

Evaluating fouling and cleaning: a pilot scale approach

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Outline

- Fouling and cleaning in dairy factories
- Pilot scale cleaning rig
- Fouling measurement and verification
- Cleaning assessment
- Cleaning rig applications

Fouling & Cleaning in Dairy Factories

- A necessity to regularly clean due to fouling
 - decreases heat transfer efficiency
 - increases plant pressure drops
 - impacts on plant process sterility
 - limits plant operation time
- Optimising CIP through evaluations
 - reduce plant downtime
 - reduce resource consumption
 - reduce environmental impact

KPI's – Cleaning Evaluations

- Visual & microbial parameters
 - visual inspection and odour
 - cleaned surface microbial quality
 - product microbial quality
- Engineering performance
 - ΔT profile (start up)
 - overall heat transfer co-efficient
 - ΔP profile
 - cleaning velocity

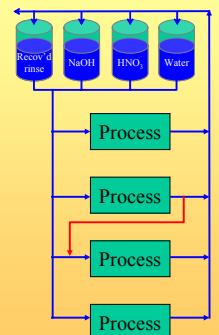


KPI's – Resource Utilisation

- | | |
|---------------------------------|--------------------------------------|
| • Water consumption ratio | kg fresh water/kg production loop |
| • Steam consumption ratio | kg steam used/kg production loop |
| • Electrical energy consumption | kJ elec energy/kg production loop |
| • Chemical consumption | kg chemical added/kg of soil removed |
| • Labour | hours/clean |
| • Total cost of clean | \$/clean |
| • Time of clean | hours/clean |
| • Residual chemical activity | titration |
| • Mass of soil removed | COD, Total Solids, Calcium etc |

Challenges to Factory CIP Evaluations

- Complex CIP circuits
- Optimisation is time consuming and incremental in approach
 - maintenance of product quality
- Validation and verification of protocols are simplified if
 - the plant fouling deposit is consistent
 - the plant is visually inspected after every CIP



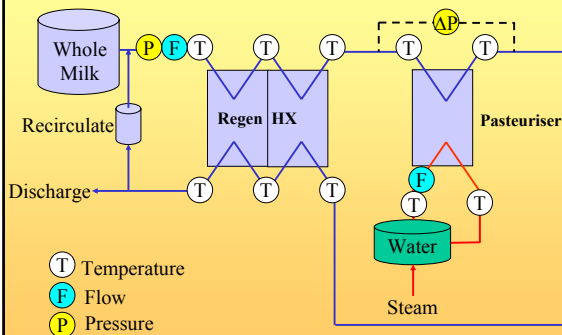
Requirements of an Evaluation System

- Reflective of factory processes
- Able to assess key CIP parameters
- Well instrumented and easy to monitor key parameters
- Repeatable fouling and cleaning protocols
- Quick and efficient

Pilot Scale Cleaning Rig

- A small scale PHE pasteuriser
 - most common unit operation is a heat exchanger
 - reflects factory process
 - skid mounted
 - throughput: 50 to 300 L milk per hour
- Purpose
 - CIP evaluation (existing and new practices)
 - CIP benchmarking
- Designed to investigate microbial and physical fouling

Cleaning Rig – Instrumentation



Performance Indicators

- Change in pressure drop (ΔP)
 - differential pressure across the pasteuriser (kPa)
- Change in log mean temperature difference (LMTD)
 - uses inlet and outlet temperatures of both streams across the pasteuriser
- Normalised Overall Heat Transfer Co-efficient (I_r)

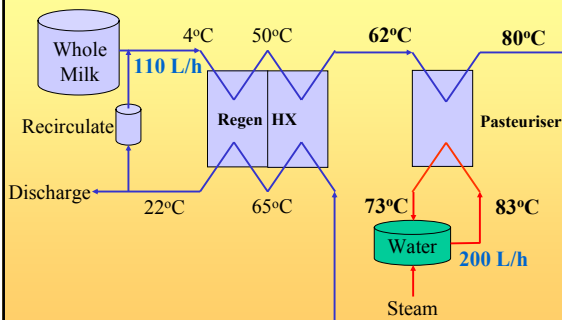
$$Q = U \cdot A \cdot \text{LMTD}$$

$$U_o = \text{initial overall heat transfer co-efficient}$$

$$U_t = \text{overall heat transfer co-efficient at time } t$$

$$I_r = U_t / U_o$$

Cleaning Rig – Operation



Performance Validation

- Performance is achieved through
 - scheduled instrument testing/calibrations
 - routine water circuit cleaning
 - insulated pasteuriser and pipe work
- Verification process on water before production
 - plant is clean
 - all initial KPI's are met (ΔP , LMTD)
 - heat balance closes within 5%

Performance Comparison with Factories

Pasteuriser Process Start-up (Liquid Milk Factories)

