We will begin shortly.
Participants, kindly note the following for this seminar.

Please rename your Zoom name to: Name, Org or Project
(e.g. Las Fernando, ADB)

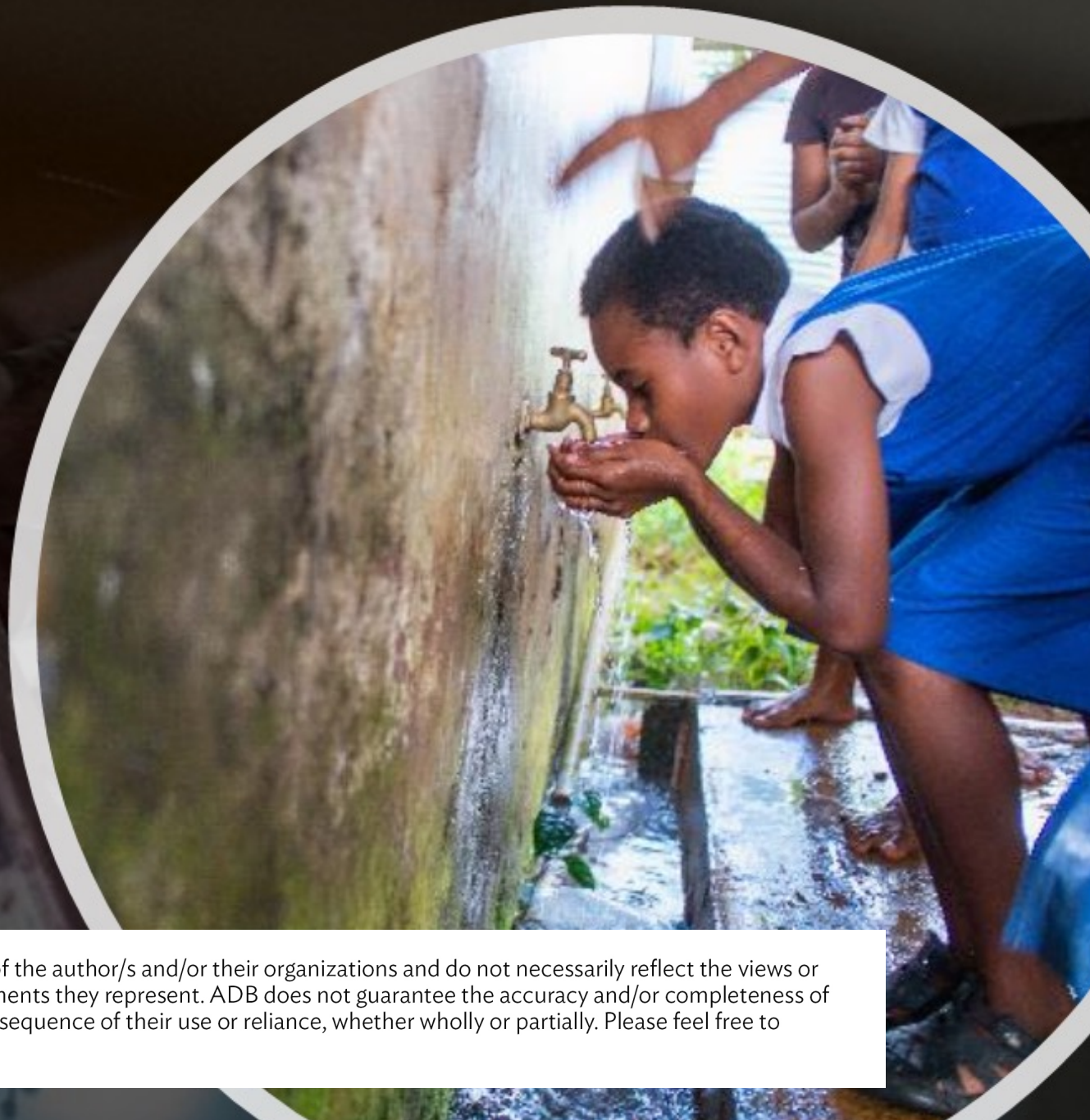
PLEASE TURN YOUR MIC OFF DURING THE PRESENTATION

RAISE HAND WHEN YOU WANT TO TALK

USE THE CHAT BOX FOR QUESTIONS/CONCERNS

WE HAVE A Q&A PORTION AFTER THE PRESENTATION

Pacific WASH Webinars



A Closer Look at Chlorination

30 June 2021

TA6551-REG: Strengthening WASH practices and hygiene behavioral change in the Pacific

