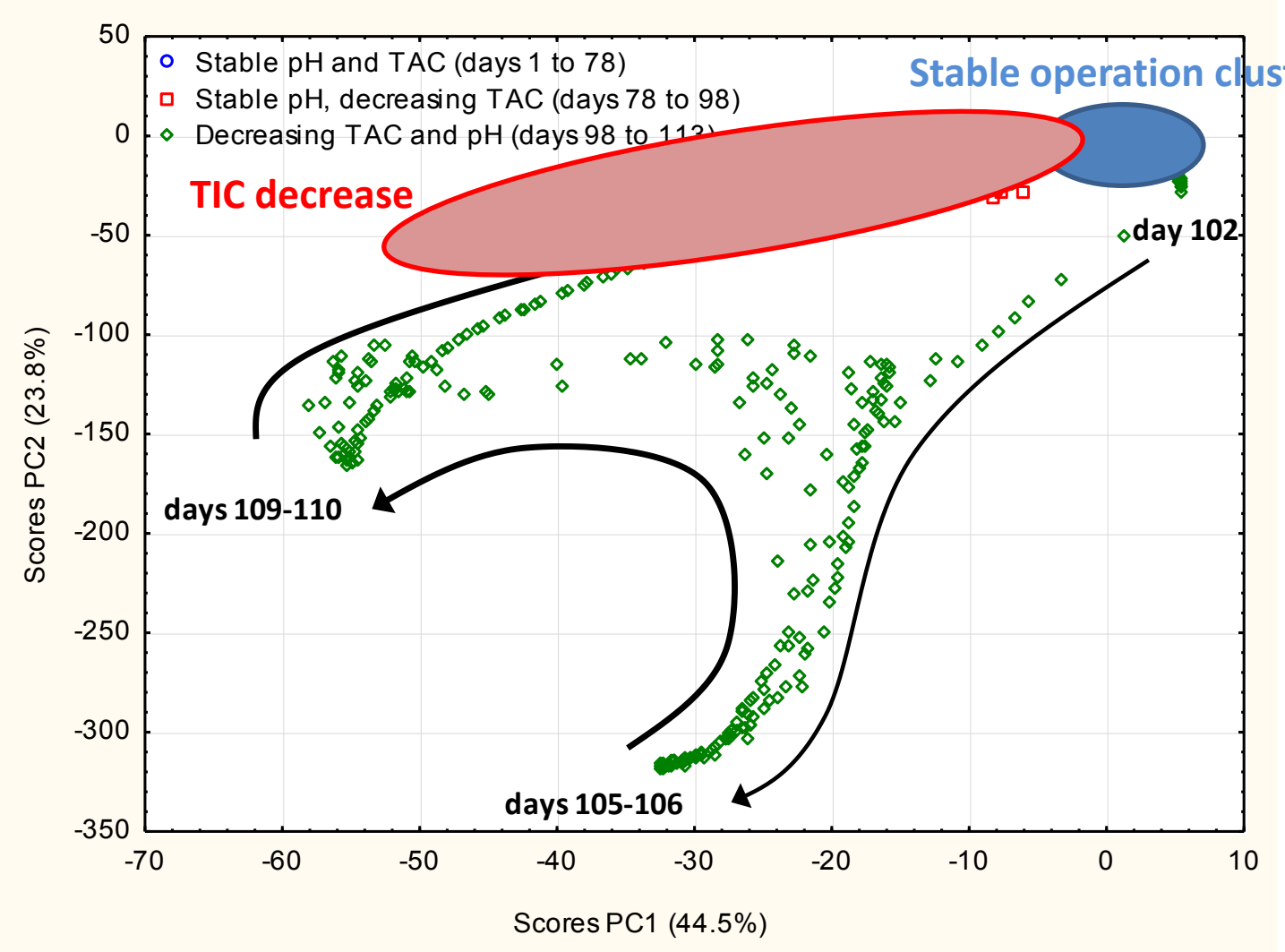
Results – Pilot-scale monitoring



Results – Pilot-scale monitoring