	LMTD	U_o
Factory A	5.6 – 6.9 °C	1700 – 1800 W/m ² K
Factory B	4.0 – 5.8 °C	N/A
Factory C	4.7 °C	N/A
Pilot Rig	6.0 – 6.6 °C	2100 – 2300 W/m ² K

Fouling – Visual Inspection

- Deposit weights – heat exchanger plates



Fouling Density = 50 g/m²

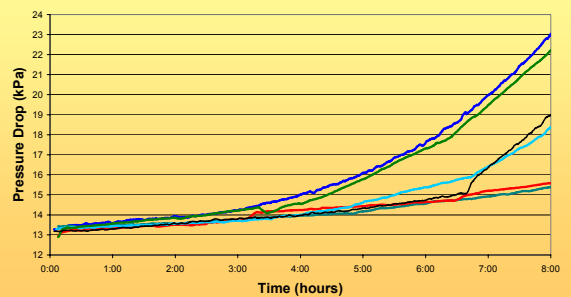


Fouling – Predicting Deposit

- Linking on-line indicators to fouling mass
- Aim for consistent fouling basis for CIP evaluations
 - avoids need to dismantle after fouling for inspection
 - nature of soil changes when dried – affects CIP
- Basis of fouling indicators
 - time?
 - defined end point?

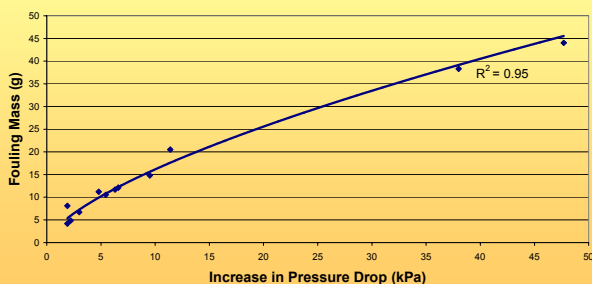
Fouling – Predicting Deposit : Pressure

Typical Pressure Drop Profiles for Milk Fouling



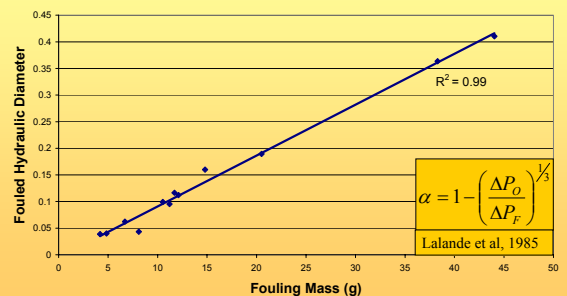
Fouling – Pressure Indicator

Pressure Drop versus Fouling Mass



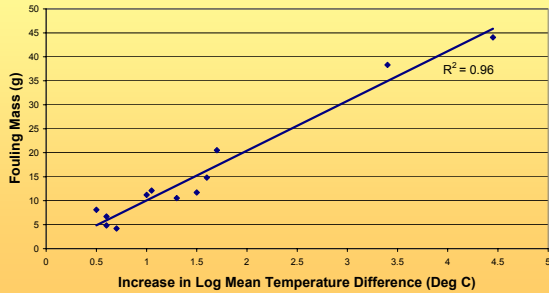
Fouling – Fouled Hydraulic Diameter (α)

Fouling Mass versus Fouled Hydraulic Diameter



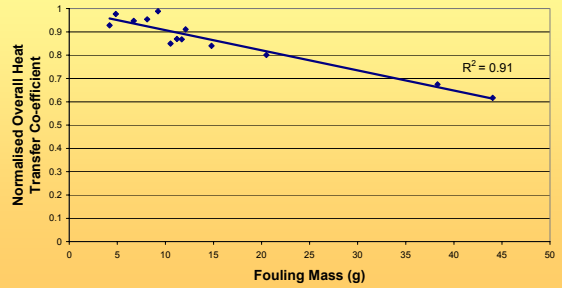
Fouling – LMTD Indicator

Log Mean Temperature Difference versus Fouling Mass



Fouling – Normalised OHTC Indicator

Fouling Mass versus Normalised Overall Heat Transfer Co-efficient



Typical CIP Cycle

1. Product flush
2. Pre-rinse
3. Caustic recirculation
4. Intermediate rinse
5. Acid recirculation
6. Final rinse
7. Sanitise

