



RO OPERATION

Problems & Latest Solutions

Iran May 2015

HOSSEIN OSTOVAR



Contents



- **RO Basics**
- **Antiscalants**
- **Cleaning Principles & Efficiency**
- **RO Fouling Theory**
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RO BASICS



Thin Film Composite Polyamide Membrane

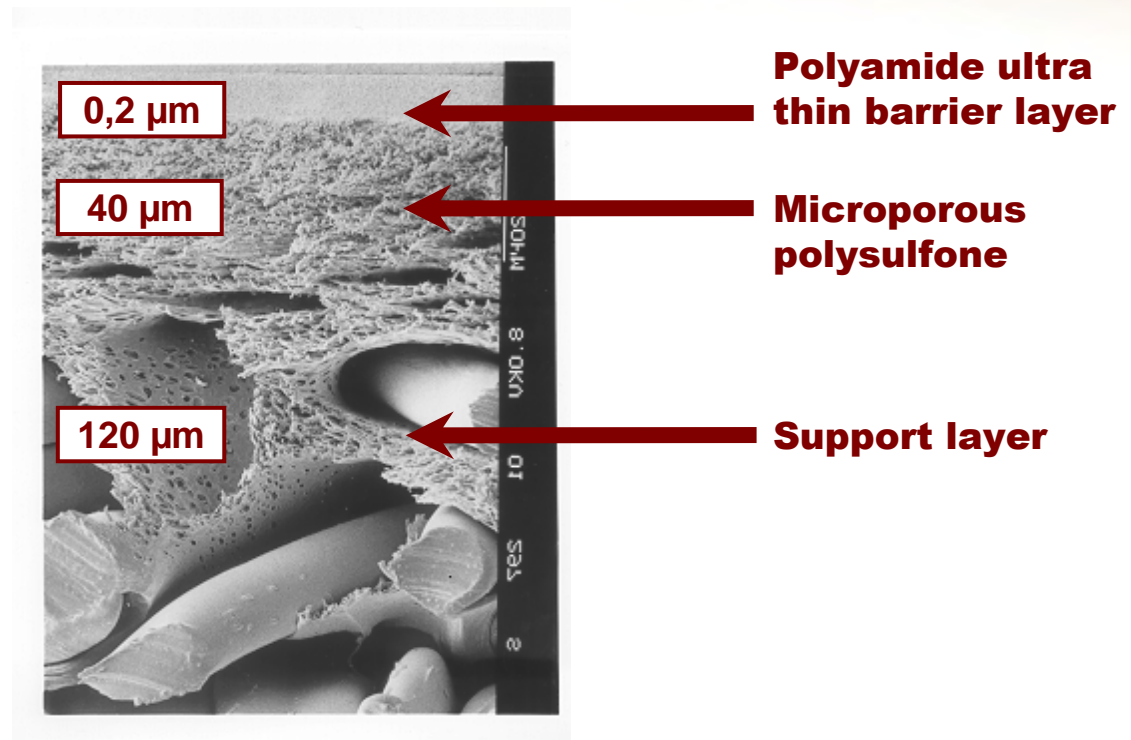


Advantages

- good salt rejection
- low pressure operation
- tough
- does not compact

Disadvantage

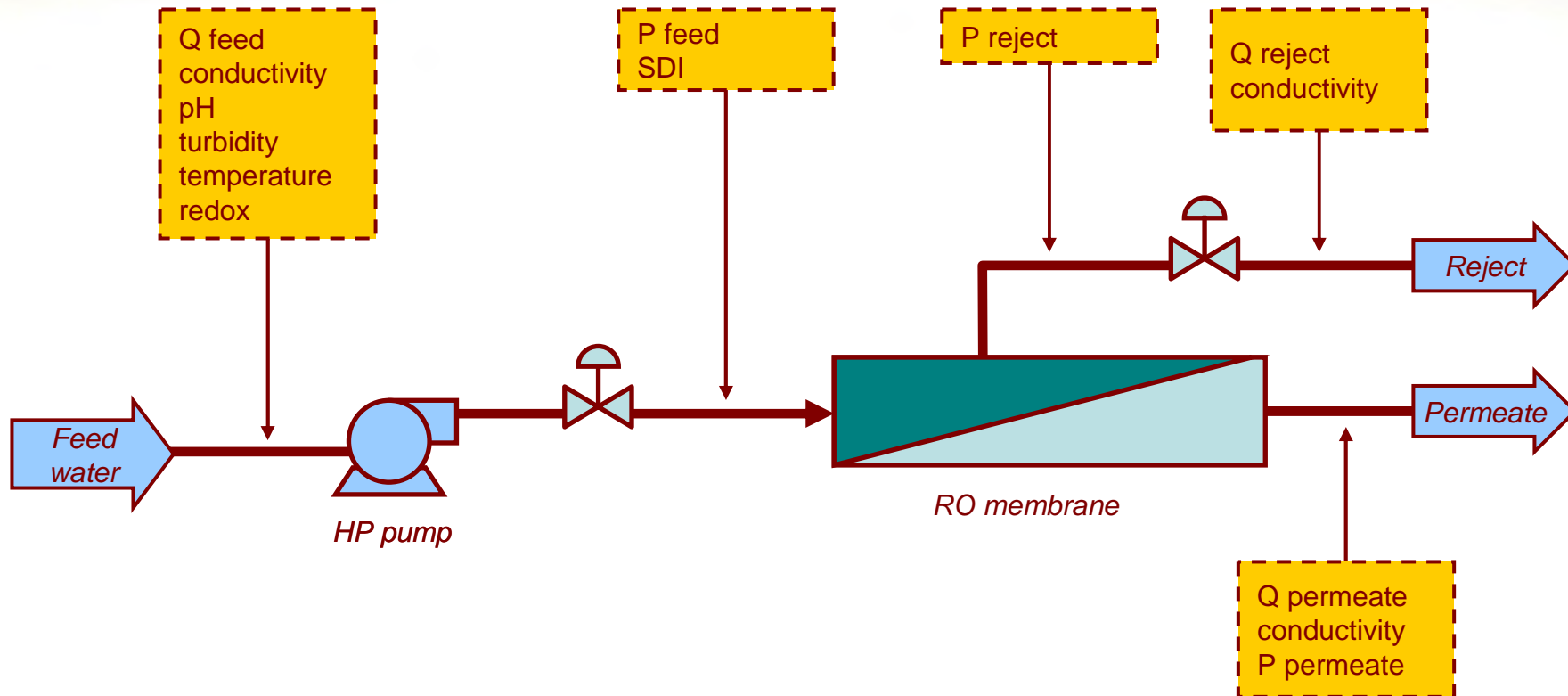
- poor chlorine tolerance





RO Monitoring : Key Parameters

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Membrane Operation

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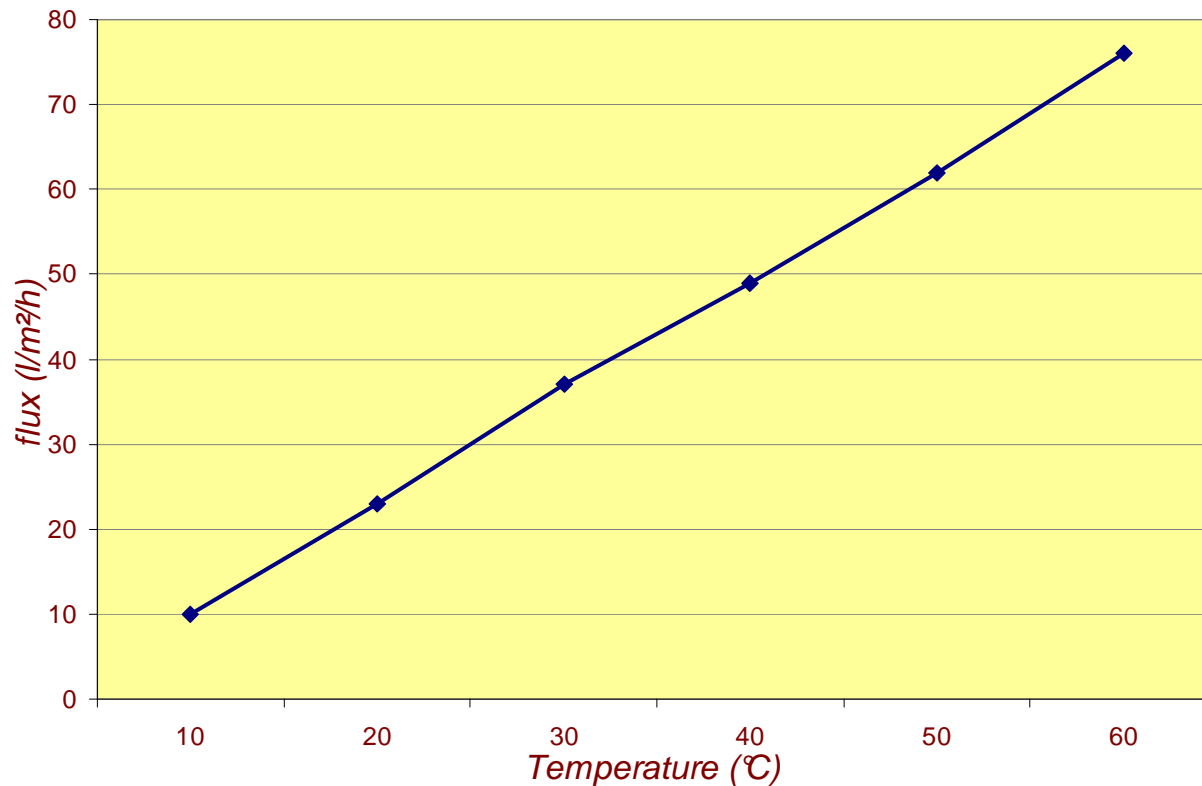
FACTORS AFFECTING PERFORMANCE (quantity & quality) :

- **Membrane material and surface properties**
- **Temperature**
- **Pressure**
- **Salinity**



Effect of Temperature on Quantity

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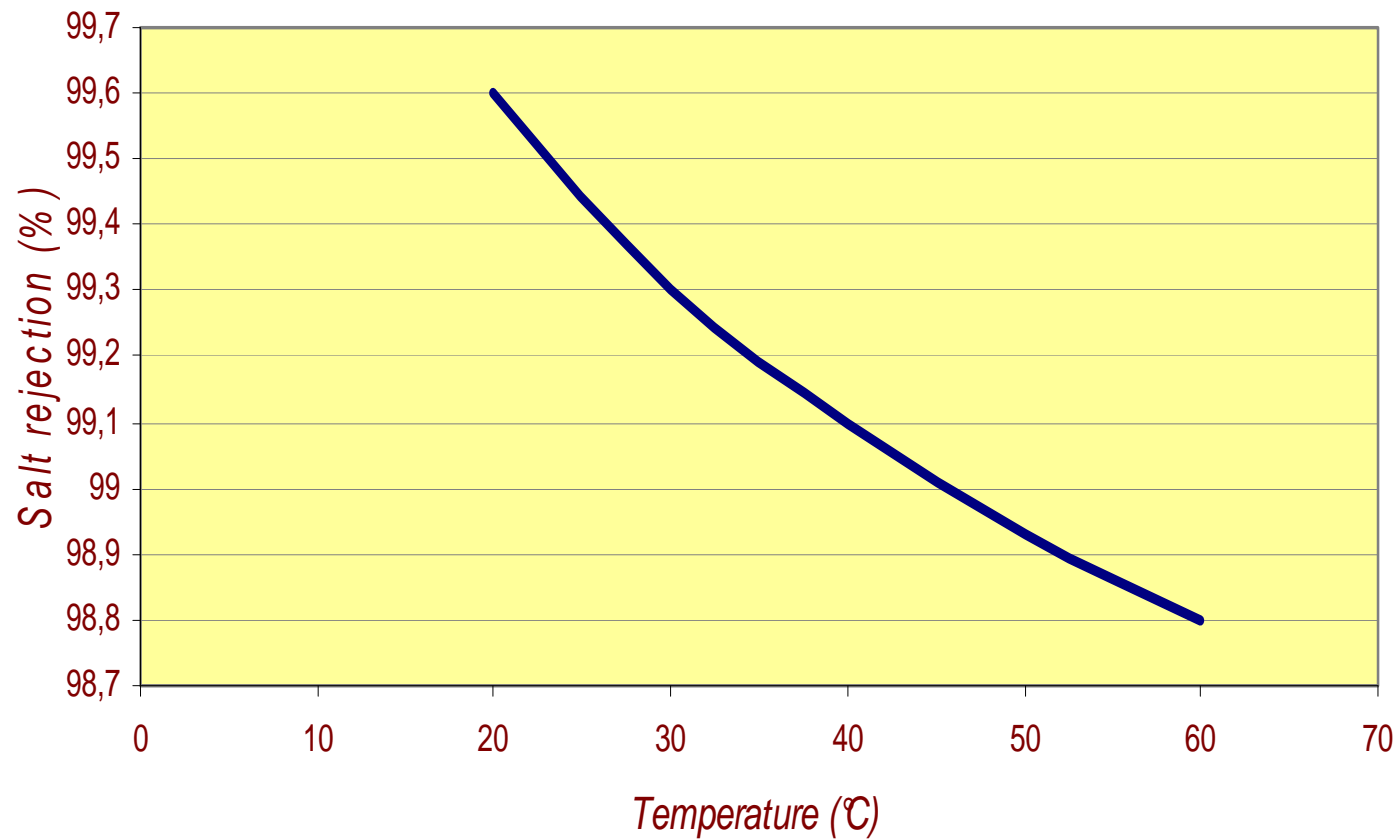


1°C = 2,7% change in flux



Effect of Temperature on Quality

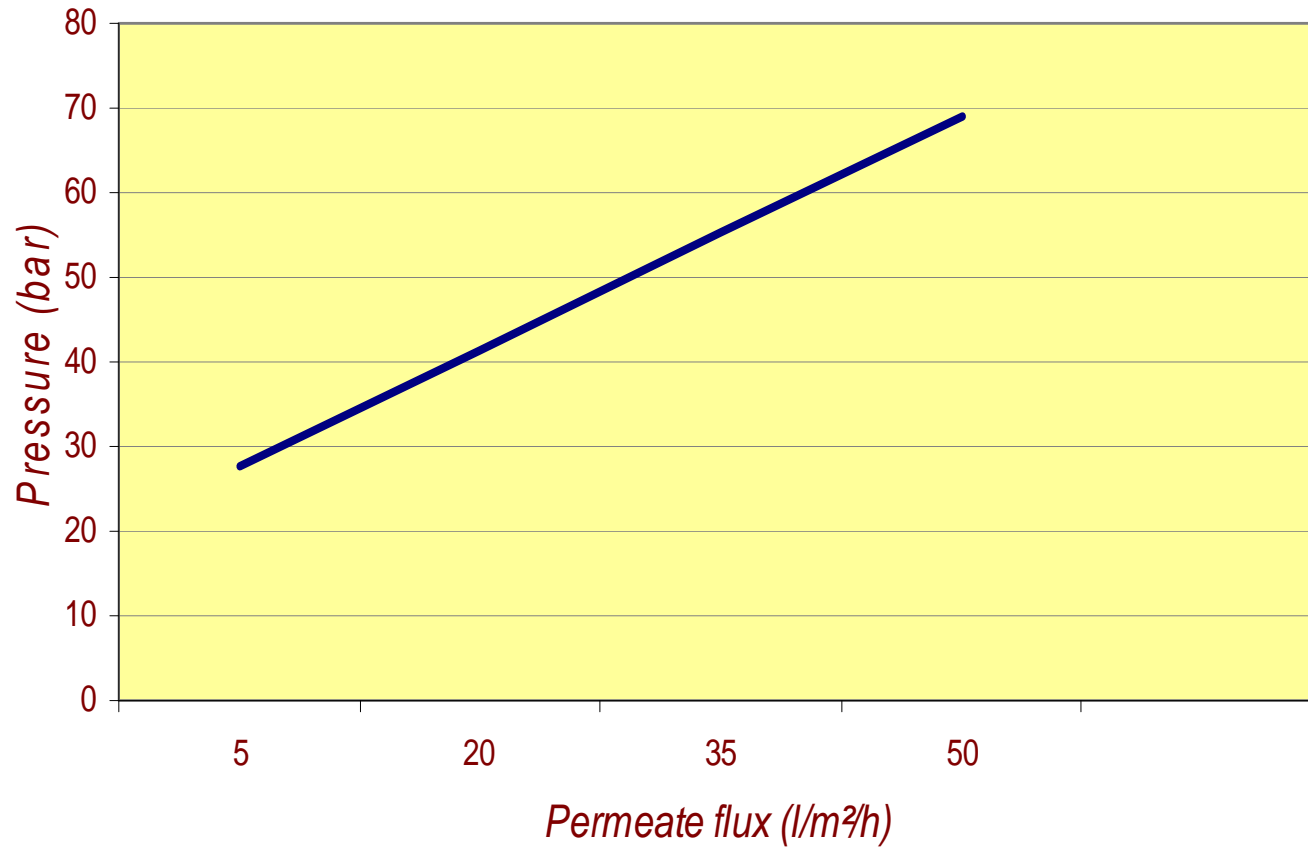
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Effect of Pressure on Quantity (seawater)