Introduction and Agenda

Allotted time	
5 min	Introductions: and why we chlorinate (Dean, Emma, Lusia)
5 min	Understanding the conditions where chlorine will work best (Peter)
15 min	Liquid (hypochlorite) and gas chlorination systems (Peter)
15 min	Operational management (Lisa)
10 min	Example of chlorination and managing chlorine residual (James)
5 min	Conversing with the community about the importance of chlorination (James and Peter)
10 min	Questions
5 min	Close

James Young
CEO, Public Utilities Board, Kiribati

Peter Greenhalgh
Principal Processing Engineer, Hunter H2O

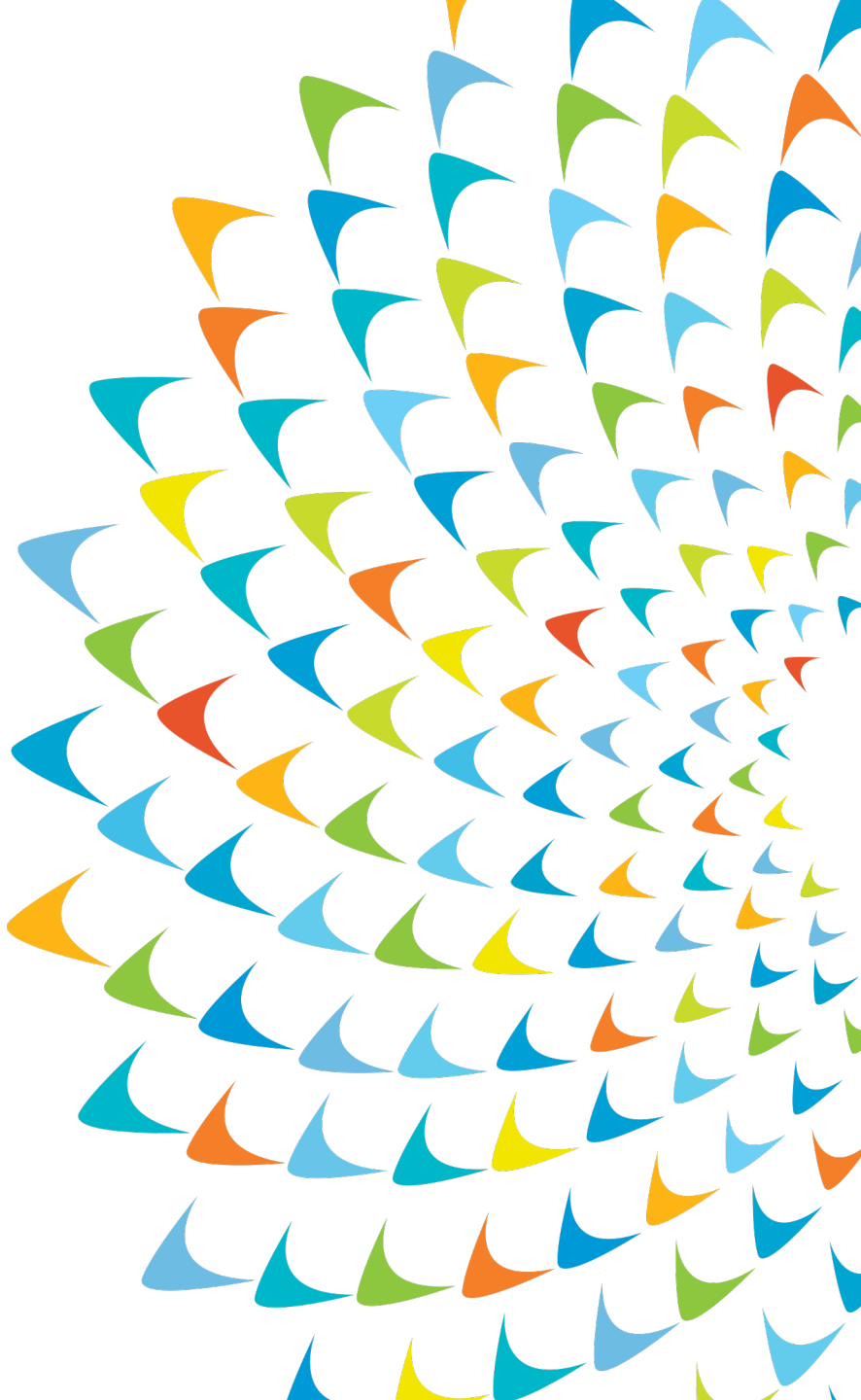
Lisa Procter
Sector Lead – Operations, Hunter H2O