Results – Pilot-scale monitoring

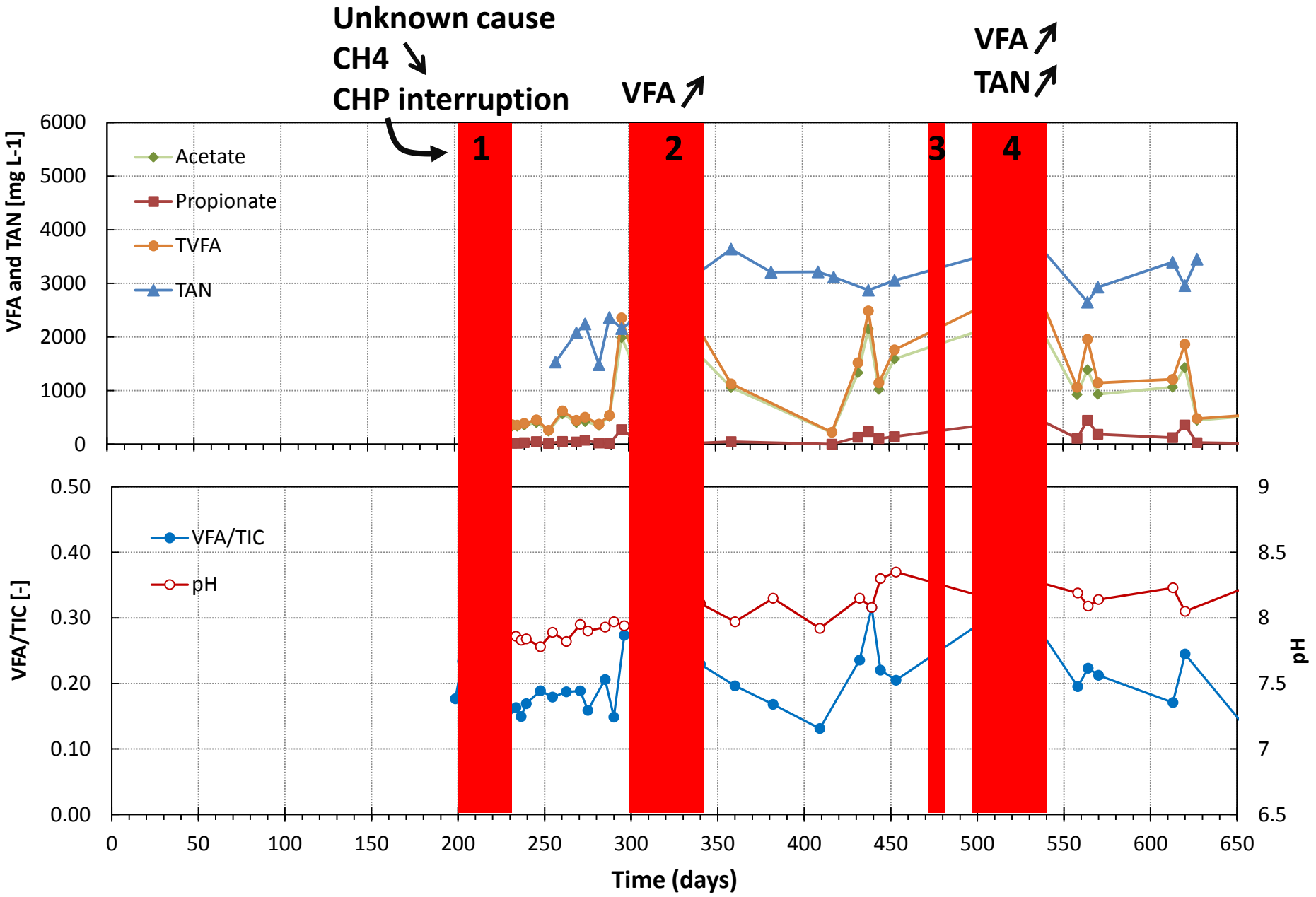


PCA monitoring