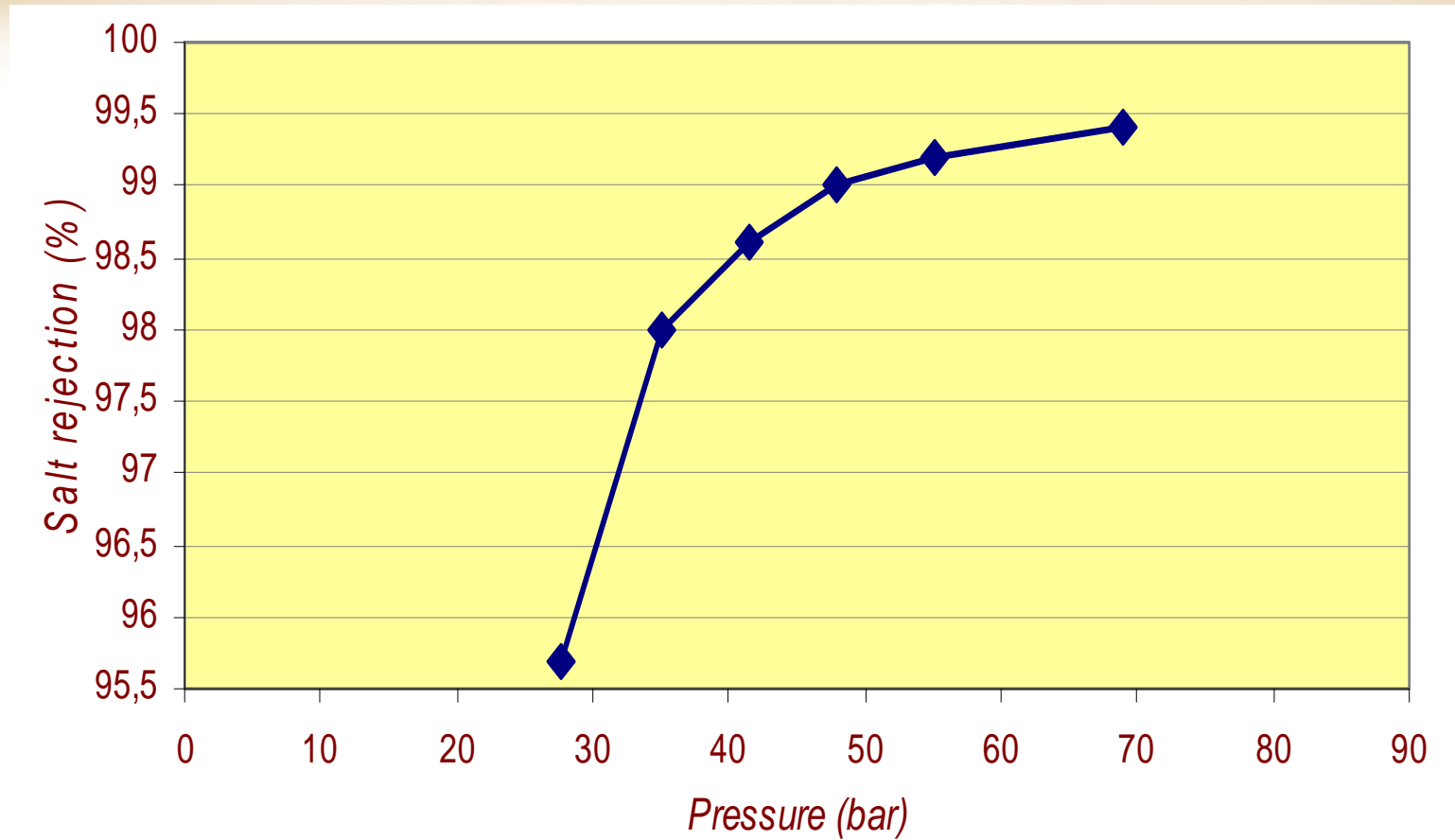
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Effect of Pressure on Quality

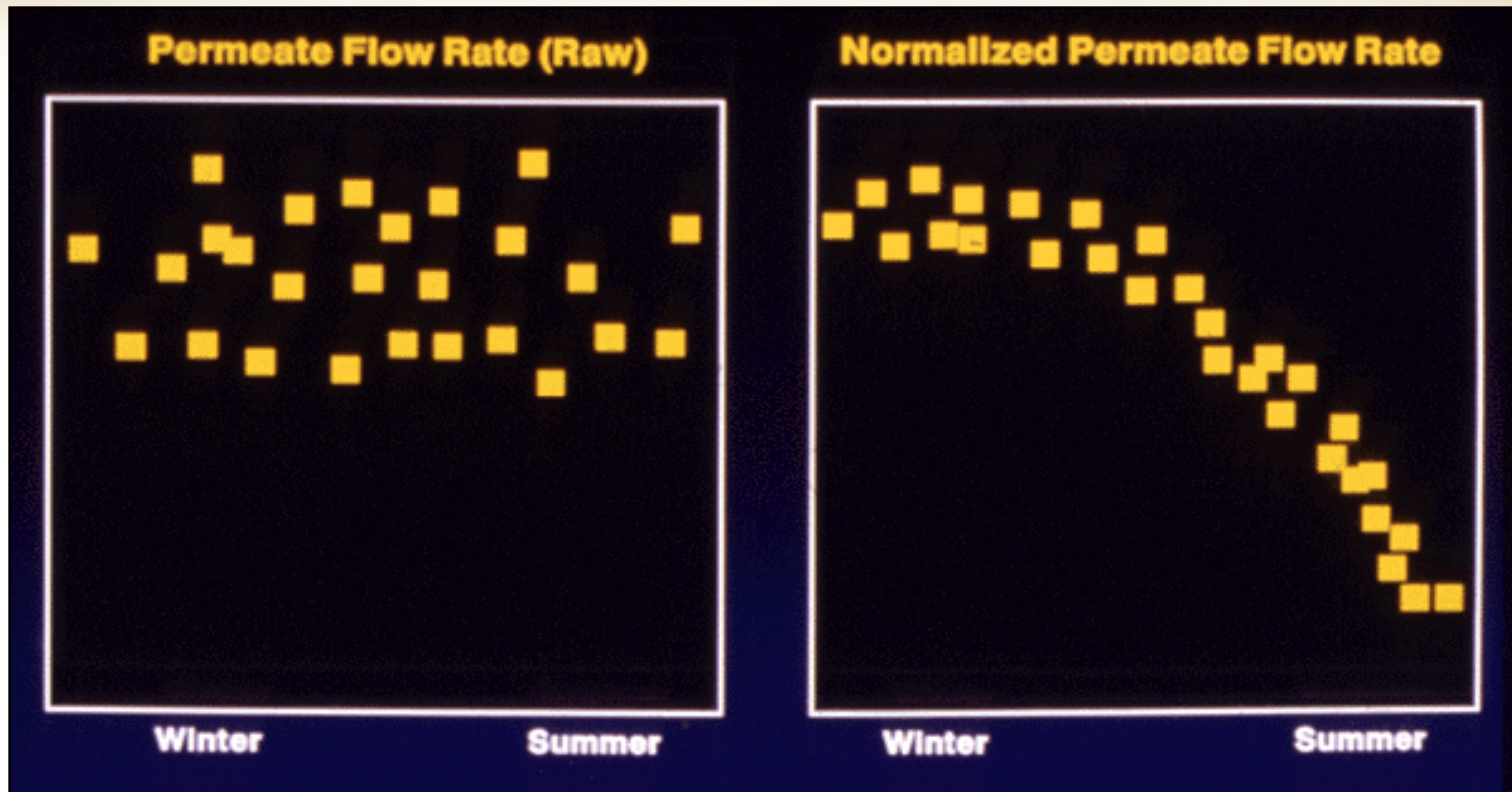
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Data Normalisation

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USE NORMALISED DATA !



RO Monitoring : Essential Parameters

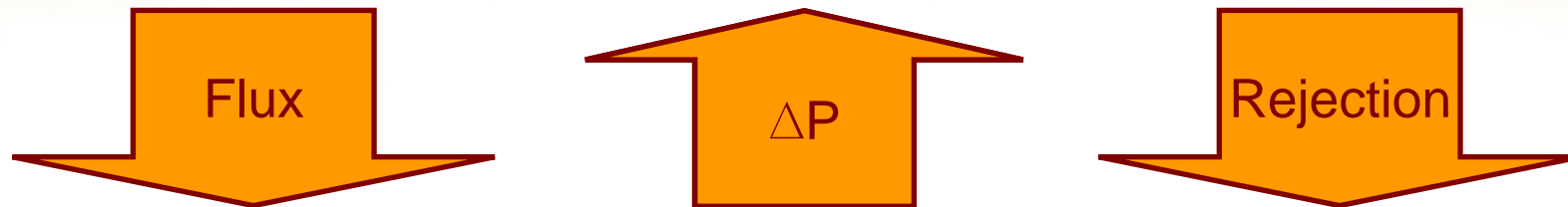
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- **Flows**
 - ↳ % recovery
- **Pressures :**
 - ↳ Delta P (by stage)
- **Conductivity**
 - ↳ Salt passage

CLEAN AT THE LATEST WHEN CHANGE IS 10-15%



Fouling & Scaling Effects in RO plants



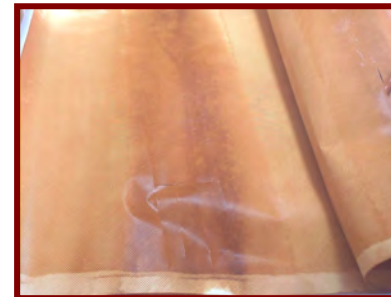
- **Clogging of spacer spiral wound elements**
- **Higher hydraulic resistance due to deposition/adsorption of material on the membrane surface**
- **Decrease in rejection due to concentration polarization in the foulant layer**



Fouling & Scaling Nature



- **Particulate fouling**
 - ↳ Suspended solids & colloidal matter
- **Inorganic fouling**
 - ↳ Iron & Manganese
- **Biofouling**
 - ↳ Growth of bacteria
- **Organic fouling**
 - ↳ Organic Compounds
- **Scaling**
 - ↳ Precipitation of sparingly soluble salts





The logo for Genesys International is located in the top right corner. It features three black mountain peaks of varying heights above the text "GENESYS INTERNATIONAL" in a white, sans-serif font. The background behind the logo is a gradient of orange and yellow, suggesting a sunrise or sunset.

ANTISCALANTS



Antiscalant Main Types



Two basic types :

- Organic Polymeric Compounds
- Phosphonates

Reaction :

- Sub-stoichiometric

Differences :

- Scale inhibition mechanisms
- Properties



Antiscaling Mechanisms



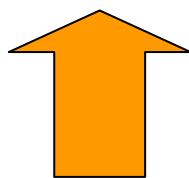
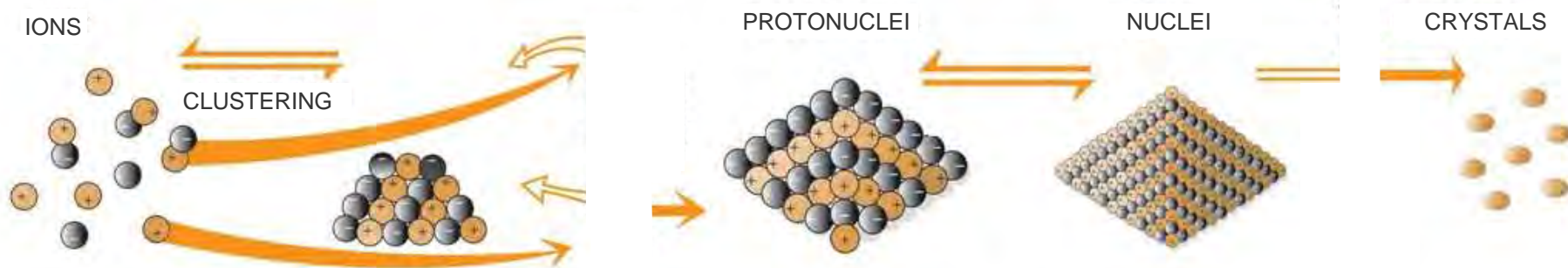
- **Crystal distortion**
- **Threshold effect**
- **Dispersion**
- **Chelation**

⇒ **Antiscalants use one or more of these mechanisms**

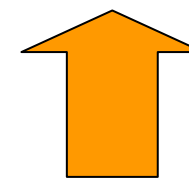


Inhibition Mechanisms

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THRESHOLD EFFECT :
PHOSPHONATES



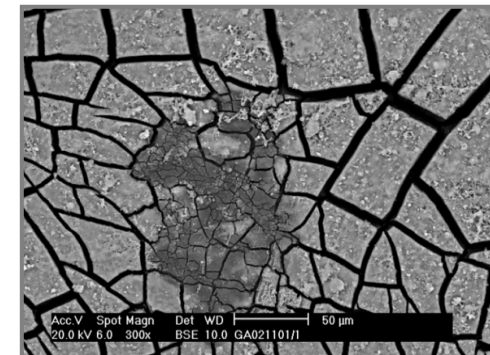
CRYSTAL DISTORTION :
ORGANIC POLYMERS



Organic Polymers



- **Based mainly on polyacrylic & polymaleic acids**
- **Main antiscaling mechanism : Crystal Distortion**
⇒ precipitation occurs but agglomeration is inhibited
- **Contain AOC, a potential nutrient for bacteria**
- **Do not sequester iron**
- **Can form iron acrylate**
⇒ irreversible fouling
- **Medium silica inhibitor**





Phosphonates



- **Based on phosphonic acid**
- **Main antiscaling mechanism : Threshold Effect**
⇒ no precipitation occurs as ordering is disrupted
- **Sequester iron**
- **Dispersant effect on colloids & suspended solids**
- **Moderate chelating effect**
- **No biological growth**
- **Strong silica inhibitor**

⇒ **Phosphonates offer the best compromise to date**



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BASIC CLEANING PRINCIPLES



Cleaning Skid Design



The fundamentals of CIP system design should be common knowledge nowadays :

- **Correctly sized tank : 25-40 litres per 8" element**
- **Flowrate 8,0 - 10,5 m³/h/PV**
- **Pressure < 4 bar - 60 psi**
- **Permeate make-up supply**
- **Possibility to clean stages separately**



Cleaning Guidelines



Basic cleaning principles should also be widespread :

- **Clean latest when plant performance changes 10-15%**
- **Always warm the cleaning solution to 25-40°C**
- **Soak and recycle the cleaning solution**
- **Check pH & adjust when needed**
- **Flush system thoroughly between cycles**



Cleaning Efficiency



Following these guidelines should in principle guarantee a fairly trouble-free system.

Yet closely monitored and regularly cleaned RO systems can still suffer from fouling build-up over time.

⇒ **The chemical formulation and site implementation can have a noticeable impact on the cleaning result**



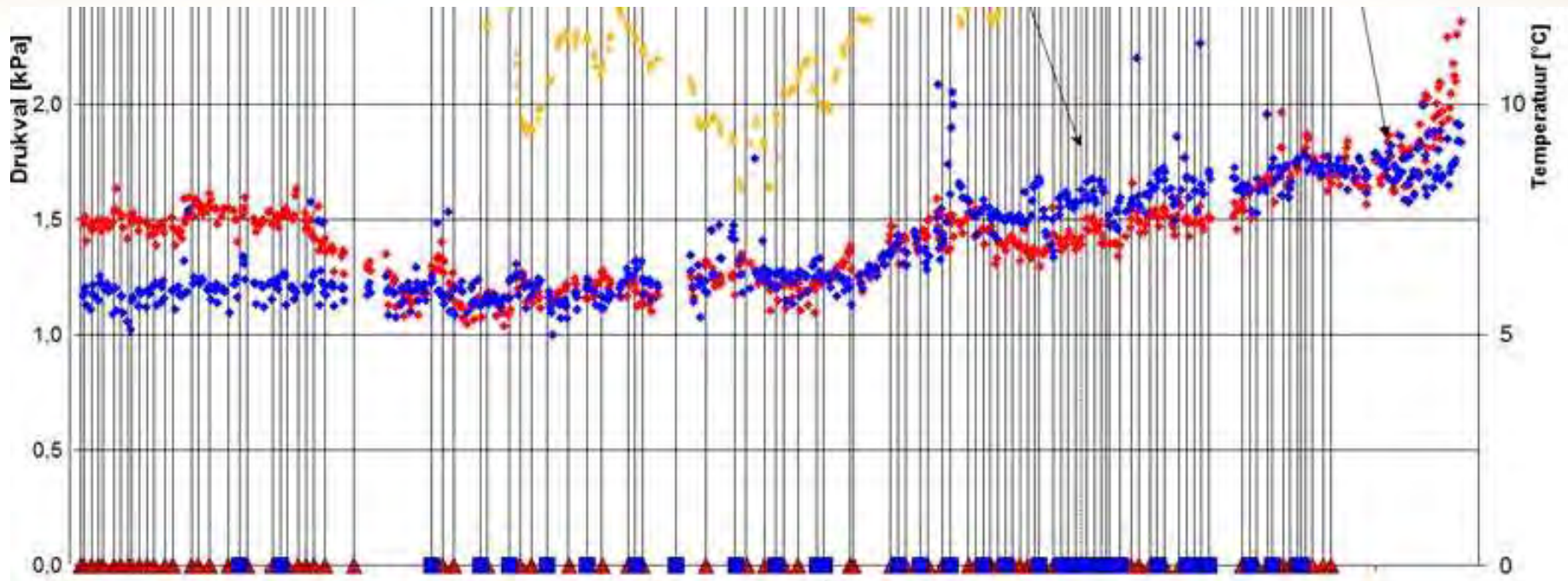
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CHEMICAL CLEANING EFFICIENCY



