TREATED MAKE UP WATER

OPTIMIZING PERFORMANCE IN INDUSTRIAL COOLING SYSTEMS

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GOALZERO SAFETY MATTERS

NALCO Champion
An Ecolab Company

Treated Sewage Effluent (TSE)

- KSA considers treated wastewater a major water source
  - aims to achieve 35% use of treated wastewater by 2020
  - over 90 percent by 2040
- Target application industry cooling system make-up
- Globally, this is best practice in water scarce areas
  - SE Asia, Mexico, Iberia, California, Brazil, South Africa etc. etc.
- Experience has taught us that TSE make-up poses risks
- As in safety, risks need assessment and mitigation requires innovation

Treated Sewage Effluent (TSE) Risks

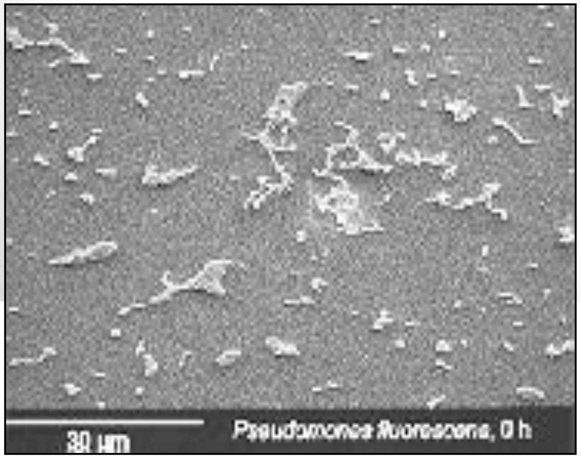
- High **scaling** potentials (normally calcium phosphate)
- High risk of **localized corrosion** by aggressive ions (e.g. chloride and sulfate)
- **Biofouling** due to the steady stream of nutrients
- **Corrosion of copper** alloys due to ammonia
- High halogen demand and **poor disinfection** by chloramine formation and side reactions (AOX).
- **Operational challenges** due to make-up variability

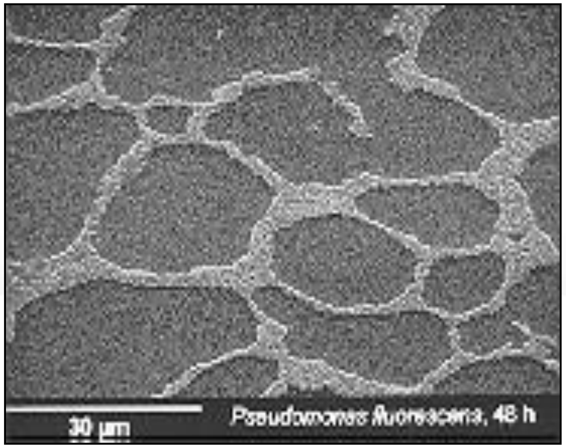
Treated Sewage Effluent Make-up Preparation

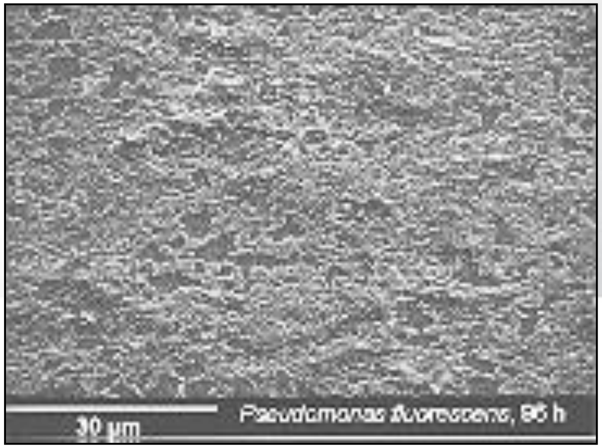
- Sand **Filtration** or Micro/Ultra Filtration (UF/MF)
  - Removes particulates & bacteria, dissolved nutrients remain
  - Pre-chlorination of water may be required
  - Maintains buffer capacity to counteract corrosion
  - Biofouling and scaling remain concerns
  - Lower cycles of concentration
- **Desalination** Reverse Osmosis or Evaporators (ZLD)
  - Biofouling of RO membranes requires good control & cleaning
  - Removes most ions allowing high cycles, high HTI
  - Ammonia not removed efficiently,
  - Biofouling a concern
  - Copper corrosion risk