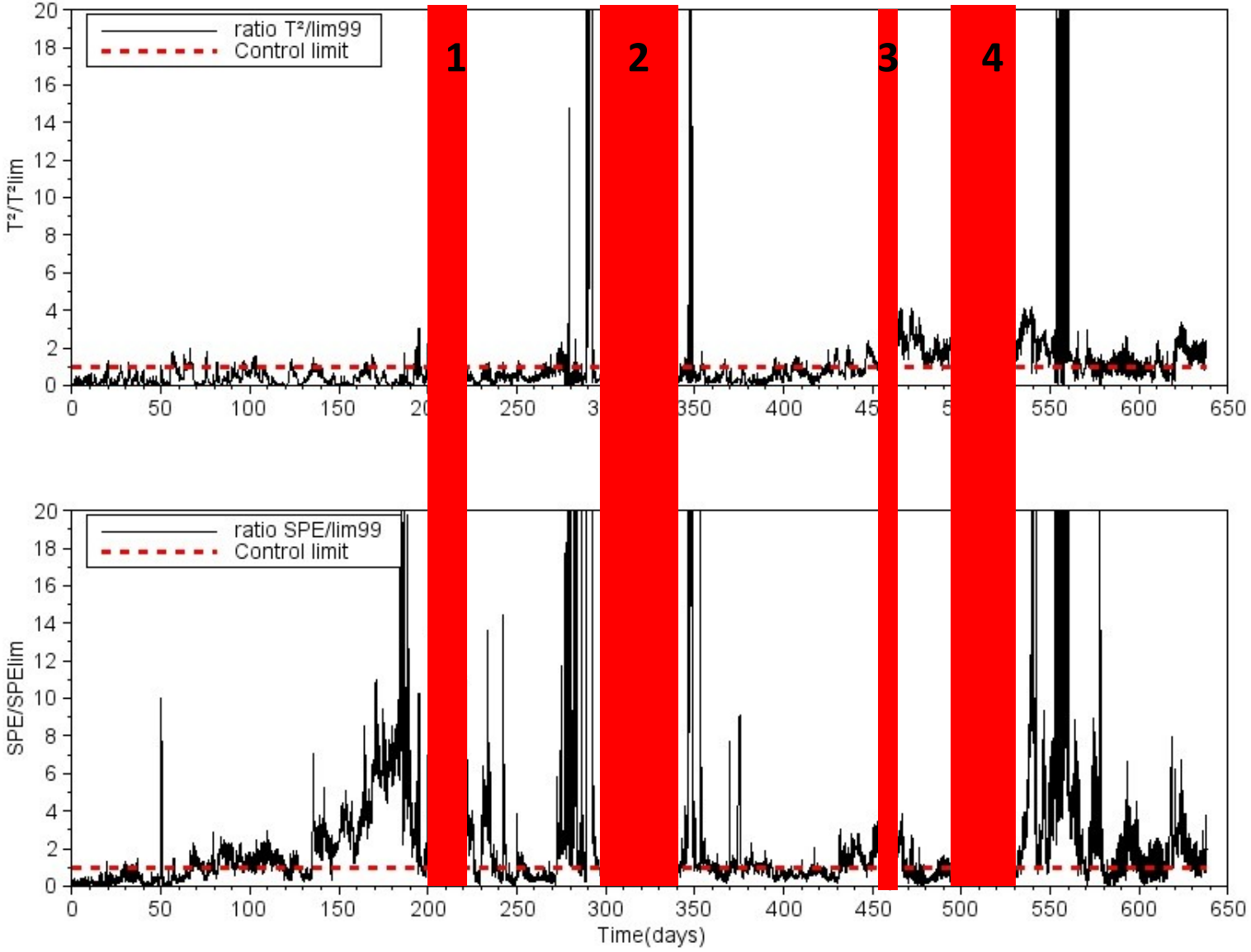
Different changes in the gas phase and liquid phase are observed by the e-nose