Historical Data Plant 1

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Automated cleaning up to 3 times / week using NaOH only



Cleaning Efficiency



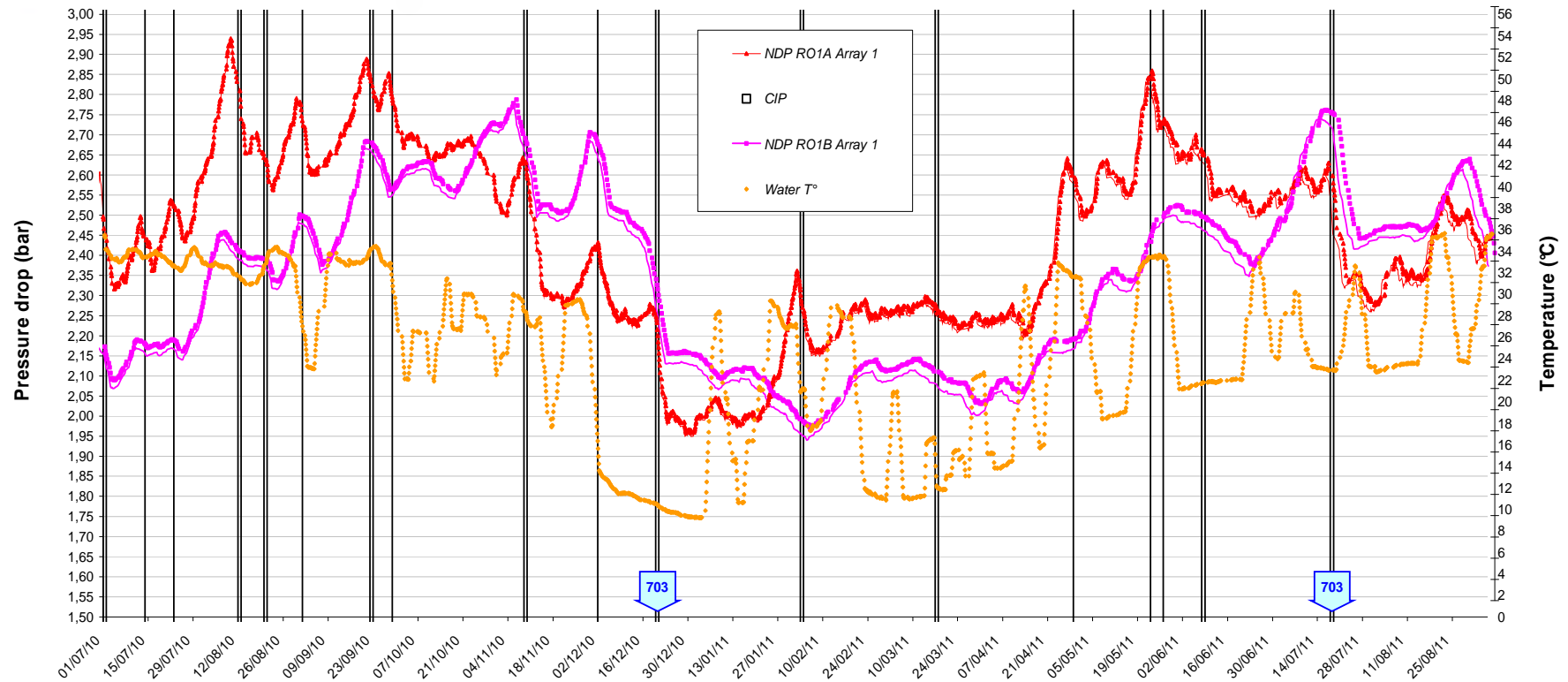
⇒ **Commodity chemical cleaning at high frequency is sufficient to contain fouling within operational limits, but cannot prevent foulant build-up over time**



Historical Data Plant 2



NDP RO1A & RO1B - Array 1 (moving average on 20 values)
BW30-400/34i resp. BW30-400FR & BW30XFR-400/34i





Results



⇒ **The implementation of powerful, targeted speciality cleaners instead of commodity chemicals enabled a larger portion of foulant to be removed and a cleaner membrane state to be achieved**



Question



Today, cleaning is considered almost purely as a form of corrective maintenance.

What if we look at it from the preventive point of view ?



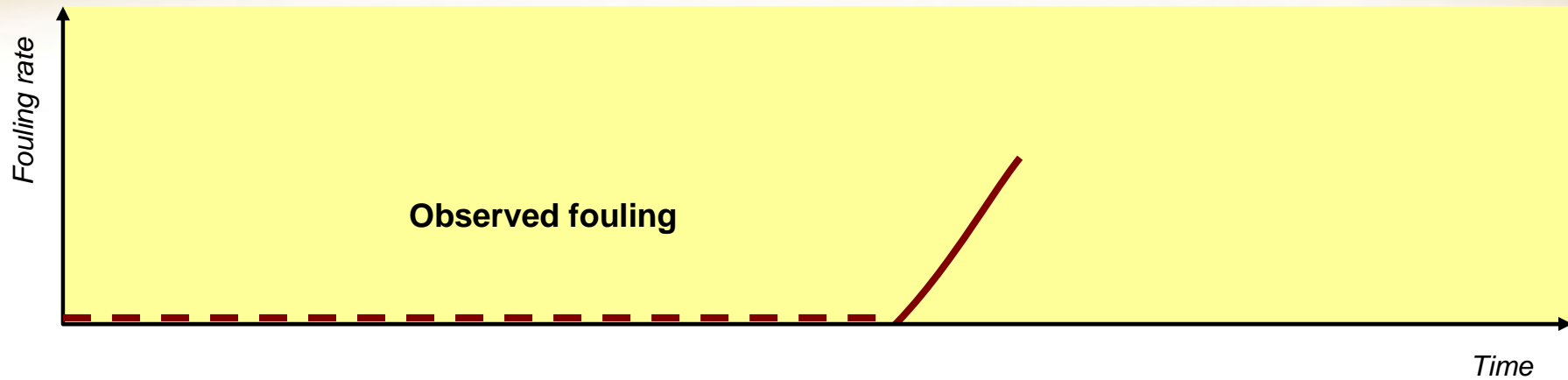
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RO FOULING THEORY



Fouling Process

Visible fouling



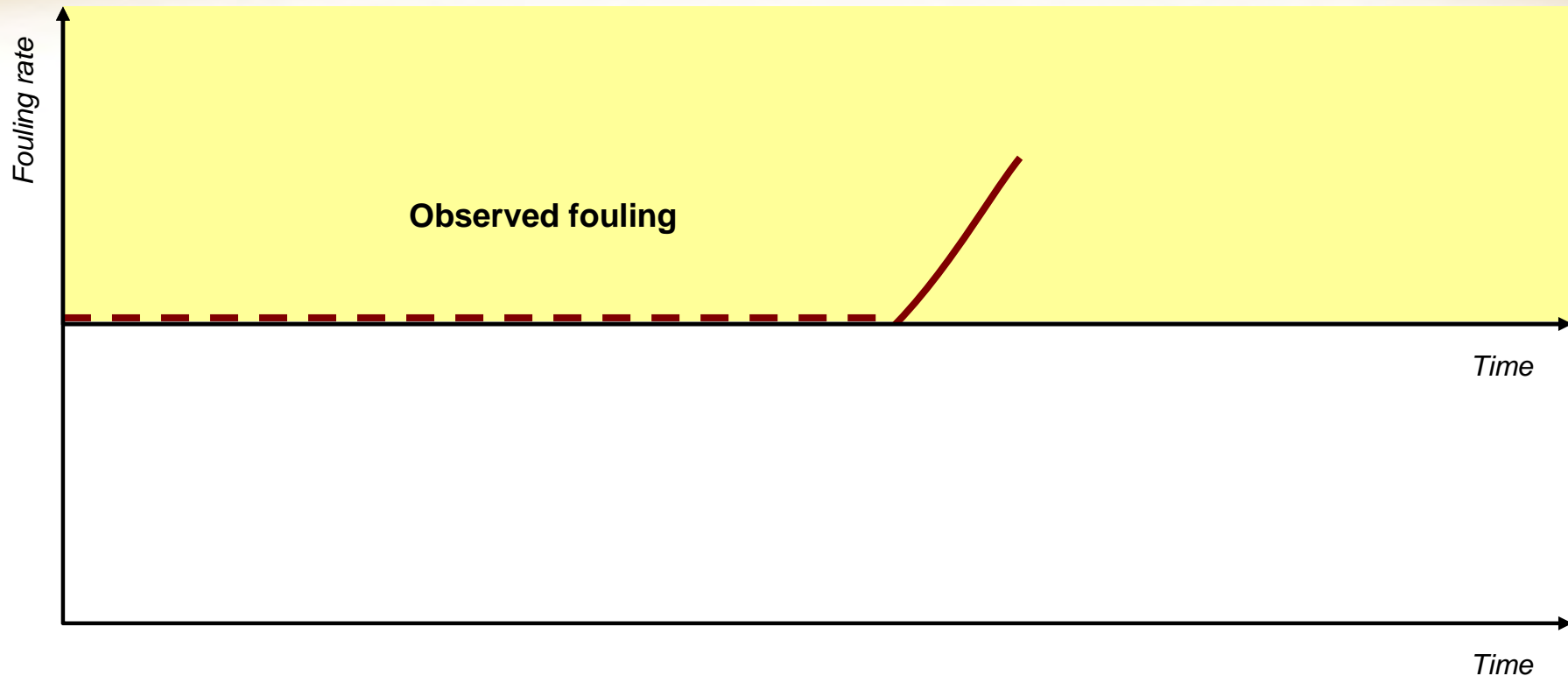
Fouling is not immediately detectable (measurable)



Fouling Process

Invisible fouling

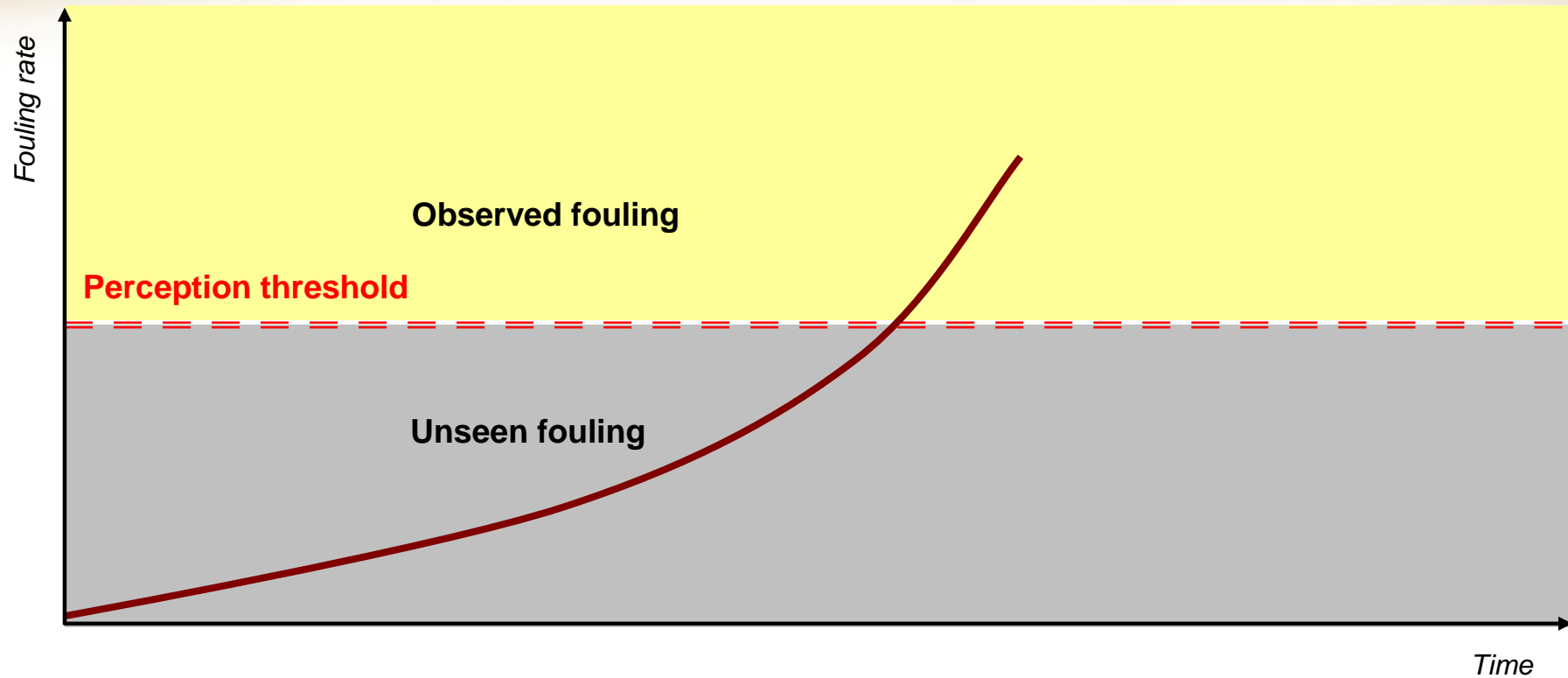
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Yet fouling starts as soon as water flows through the membrane, at a rate which is roughly constant for a given system