Biofouling risk mitigation

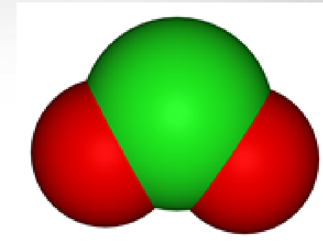
- Treatment of the make-up with biocide
  - ClO2 for efficiency, low AOX, Cl contribution
- Reduce N, P and organic nutrient through desalination
- Model ammonia behaviour in tower to control nutrient
- Review oxidising biocide: bleach may not be the best option in high HTI or high pH
- Supplimental treatment and non-oxidising biocide as second line of defence
- Automation and control of biocide dosage real time







Advantages of ClO_2 over Cl_2 / Hypo



Advantages

- Effective on bacteria, fungi and algae
- Penetrates biofilms
- Very fast acting
- Reduced corrosivity vs. bleach
- Able to reduce chlorides
- Wide pH range 4 – 10
- Non-reactive to most organics, ammonia
- Breaks down rapidly
- No THM, Low AOX formation

Disadvantages

- Very volatile
- Not persistent in use
- On-site generation required
- Acid contribution in low alkalinity waters

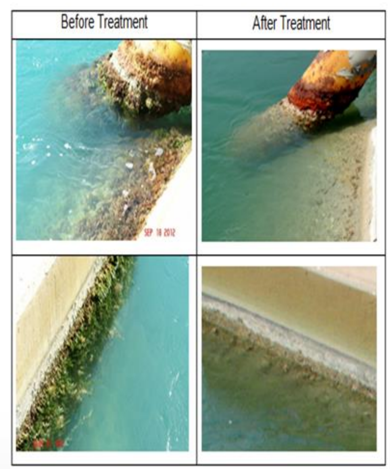
High Admiralty Corrosion (> 0.3 mpy)

Poor MU Water Quality

Process Leaks

Chlorides Limiting Cycles

AOX and THM Discharge Limitations



Scaling risk: Calcium hardness & Phosphate

- Scaling risks
  - High Tricalcium phosphate scaling potential
  - Variation in phosphate levels hampering scale control
- Risk Mitigation
  - Robust polymer designed for phosphate control.
  - Online monitoring and control essential
  - Real time on demand inhibitor feed with tagged polymer control
  - Digital risk control with alarm emails for quick action

Desalination: Corrosion risk

- Lack of buffering capacity and calcium carbonate accelerates the corrosion reactions exponentially
  - Corrosion produces acid, localized pH dip, more corrosion
  - Ca is needed in the inhibitor mechanism
- Soft iron oxides allows continued metal dissolution
- Chlorides in un-buffered waters accelerates corrosion
  - The flow of anions, particularly Chloride ions, disrupts passivation
  - Chloride ions cause pitting by penetrating pores, no Ca to balance Cl
  - Stability of complexes such as $ZnCl_4^{-2}$, $FeCl_6^{-3}$, $CuCl_2^{-}$, $AlCl_6^{-3}$

Corrosion risk mitigation

- Reduce chlorides from bleach
  - Bleach provides significant Cl with long HTI or make-up disinfection
  - Chlorine dioxide more effective in high organics/ammonia water
- Addition of bicarbonate / carbonate buffer and some calcium hardness in desalinated water, tight pH control
- Innovation: Stronger cathodic and anodic inhibitors
- R&D had to revise scaling models as French Creek does not cover very high or low salinity water chemistry
- Online monitoring and control to deal with variations

Development of a best practice programme.