4

Group Topics

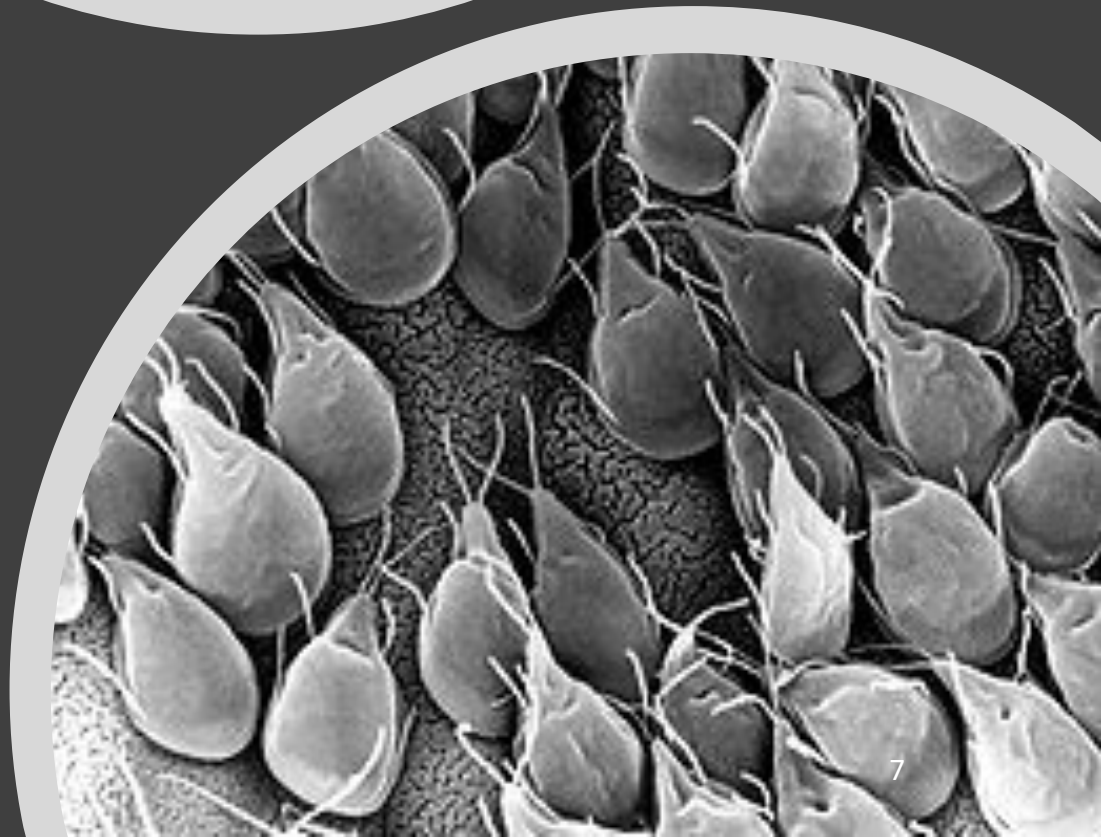
- Selecting the technology
- Managing network residuals
- Managing safety risks
- Community engagement

Why we disinfect?



Why disinfect?

- Disinfection is used to kill / inactivate pathogens.
- Without disinfection the water treatment process would not achieve its purpose of making water safe to drink.