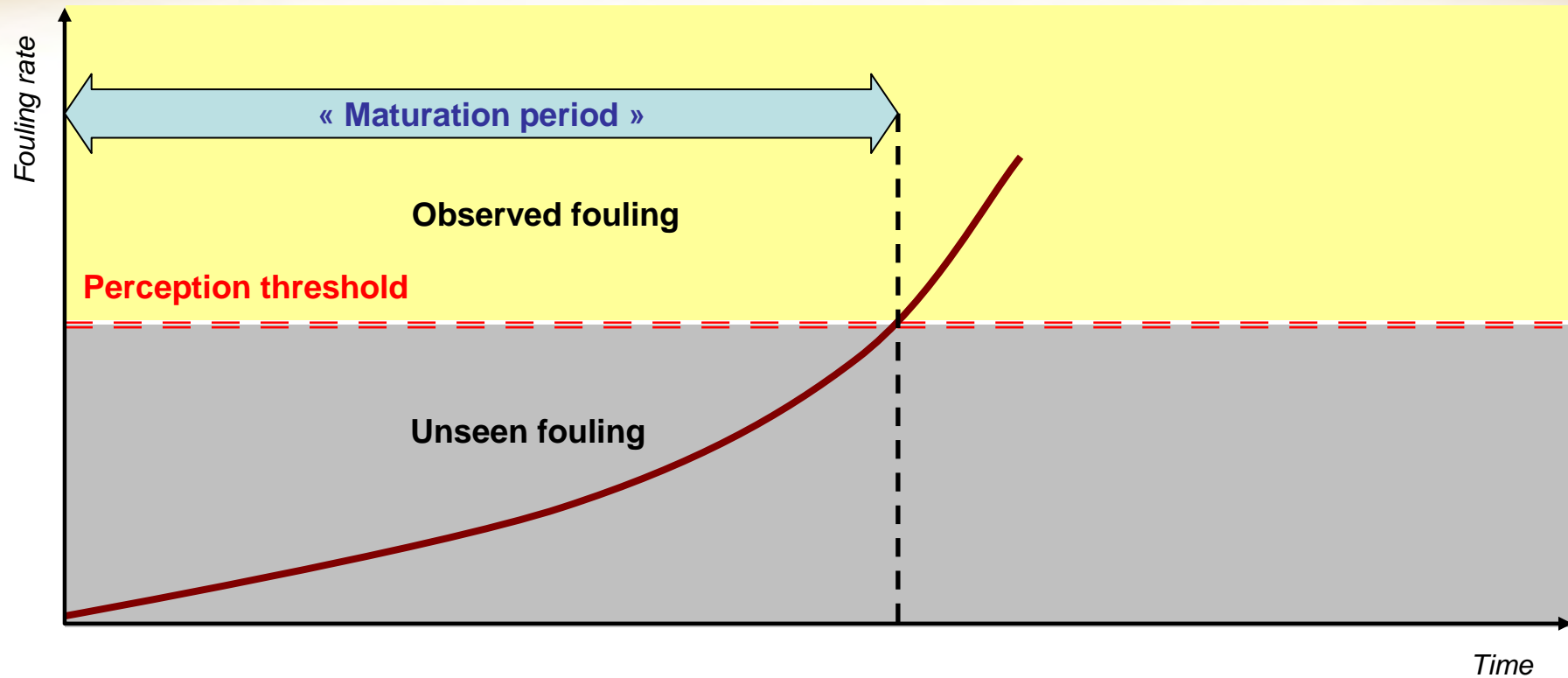


Fouling Process Perception Threshold





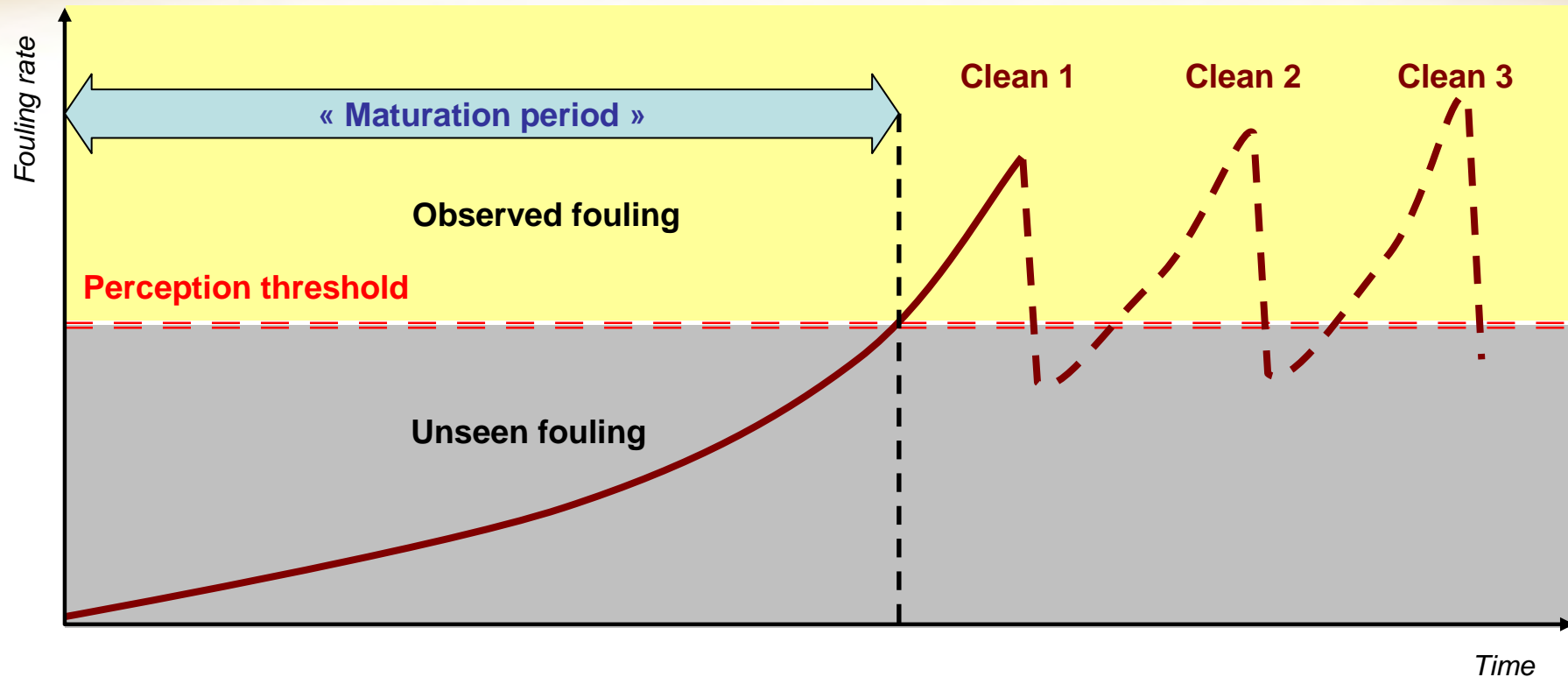
Fouling Process Maturation





Fouling Process Late Cleaning Interval

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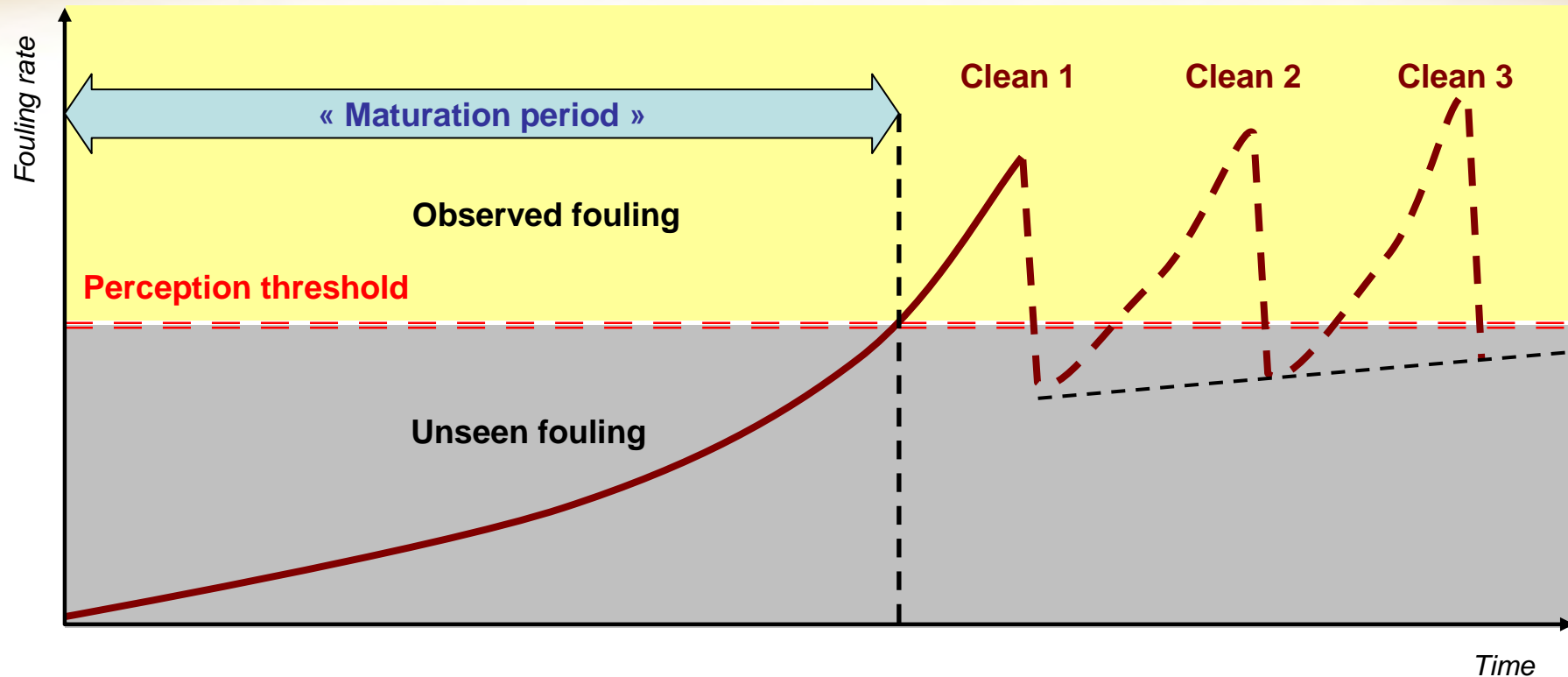


A clean is only triggered when “enough” fouling has taken place.



Fouling Process Late Cleaning Interval

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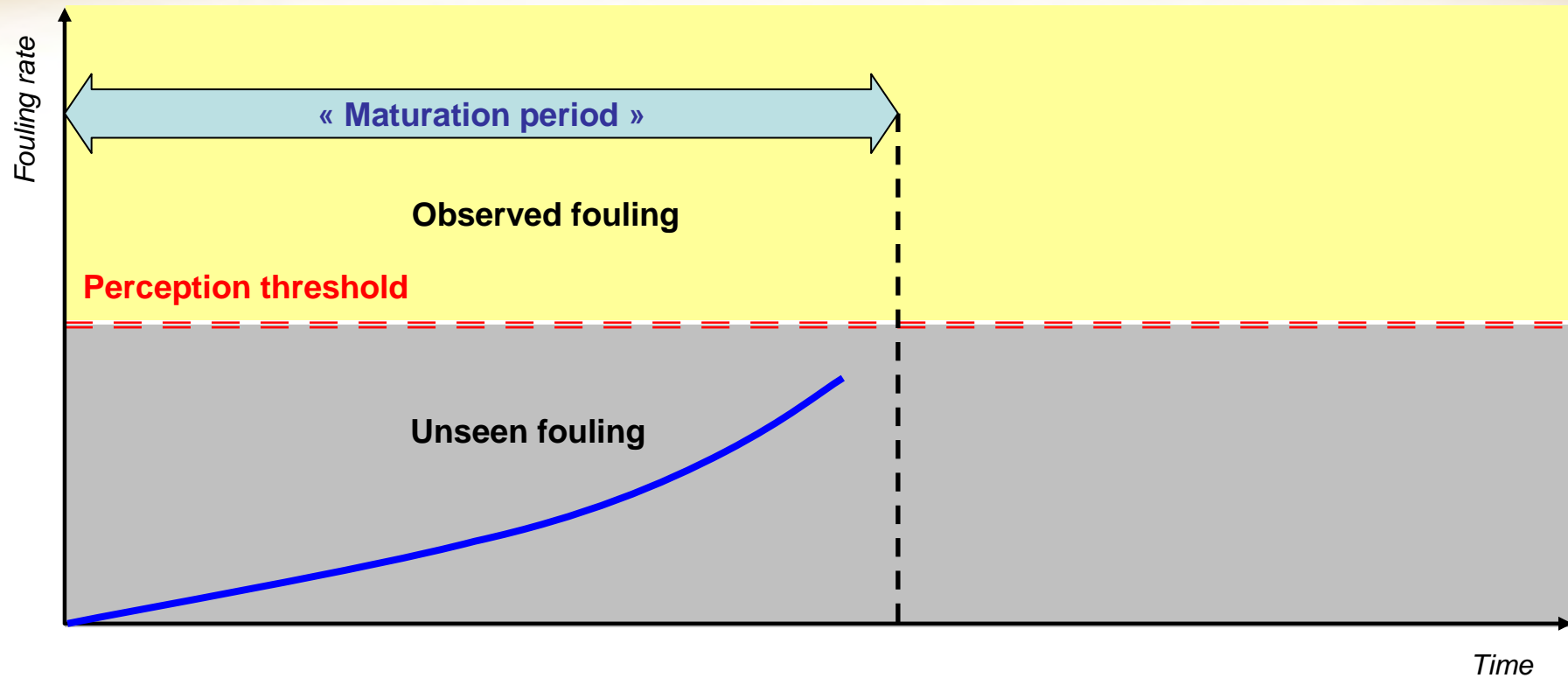


**The membrane is seldom cleaned to its original state
⇒ a layer of stable foulant builds up with time**



Fouling Process Early Cleaning

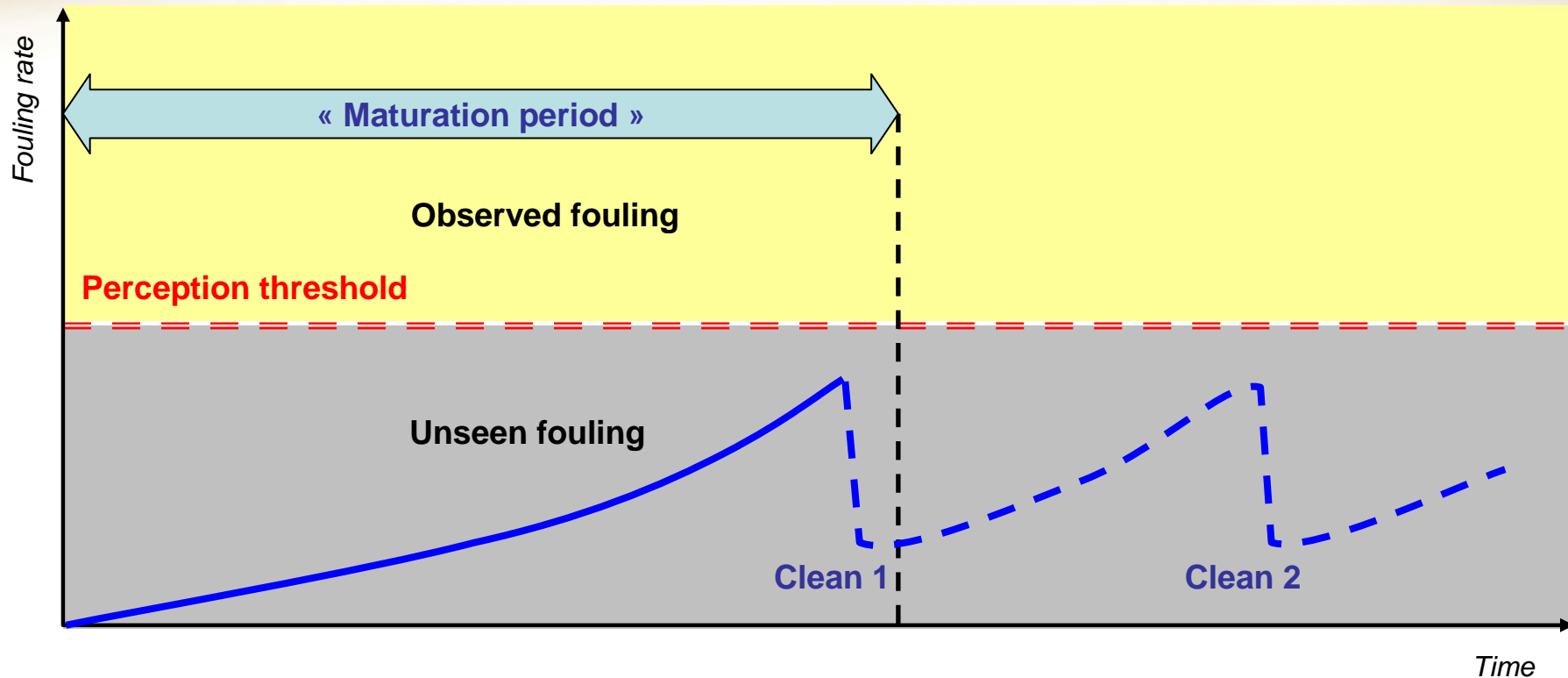
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Fouling Process Early Cleaning Interval

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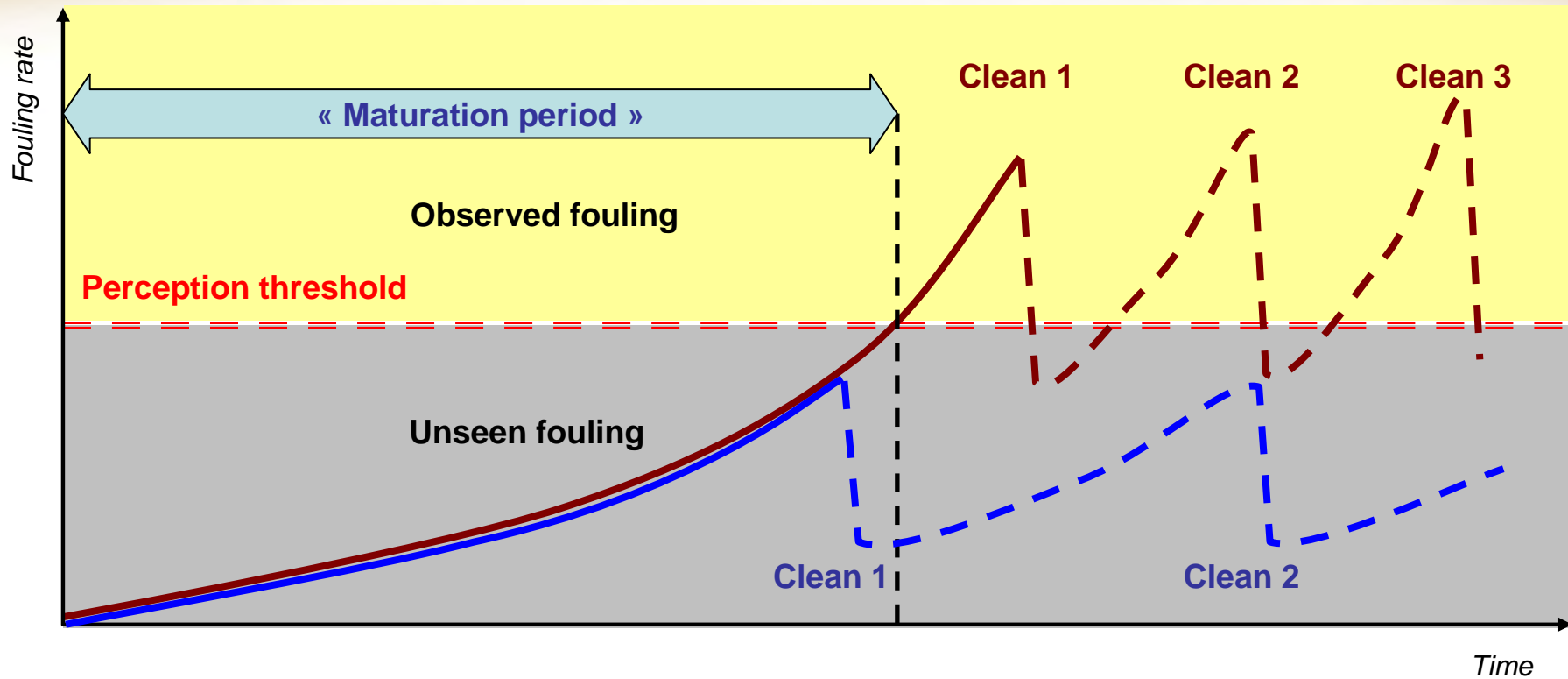