Phase II: Full-scale reactor monitoring

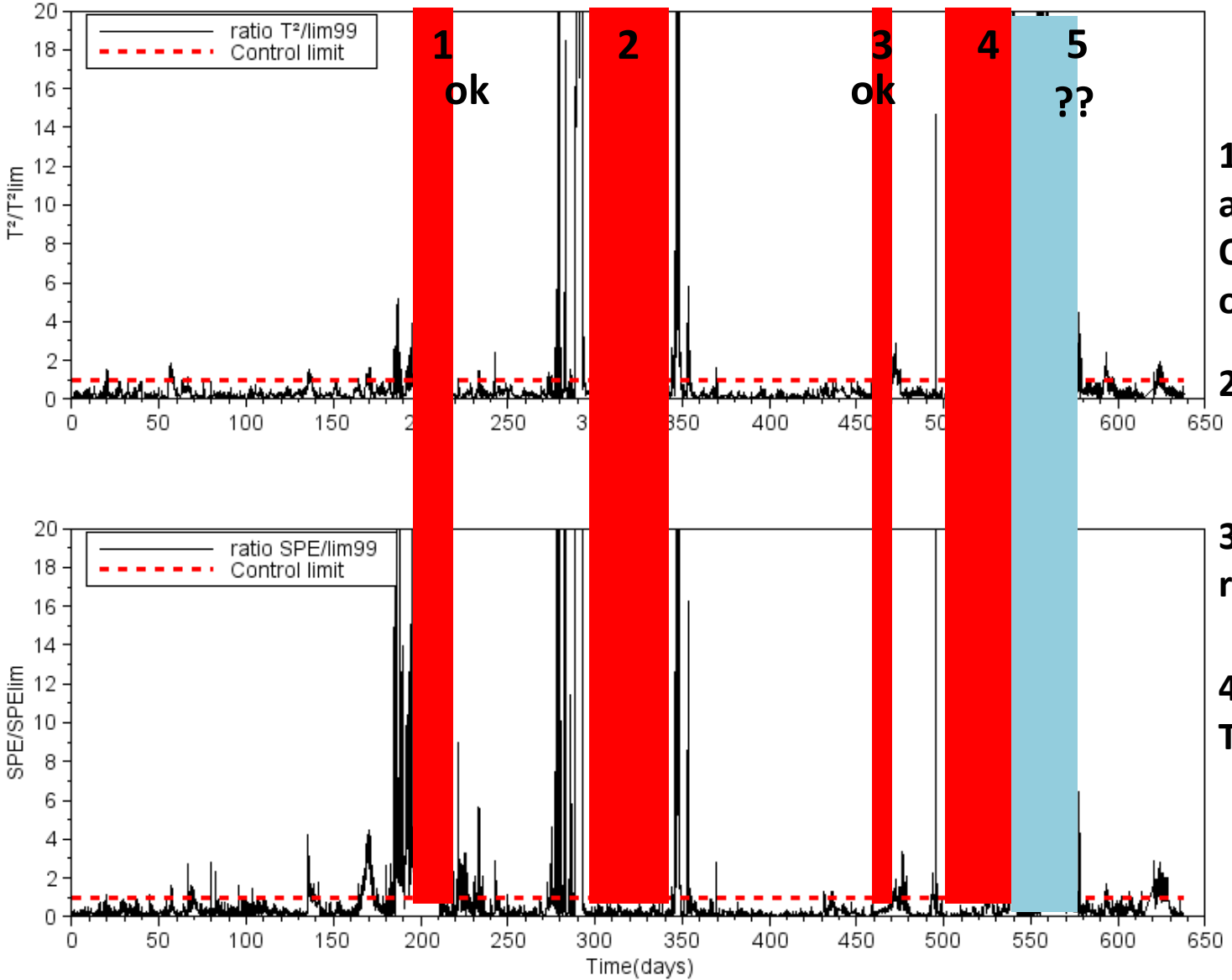
Results – real-scale monitoring



Signal drift decreased model perfomance



Adaptive model: detection of variation in process state



1. Low gas quality and production. One engine turned off

2. VFA > 3500mg/L

3. Emptying and refilling reactor

4. VFA > 4000mg/L
T-NH3> 3500 mg/L

Highlights

- Gas phase monitoring should be considered to assess anaerobic digestion reactor state
- The e-nose could detect process AD disorders by monitoring the gas phase at the pilot-scale level
- A simple indicator, derived from the complex e-nose data, summarizes reactor state
- At the real-scale level, the e-nose failed for robust monitoring of the reactor state

Acknowledgements

Thanks for your attention

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www.ecobiogaz.eu

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www.optibiogaz.eu

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