How we disinfect?

Ensure that the quality of water is suitable for disinfection

Target the disinfection to the relative risk of the catchment

Chlorine is critical but alone not always sufficient


Treatment Risk Management

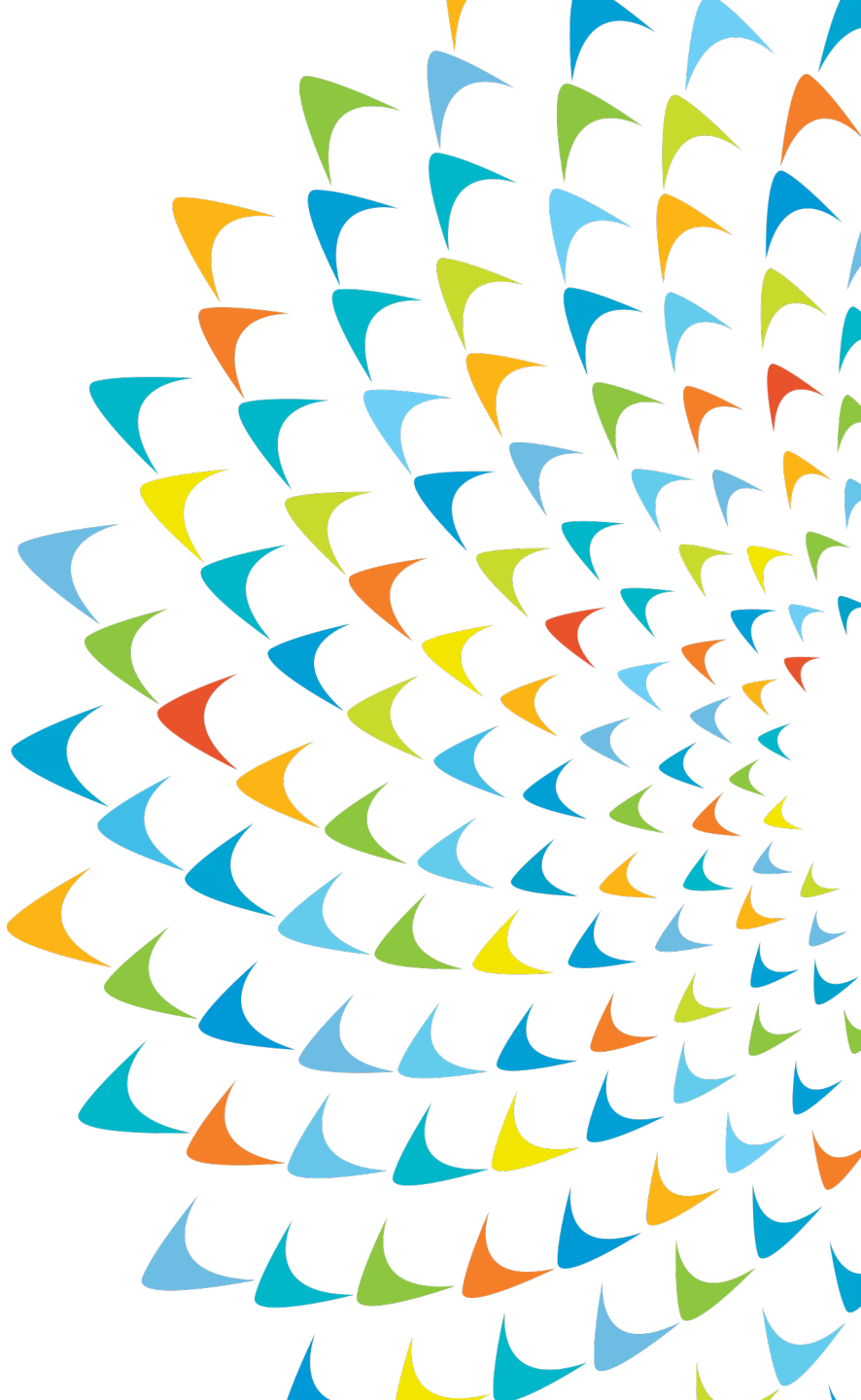