Although it may seem counterintuitive, early cleaning is far preferable



Fouling Process

Advantages of Early Cleaning



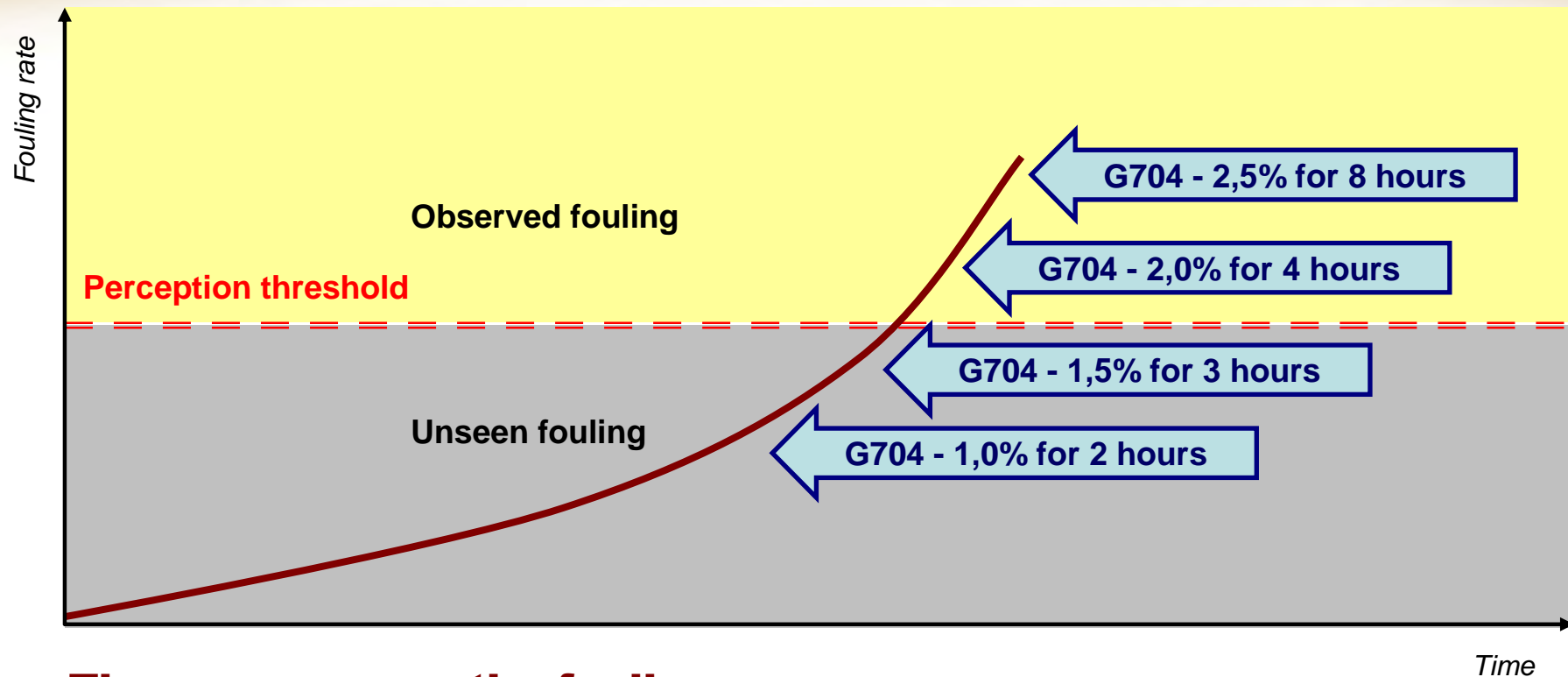
- ⇒ **Foulant easier to remove**
- ⇒ **Increased interval between cleans**



Fouling Process

Advantages of Early Cleaning

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The more severe the fouling :

- ⇒ **The more extreme the chemical cleaner required**
- ⇒ **The longer the contact time required**



Preventive Cleaning

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Early cleaning has many direct and indirect advantages :

- **foulant easier to remove**
- **use of gentler cleaning solutions (pH & temperature)**
- **shorter cleaning time**
- **increased interval between cleans**
- **significant savings in energy and water**
- **extended membrane life**



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LATEST CLEANING PRODUCTS



Membrane Limits

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Membrane resistance to aggressive cleaning is limited and varies with membrane manufacturer and type.

Exposure to radical pH and temperatures always puts a strain on the membrane, each time shortening its life.

Yet most cleaning chemicals are more effective at extremes of temperature and pH.

⇒ **Cleaning programmes running at more neutral pH values and ambient temperatures would be preferable**



**More Efficiency
Less Bite**

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Early cleaning enables higher efficiency against fouling while requiring less aggressive cleaning solutions.

⇒ **Genesol 704 (alkaline) and Genesol 701 (acidic) are the first examples of this new breed of cleaning products**



Genesol 704 Alkaline Powder Cleaner

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Alkaline powder cleaner

⇒ **blend of surfactant, sequestrant, inorganic phosphate**

Effective against :

- aluminosilicates (clays)**
- organics**
- biofouling, algae & fungi**

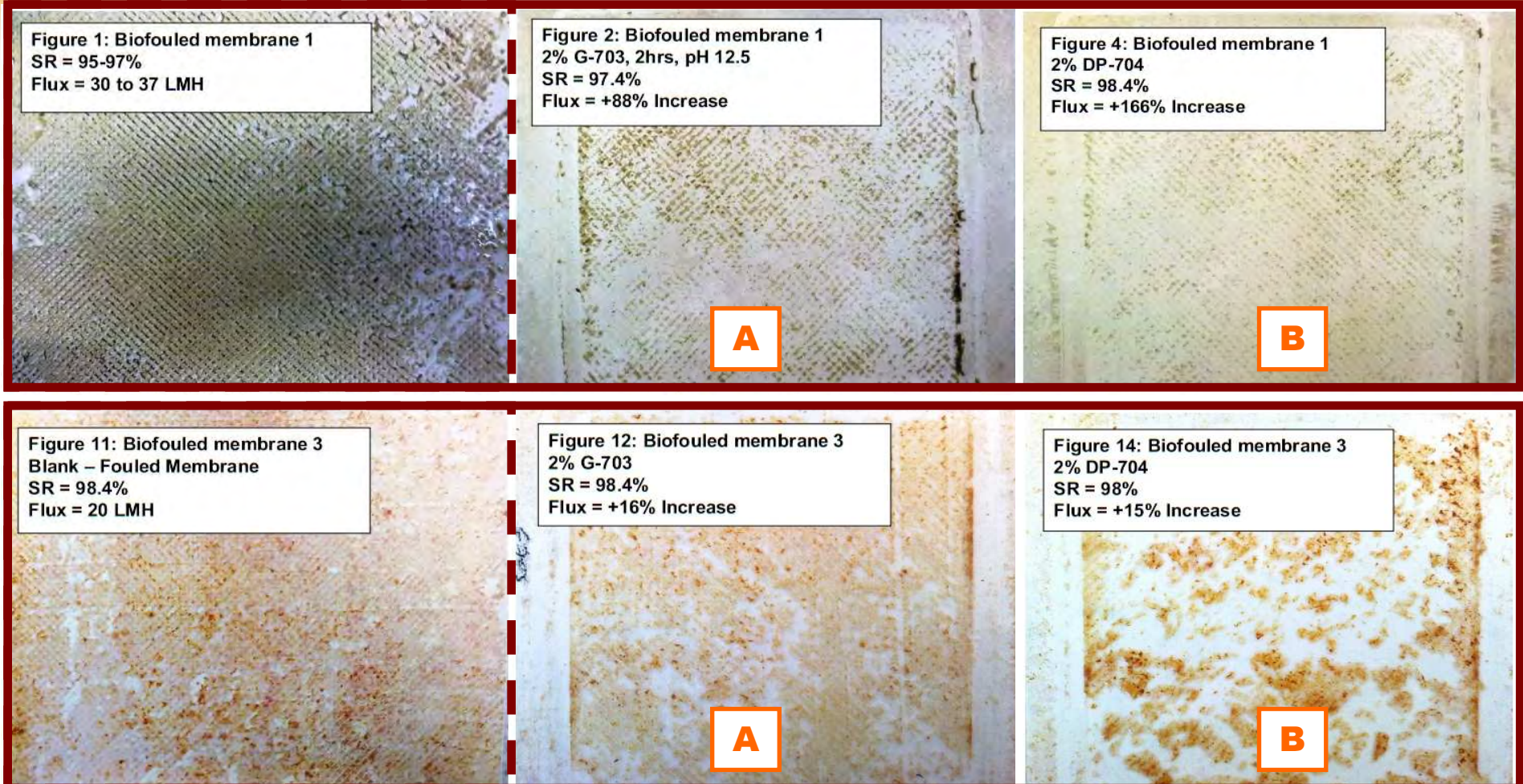
pH of 1,5% solution : around 11,6

Use 1-2 % for 2 to 4 hours against light to heavy fouling



Genesol 704 Biological Fouling

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Genesol 701

Acid Powder Cleaner

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Acid powder cleaner

⇒ **mixed blend of non-toxic acid chelants**

Effective against :

- **iron & manganese**
- **CaCO₃ & other acid soluble scales**
- **algae, fungi & bacteria**

pH of 2% solution : 2,8

Use 1-2% for 2 to 3 hours against iron fouling and light inorganic scale



Genesol 701 Inorganic Fouling

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**CaCO₃
&
Al-silicates**

Fig 7: Blank: CaCO₃ Fouled membrane

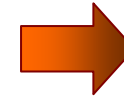


Fig 12: Test 6b G-701F 2hrs: +53% Flux increase



Iron

Fig 3: Blank: Fe Fouled membrane

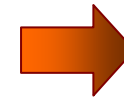


Fig 6: Test 3b G701F: +46% Flux increase





Genesol 61

Neutral Liquid Cleaner



Neutral liquid cleaner

⇒ **blend of organic acids & chelants with inhibitors**

Effective against :

- organics**
- biofim**
- iron & calcium based deposits**

Safe and low tox

Protects metal during cleaning

pH of 1.5% solution : around 8.0

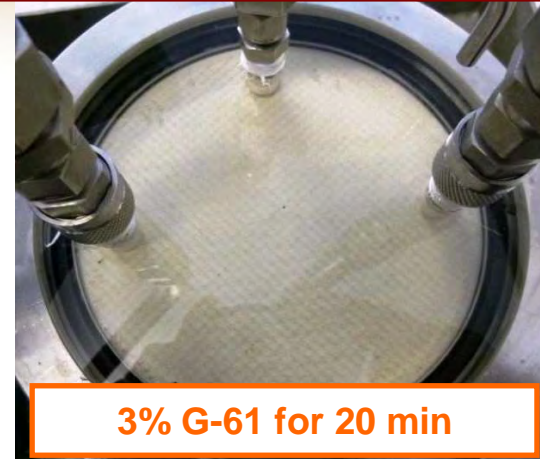
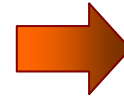
Use 1-2 % for 2 to 4 hours against light fouling



Genesol 61 Neutral pH Cleaning

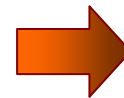


Manganese

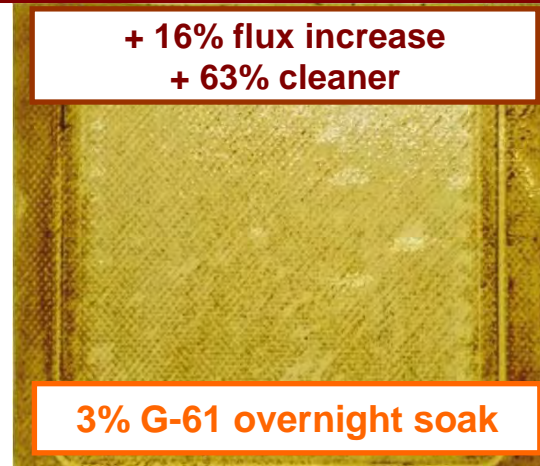


3% G-61 for 20 min

**Iron
&
clays**



**+ 16% flux increase
+ 63% cleaner**





3% G-61 overnight soak



Genesol 61 Neutral pH Cleaning



Iron & organics	<p>+ 11% flux increase</p>  <p>3% G-61 for 2 h</p>	<p>vs. G-38 clean at pH 3.8</p>	<p>- 49% flux decrease</p>  <p>3% G-38 for 2 h</p>
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Heavy organic fouling	<p>Partly cleaned</p>  <p>2% G-61 for 2 h</p>	<p>vs. G-40 clean at pH 11.9</p>	<p>No result</p>  <p>2% G-40 for 2 h</p>
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Conclusion



The combination of the “Early Cleaning” philosophy and new, gentler cleaning products is the key to :

- ⇒ **Easier CIP planning**
- ⇒ **Reduced cleaning and operational costs**
- ⇒ **Increased membrane life**
- ⇒ **Improved system availability**



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Genair
clean

A novel technology to increase the efficiency of RO/NF membrane cleaning using dual chemical - physical bubble generation approach



Background : BWRO & SWRO Foulants



- **More than 500 autopsies performed since 2001**
- **BWRO & SWRO from all over the world**
- **Huge variety of different feed waters & applications**
- **We understand the nature of membrane fouling**
- **Therefore we should know how to clean membranes**





Background : Membrane Failure

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Scaling / Fouling

**Physical
damage
(abrasion)**

**Chemical
damage
(oxidation)**

Reversible

(> 60% autopsies)

Irreversible

ΔP

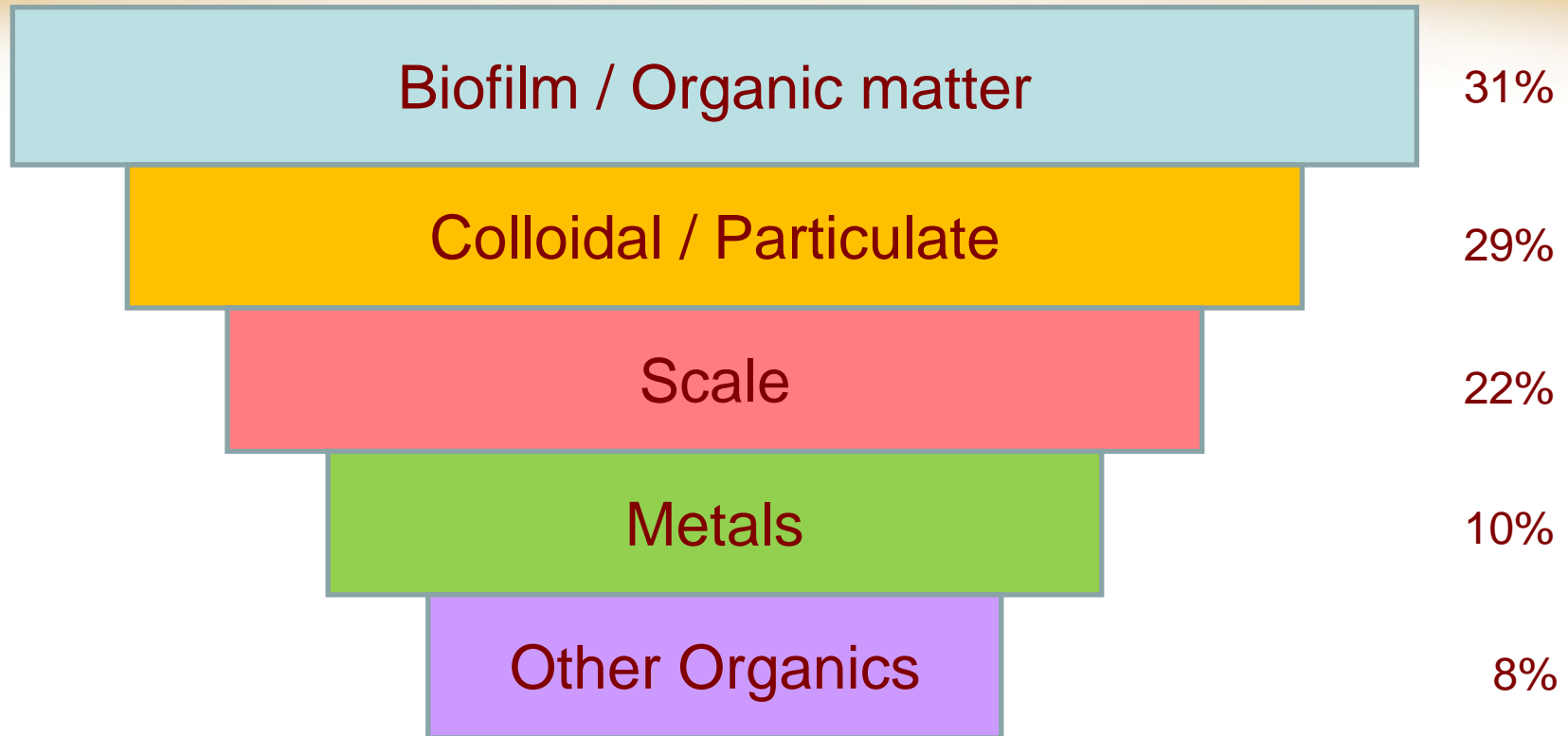
Δ flux

ΔSR



Fouling

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$\Delta P \nearrow$ $SR \searrow$ Flux \searrow



Fouling Experience



- **Pure foulants rarely occur**
- **First stage membranes – most common foulants are complexes of biofilm/organics/colloids & inorganic deposits such as Fe & Mn**
- **Different foulants require different chemistries/techniques to achieve complete removal**



GENAIRCLEAN



Fouling Summary



- GenAirClean uses both chemical and physical cleaning mechanisms (air bubbles) to enhance cleaning during CIP
- Uses a specially designed device to introduce air from the atmosphere
- Bubbles are also generated chemically using our new cleaners Genesol 704 and 701 (effervescent)



Genairclean Concept Background



- **R & D Project funded by the UK government**
- **Key Test Equipment Supplied by Salt Separation Services, UK**
- **Patent Pending – “improved method for cleaning RO & NF membranes”**
- **Dual CIP approach – microbubble generation by chemical & physical means to agitate & remove membrane foulants**



Why use Air ?