Survey of various treatment approaches by consultation of our network of experts around the world

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Selection for the best approach for RO treated municipal effluent

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Testing this approach in 22 Bench top PCTs
Testing the program’s robustness to fluctuations

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Validating the program using Pilot Cooling Towers

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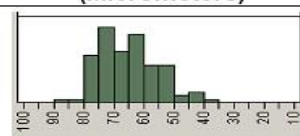
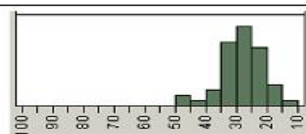
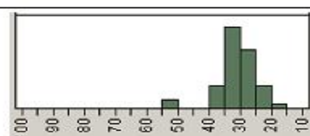
On-site application of best solution

PCT-test: worst case scenarios

LOW HEAT FLUX

Conditions	MS CR	MS coupon	Binocular (7X)	Copper Coupon
Make-up: 0% ROW Current program Cy = 4 , pH =7,5	2,6 mpy	 The coupon is covered with hundreds of tubercles (pits).		 CR = 0,06 mpy
Make-up: 90% ROW New Program Cy = 6,5 , pH = 8,5	0,43 mpy	 The coupon in pristine condition except for a few tiny stains and a small area of localised corrosion at its extremity.		 CR = 0,03 mpy
Make-up: 90% ROW New program + 30% Cy = 7,3 , pH = 8,5	0,26 mpy	 The coupon is in pristine condition except for a very few number of small pits (8 in total)		 CR = 0,02 mpy

HIGH HEAT FLUX

	Pit depth Distribution (Micrometers)	MS Tube (Day 1)	MS Tube (Day 7)	MS Tube (Day 20)
Make-up: 0% ROW Current program Cy = 4 , pH =7,5				
Make-up: 90% ROW New Program Cy = 6,5 , pH = 8,5				
Make-up: 90% ROW New program + 30% Cy = 7,3 , pH = 8,5				

Saudi Arabia Example: value of alarm emails

Examples of upsets that were handled by the on-line controller

Detected by 3DT	Source	3DT action	operator action	Consequence avoided
Massive Conductivity increase. Spike in online corrosion.	Contamination of CW by chlorides from process.	Emailed operators. Entered failsafe mode: decreased product feed, initiated BD.	Total blowdown, product feed interrupted.	Major corrosion in all the system. High concentration of corrosion products blocking pipes and creating low flow regions. The system could have lost multiple years of life.
Moderate conductivity increase. increase in online corrosion.	Blow down valve manually blocked.	Emailed operators. Entered failsafe mode: decreased product feed, initiated BD.	Opened valve	Major increase in corrosion rates
Major pH decrease	Feed tube of NaHCO3 blocked by deposit.	Emailed operators	Unblock/change feedtube within a few hours	Major increase in corrosion rates

Conclusion

The program was successful in cost-effectively replacing a molybdate/zinc program at low Ca.
Excellent system control was implemented, significantly limiting the damage caused by upsets.

Examples TSE and RO treated TSE as MU

- RO treated effluent in Spain saves water for 24.000 inhabitants

Customer Impact	eROI	Economic Results
22% less river water used	WATER	160 m³/h of river water saved, equivalent to the water usage of 24,600 inhabitants
49% reduction in wastewater from cooling	WASTE	76 m³/h less discharge; €24,455/year blowdown charges
Reduction of mild steel corrosion from 0.5 to 0.2 mpy	ASSETS	Prolonged lifespan of heat exchangers

- Sandfiltration TSE improved biofouling control reduces cleaning and $10M annual production loss

Environmental Indicators	eROI	Economic Results
Use of chlorine reduced by 50% per year through use of the new Nalco programme, and use of supplemental hypochlorite eliminated completely Eliminated the cleaning of heat exchangers (3 times per year), and increased production by 21 days per year	ASSETS	Reduced treatment commodity consumables costs by $226,000 (ZAR 1.9M) per year Reduced maintenance costs by $140,000 (ZAR 1.2M) per year Production increase by $10.5 M (ZAR 87M) per year Combined reduction in the Total Cost of Operation (TCO), and production increase of $10.9M (ZAR 90.1M) per year
All data verified by the customer		

Conclusions

- KSAs ambition of reusing 90% of TSE in 2040 requires good understanding of water treatment
- Globally, extensive experience has been gained in using TSE as make-up in industrial cooling
- Experience has taught us that TSE make-up poses risks:
  - High corrosion, scaling and biofouling potential
  - If desalinated, novel models are needed for unnatural water
- As in safety, risks need **assessment** and **mitigation**, this requires the use of **innovation**
- **Consult** global water experts to tap into their experience

QUESTIONS.