Cleaning – Measuring Performance

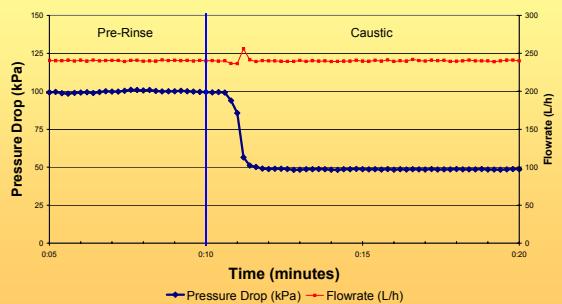
- How do you know that the system is clean?
 - Physical (pull plates apart)
 - visual
 - mass
 - Chemical
 - residual chemical concentrations
 - residual organic matter and minerals on plates
 - Bacteriological
 - residual micro-organisms

Cleaning – Indicators

- On-line fouling KPI's: ΔP , LMTD
 - not appropriate during CIP
 - validates cleanliness of system on water after CIP
- Other indicators for CIP:
 - Turbidity
 - COD
 - Conductivity
- 2nd CIP to confirm system is clean

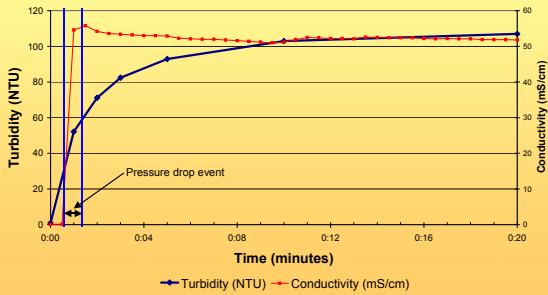
Cleaning – Pressure Profile

Typical Pressure Drop Profile versus Time during CIP



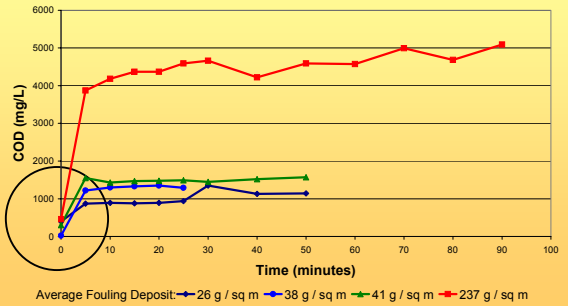
Cleaning – Caustic Indicators

Typical Turbidity Profile versus Time during Caustic CIP



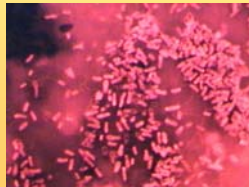
Cleaning – Caustic COD Profiles

Typical COD Profiles versus Time during Caustic CIP



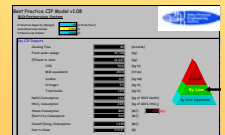
Rig Applications – Microbial Evaluations

- Investigation of CIP on microbial biofilm removal in conjunction with soil fouling
- Coupon system mounted onto rig around regeneration plate HEX for thermophile biofilm growth
- Preliminary findings
 - Soil removal does not necessarily imply microbial removal



Cleaning Rig Applications

- Currently being used to evaluate cleaning chemicals
 - effectiveness of low sodium chemical alternatives
 - reuse efficacy after reclamation
 - develop criteria of reuse
 - evaluate reclamation technologies
- Surface treatments to reduce fouling
- CIP knowledge system for industry



Summary

- Cleaning rig reflects factory pasteurisation processes
- Consistent fouling basis for cleaning evaluations
 - evaluates both soil and microbial fouling
- Cleaning evaluations
 - “real” soil and microbial removal kinetics
- Current focus on sustainable cleaning applications
 - criteria for CIP reuse
 - alternative CIP chemicals

Acknowledgements

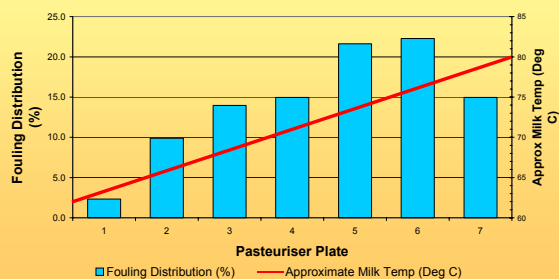
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- Dairy Australia
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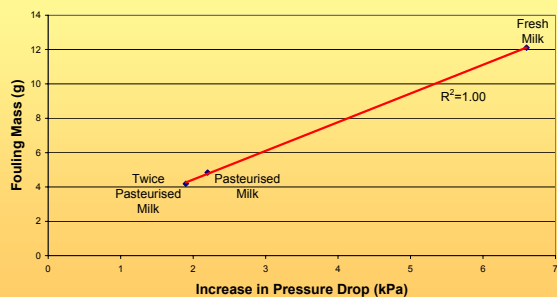
Plate Fouling Distribution

Typical Fouling Mass Distribution across the Pasteuriser Plates



Fouling – Re-processing Milk

Pressure Drop versus Fouling Mass for Re-Processed Milk



Cleaning – Caustic COD Profiles

Typical COD Profiles versus Time during Caustic CIP