- Normal way to increase turbulence at the boundary layer is to increase cross flow which requires more energy
- A two-phase flow of air/chemical results in an increased turbulence at the boundary layer (increased rotating fluid flow) at no extra energy !
- Commonly used in MBRs and UF capillary membranes for periodic cleaning - but not RO/NF
- The trick is to get the right air:liquid ratio. Too much air intrusion leads to air-lock and stops fluid flow
- Use correct bubbles size and velocity - tailor made generating device and cleaning chemicals



Test Equipment



FSTR with viewing window :

- observe and monitor bubble size, distribution and effect on foulant removal
- characterise removal of variety of common membrane foulants

RO Pilot Plant :

- measure cleaning efficiency full scale 8" membranes
- process compatibility with new membranes
- observe bubble generation

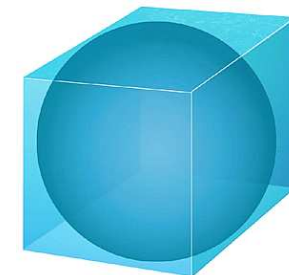
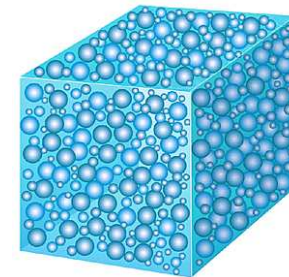




Bubbles

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<i>Description</i>	<i>Size</i>	<i>Production</i>
Nanobubble	0.5-5 μm	Ultra-sound, pressure
Microbubble	5-50 μm	Ultrasound, pressure, venturi, chemicals
Minibubble	50-100 μm	Venturi, chemicals
Midibubble	100-500 μm	Venturi, chemicals

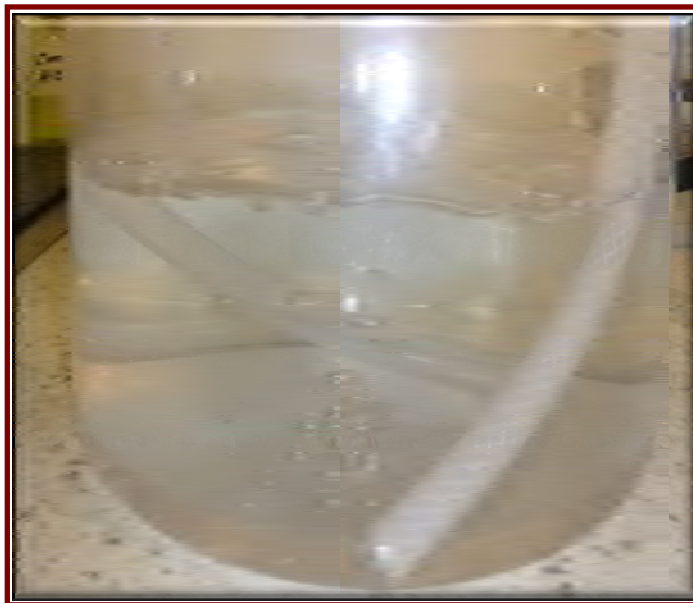




Microbubble Generation Laboratory



NaOH + Air



- ⇒ Large bubbles
- ⇒ Air locks in feed line

Genesol 704 + Air

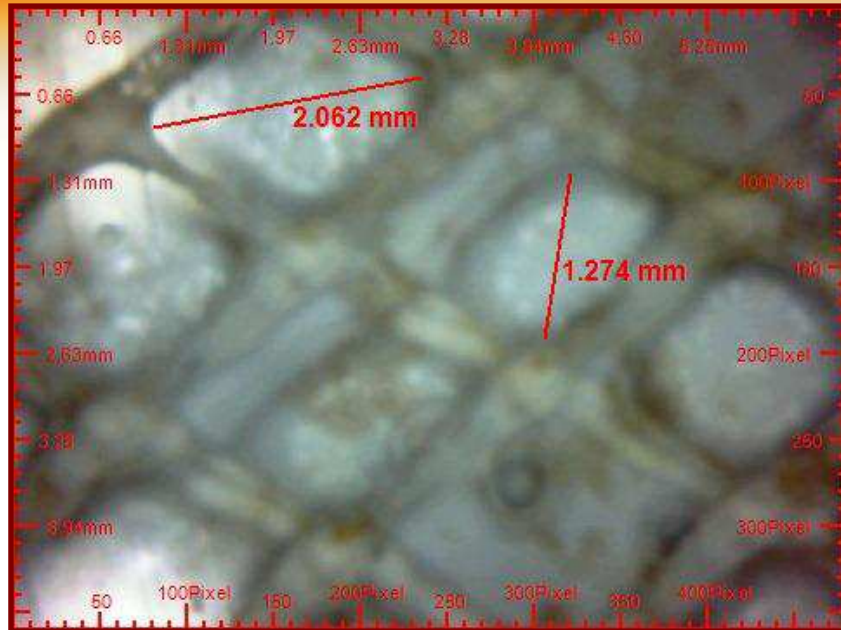


- ⇒ Small, refined bubbles
- ⇒ Pulsing action

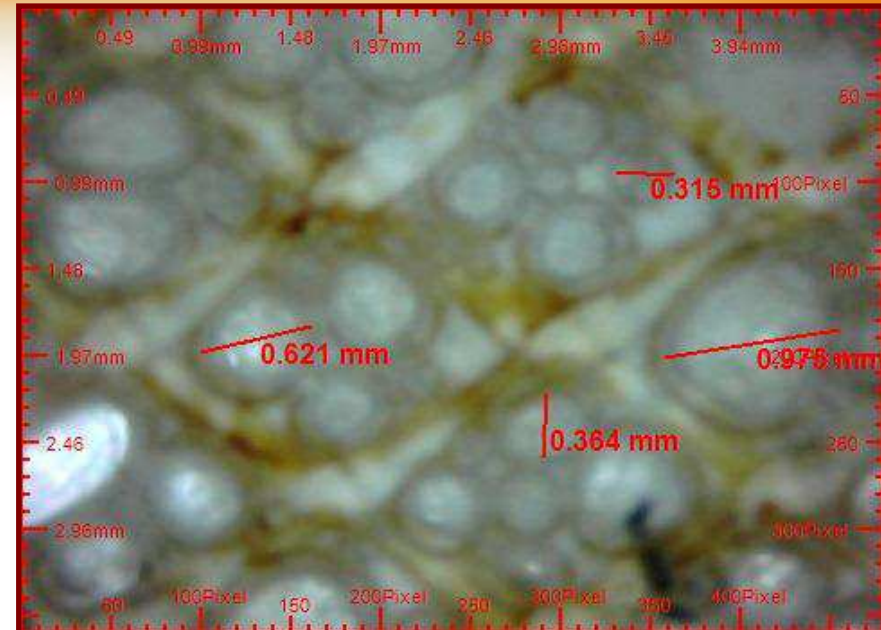


Bubble Optimisation

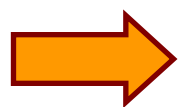
Endoscope/Microscope Measurements



Physical bubble generation
Bubble size 1-2mm \Rightarrow size of spacer



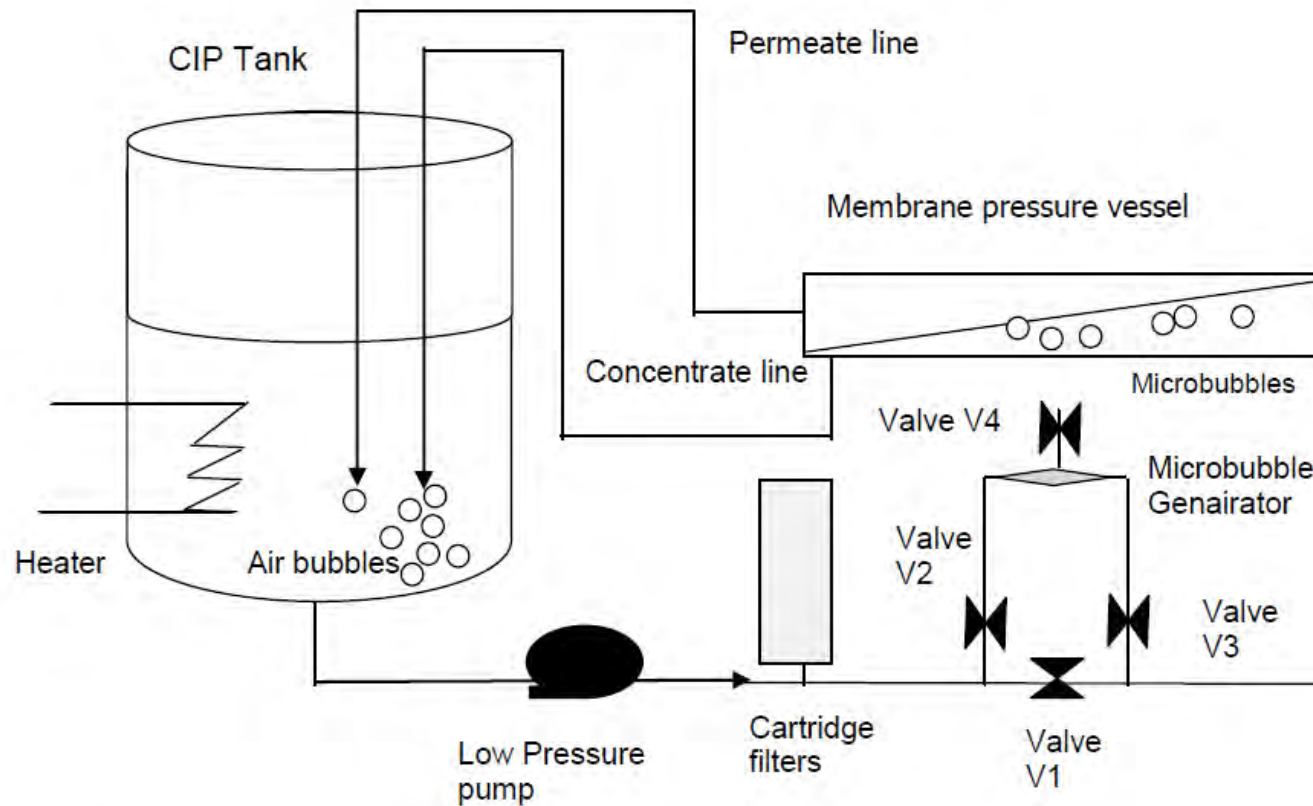
Chemical & physical generation
Reduce bubble size to 5-500 μ m



Dual generation approach increases no. of bubbles in contact with spacer & membrane surface & foulant removal

INNOVATIONS

Microbubble Genairator



Key

- Valve V1 = Valve in CIP line
- Valve V2 = Bypass valve for inlet to Microbubble Genairator
- Valve V3 = Bypass valve for outlet from Microbubble Genairator
- Valve V4 = Air control valve for Microbubble Genairator



Air Summary



- **Increasing air flow to an optimum level – increases chaotic flow, results in more mixing (generates vortices etc) and flow pattern changes**
- **When air/water ratio is right – small pressure pulses are seen in the cleaning solution flow**
- **Too much air leads to complete separation of air and liquid and can lead to air lock**
- **Bubble size remains fairly constant due to Genesol surfactant chemicals used**



Membrane Compatibility



Membrane Autopsy Verification

- Virgin membranes from major manufacturers tested with new CIP process.
- Membranes sent for autopsy for verification of condition post CIP - tests for physical & chemical damage
- Hydranautics, DOW, Toray



Genairclean Process

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FOULING | All new membranes foul.
Biofilm and clay can build up
rapidly in lead elements.

Visit www.genesysro.com



Genairclean Process

GENESYS
INTERNATIONAL



FOULING | Fouling rate increases as surface becomes rougher.



Genairclean Process

GENESYS
INTERNATIONAL



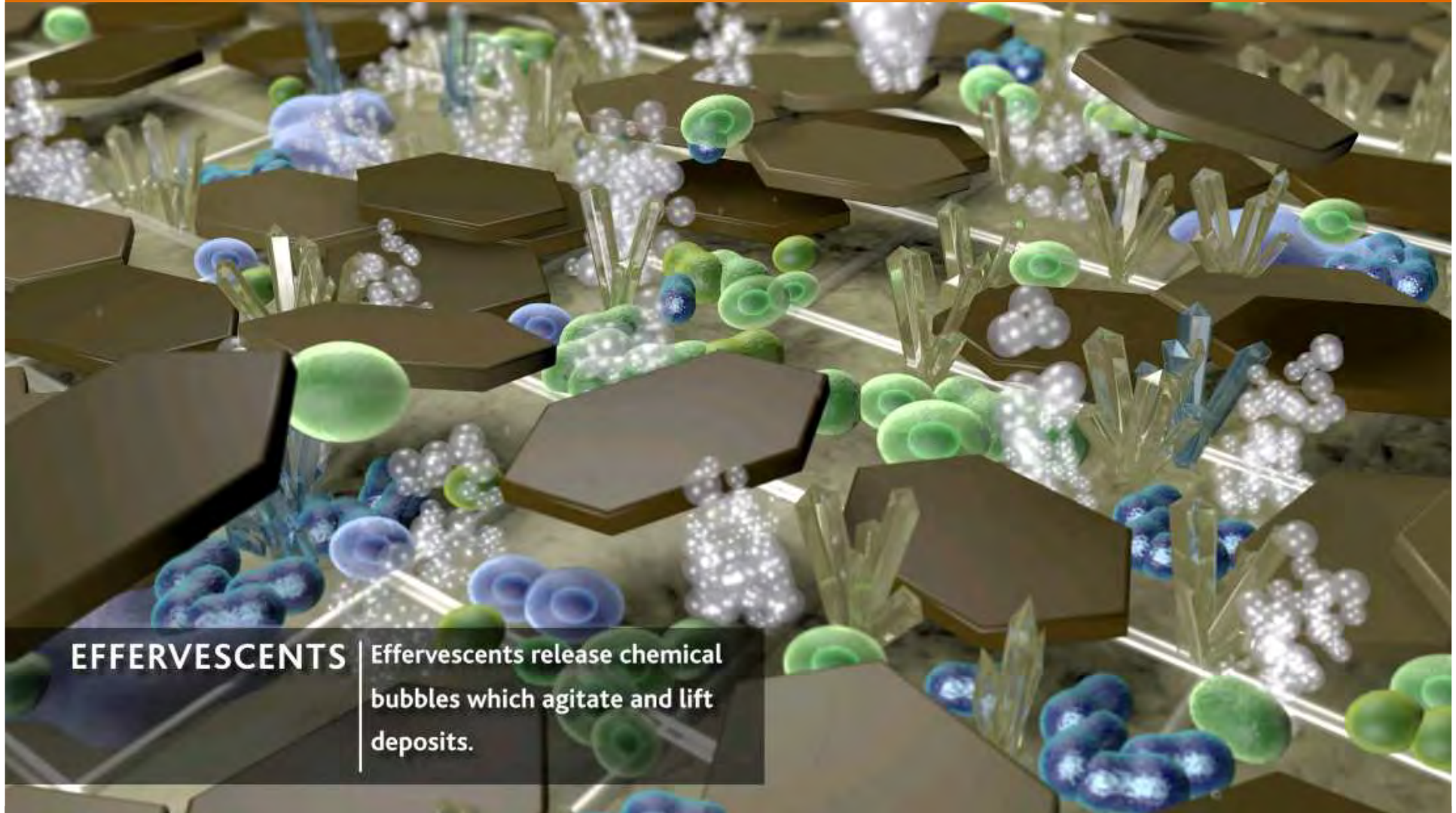
CLEANING Genesol cleaners combine detergents, chelants, effervescent and surfactants.

Visit www.genesysro.com



Genairclean Process

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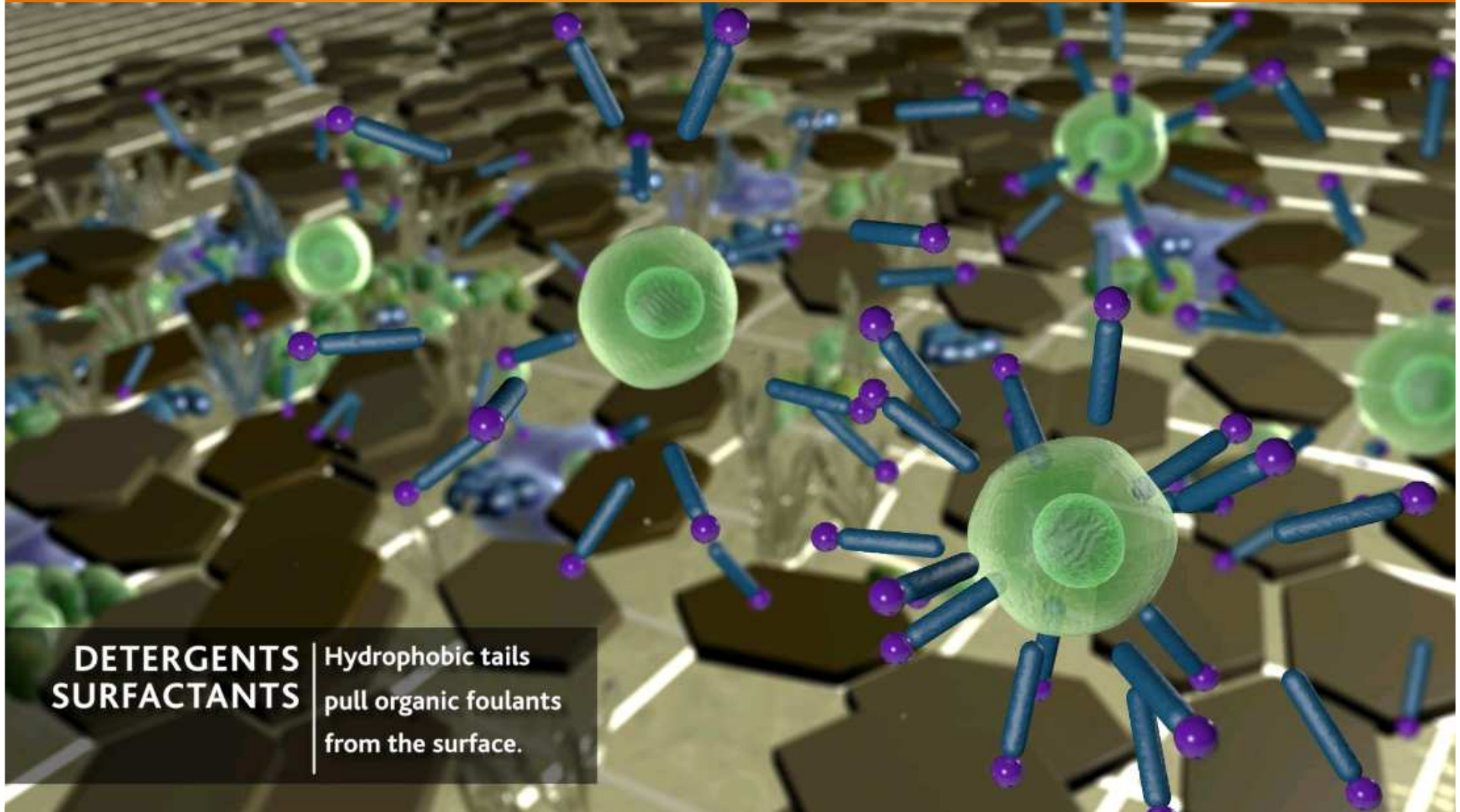
EFFERVESCENTS | Effervescent release chemical bubbles which agitate and lift deposits.

Visit www.genesysro.com



Genairclean Process

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**DETERGENTS
SURFACTANTS**

Hydrophobic tails
pull organic foulants
from the surface.

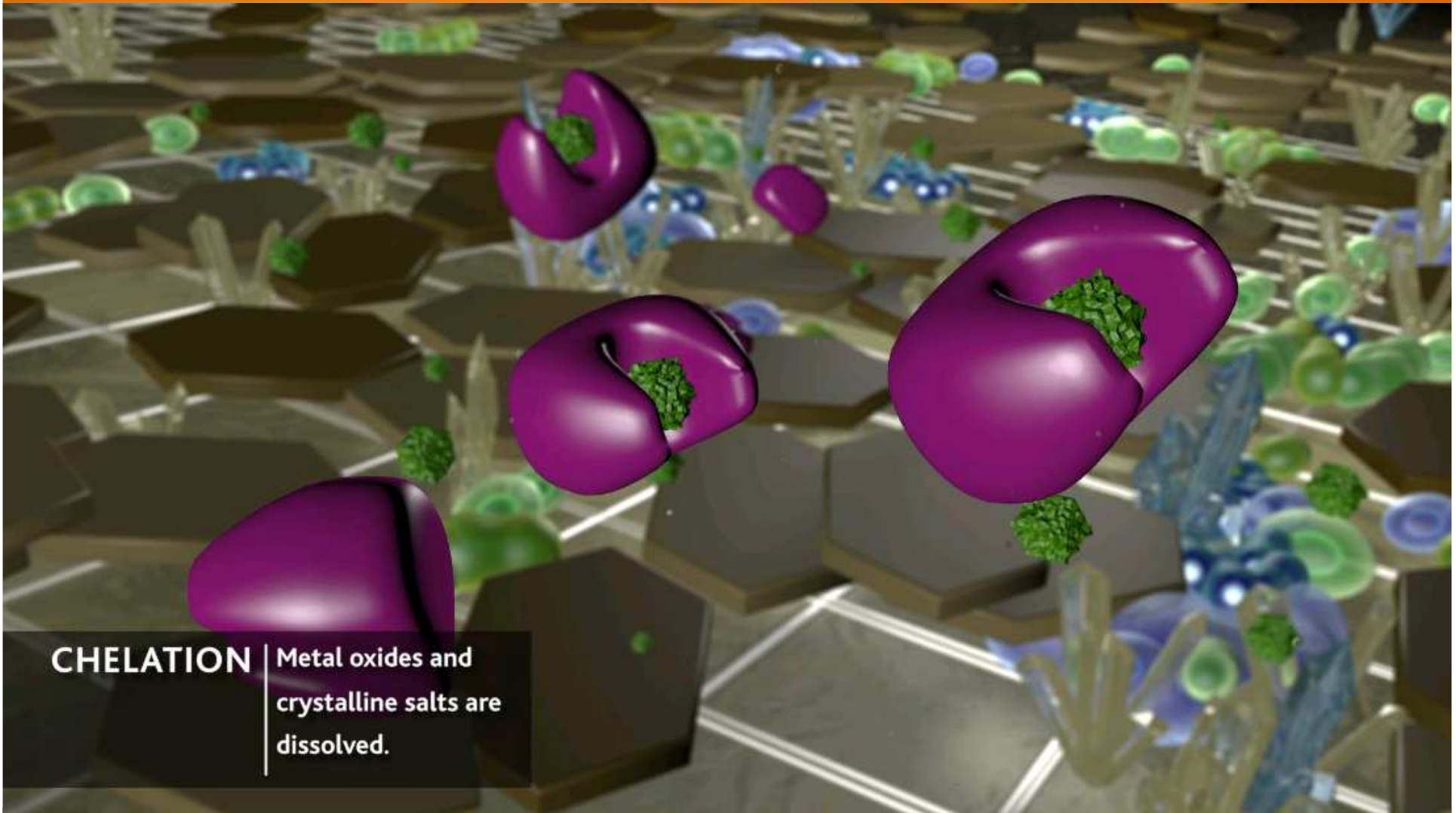
Visit www.genesysro.com



WAHANG SARAN CO.

Genairclean Process

GENESYS
INTERNATIONAL



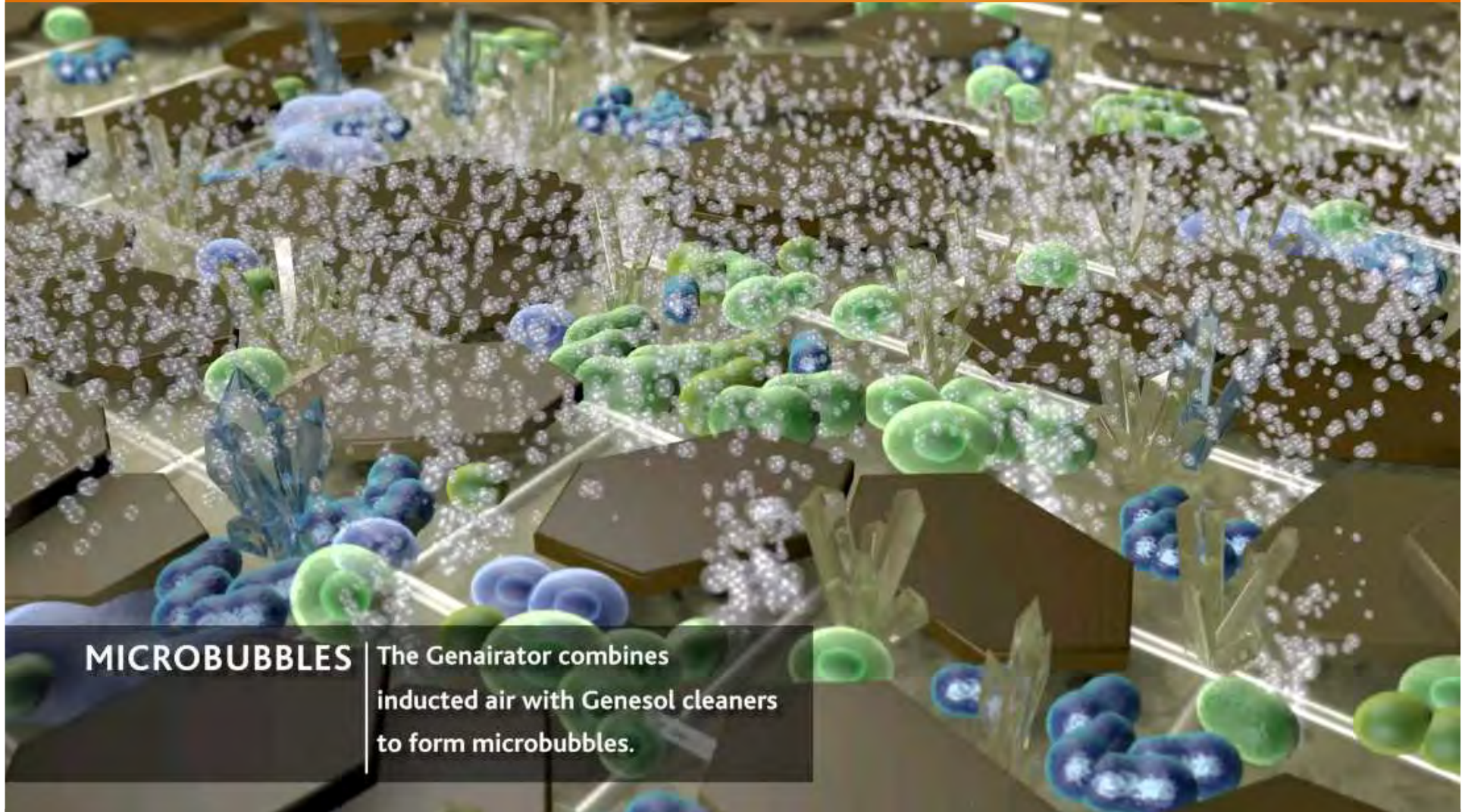
CHELATION | Metal oxides and crystalline salts are dissolved.

Visit www.genesysro.com



Genairclean Process

GENESYS
INTERNATIONAL



MICROBUBBLES | The Genairator combines inducted air with Genesol cleaners to form microbubbles.

Visit www.genesysro.com



Genairclean Process

GENESYS
INTERNATIONAL



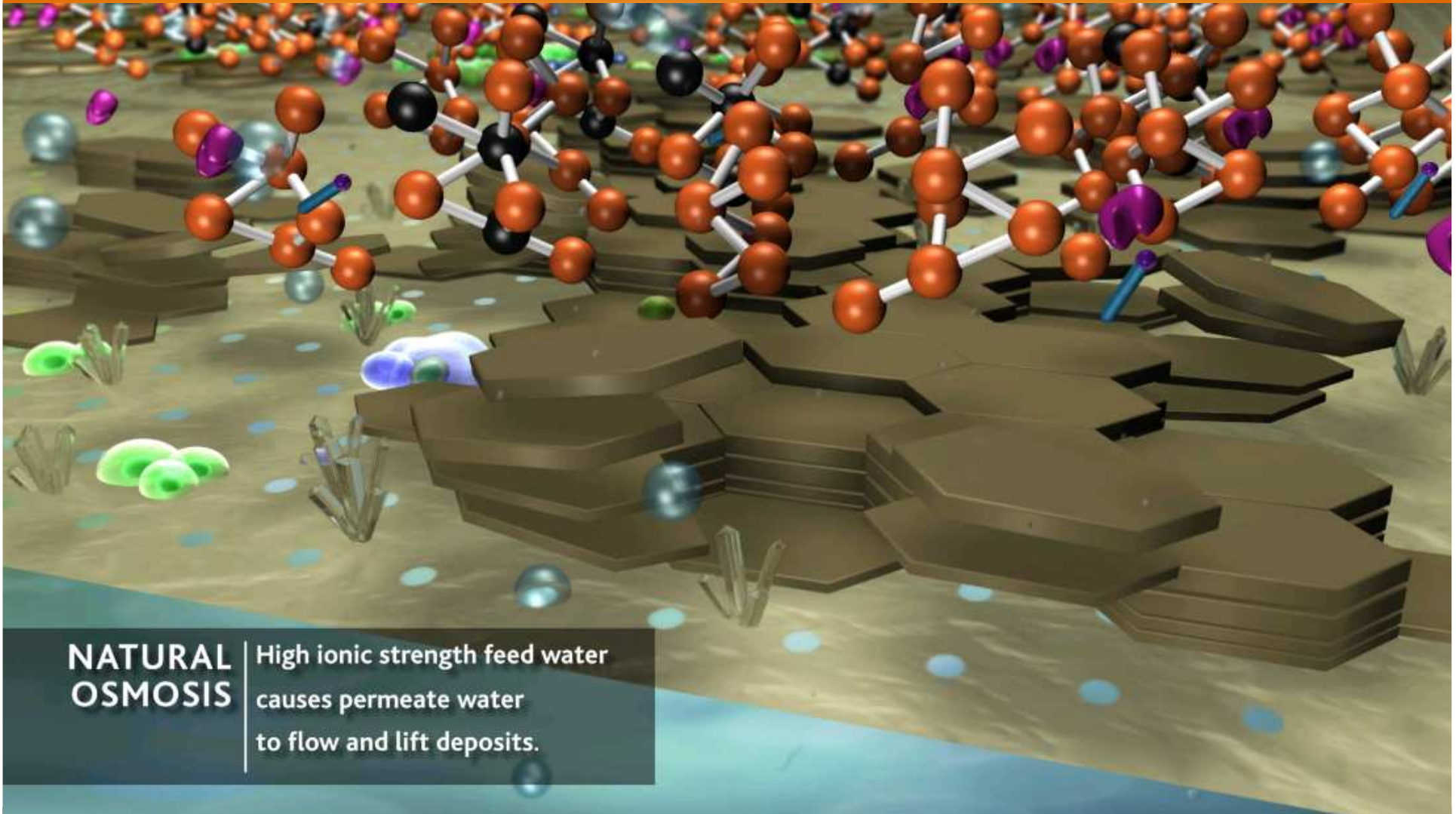
MICROBUBBLES | Microbubbles agitate the deposits, helping dislodge and break them up.

Visit www.genesysro.com



Genairclean Process

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NATURAL OSMOSIS

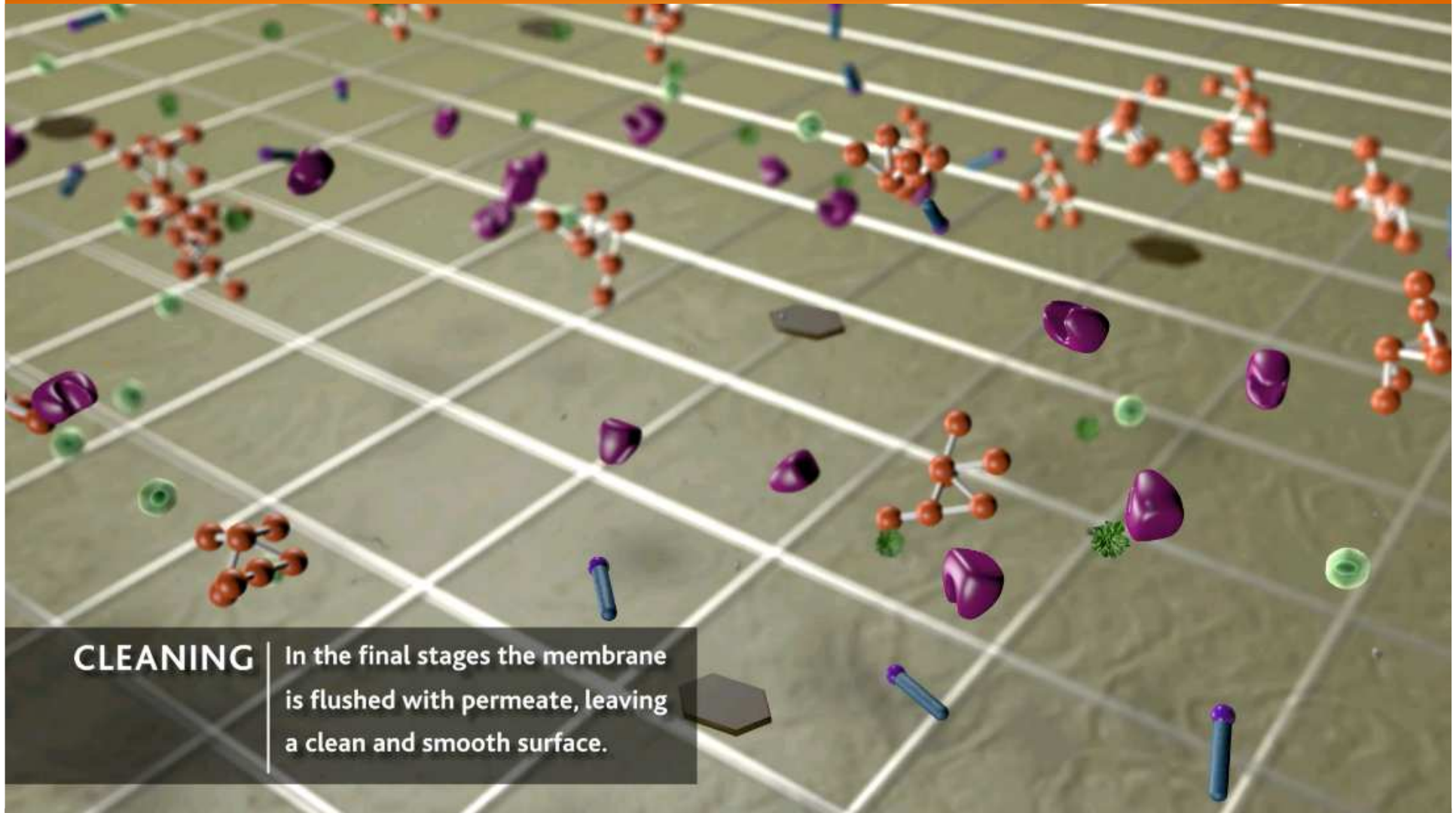
High ionic strength feed water causes permeate water to flow and lift deposits.

Visit www.genesysro.com



Genairclean Process

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CLEANING | In the final stages the membrane is flushed with permeate, leaving a clean and smooth surface.



Combined Mechanisms Cleaning



Original



2 Mins



5 Mins



10 Mins



20 Mins



**Chemical
Effervescence
High ionic strength
Microbubbles**



Genesol 700 series

GENESYS
INTERNATIONAL

Advanced Micro-Bubble Technology for Cleaner Membranes

- ◆ 100% Active
– Low Dose – Superior
Foulant Removal
- ◆ Effective against a wide range of foulants
- ◆ Suitable for use with Cellulose Acetate
Membranes

For more information see www.genesysro.com



Genesol
701
704

GENESYS
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Tel: +44 (0)1606 837 605 | www.genesysro.com



Visit www.genesysro.com



Genesol Products with Genairclean



Genesol 703 & 704 :

- high pH, surfactants, sequestrants, chelant and osmotic shock
- Genesol 704 also has effervescent reactive properties
- for : organics, colloidal fouling, biofouling

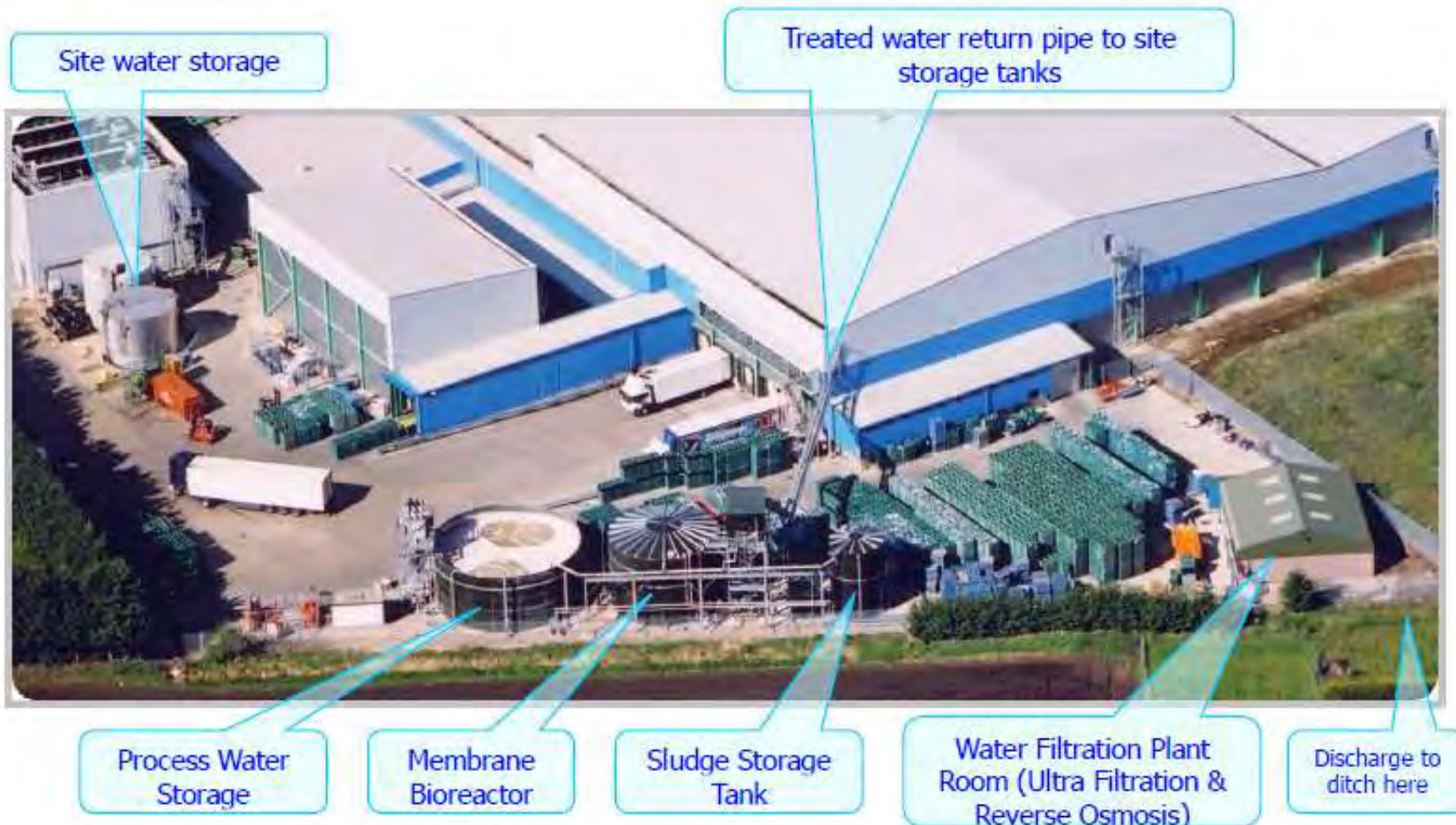
Genesol 701 :

- chelants, low pH acids, osmotic shock & effervescent reactive properties
- for : carbonate scale, iron oxide and metal oxides



Food Factory, UK Water Filtration Plant

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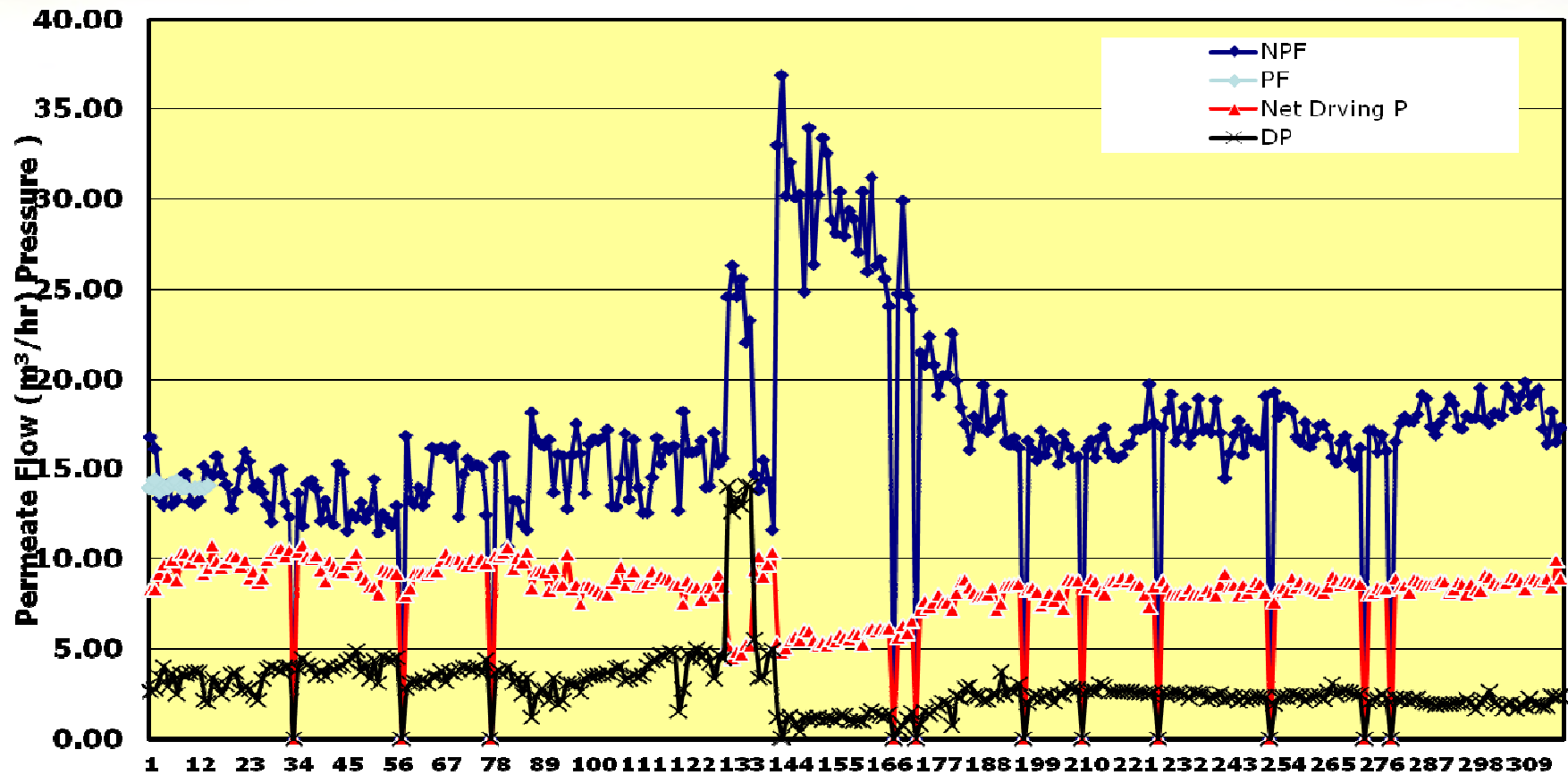




Food Factory, UK Performance 2013 2 stages

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Permeate and dP





Food Factory, UK Performance

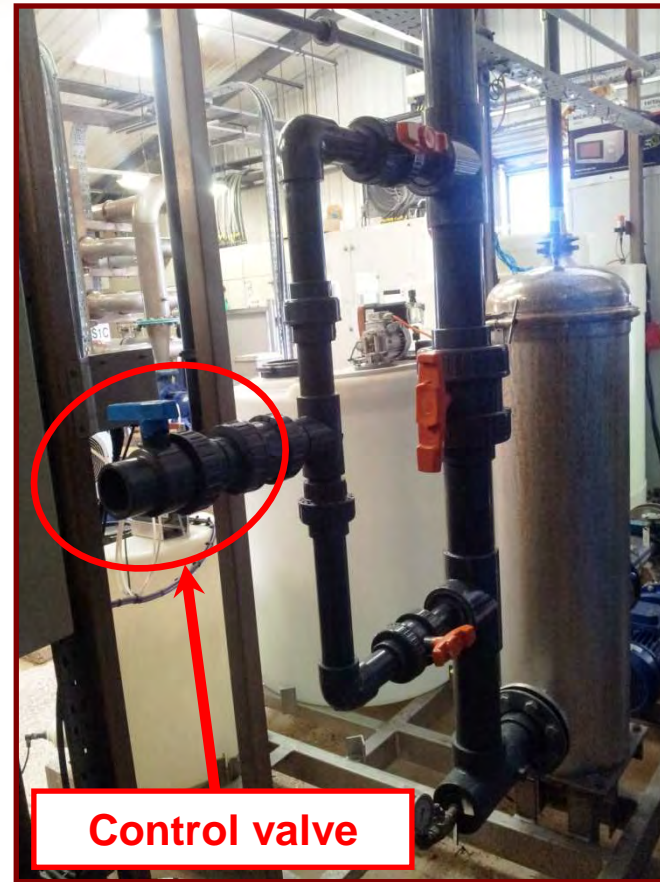
**G E N E S Y S
I N T E R N A T I O N A L**

- **RO Plant cleaned every 1-2weeks**
- **Membranes replaced 1-2 years**
- **Fouling with : clay, bacteria, calcium phosphate**
- **Detergents from factory cleans in system**
- **High phosphate loading : calcium phosphate**
- **Food washing volume increased 2012-13**
- **Conventional cleans showed good results but rapid refouling**



Food Factory, UK GenAerator Installation

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Control valve

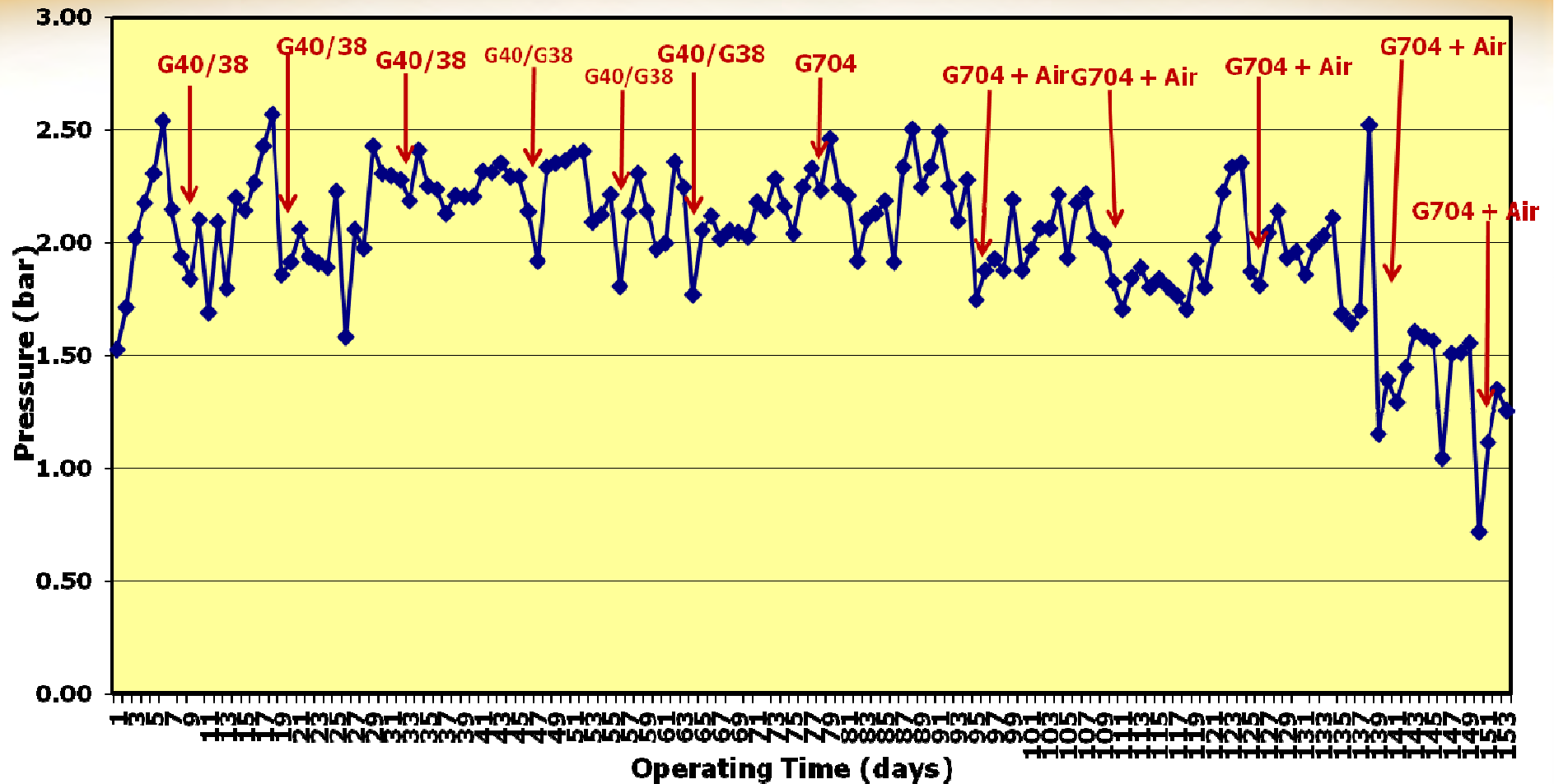


Food Factory, UK

New Cleaning Regime - July 13

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1st Stage DP





Food Factory, UK Conclusions



- **Cleaning time can be reduced using this method**
- **Frequency between cleans can be reduced**
- **This concept can be easily and cost effectively applied to any RO/NF cleaning system**



GenAirClean Needs



- **GenAerator**
- **Genesol effervescent products
(surfactant to optimise bubble size/flow)**
- **Right flow pattern of air-liquid ratio to generate vortices
& turbulence (without any extra energy required)**

⇒ **GenAirClean delivers a more effective clean without increasing energy consumption !**



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Genairclean

Harnessing the power of microbubbles



A revolutionary **NEW** approach
to RO membrane cleaning



Genesys -
Developing
Technology to
Improve your
Operation

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