Distribution Risk Management


Customer Risk Management


Catchment Risks Management

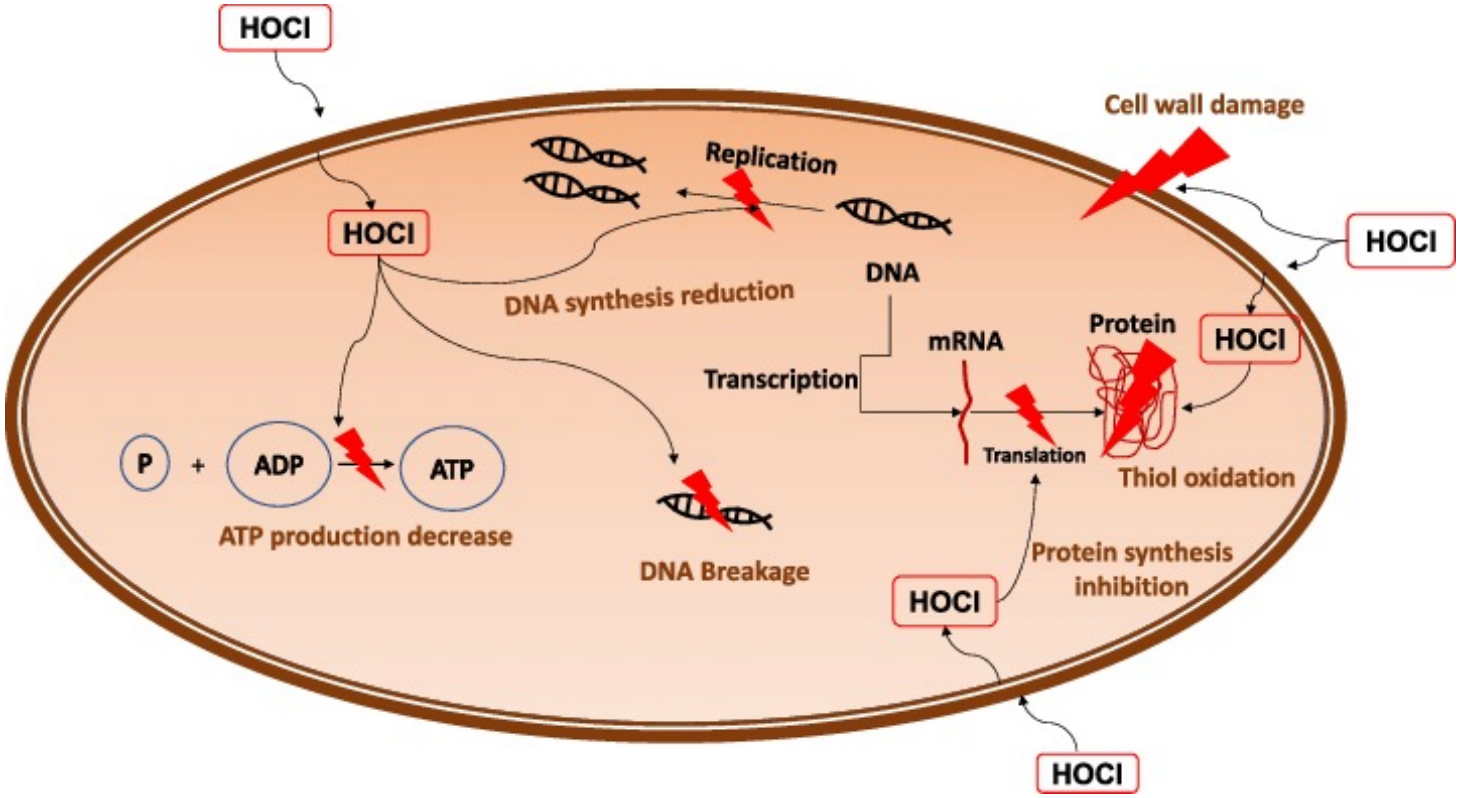
It’s an important step amongst many

How does chlorine disinfect?



How does chlorine work

- Chlorine is a strong oxidant
- Cell wall disruption
- Protein bond breakage

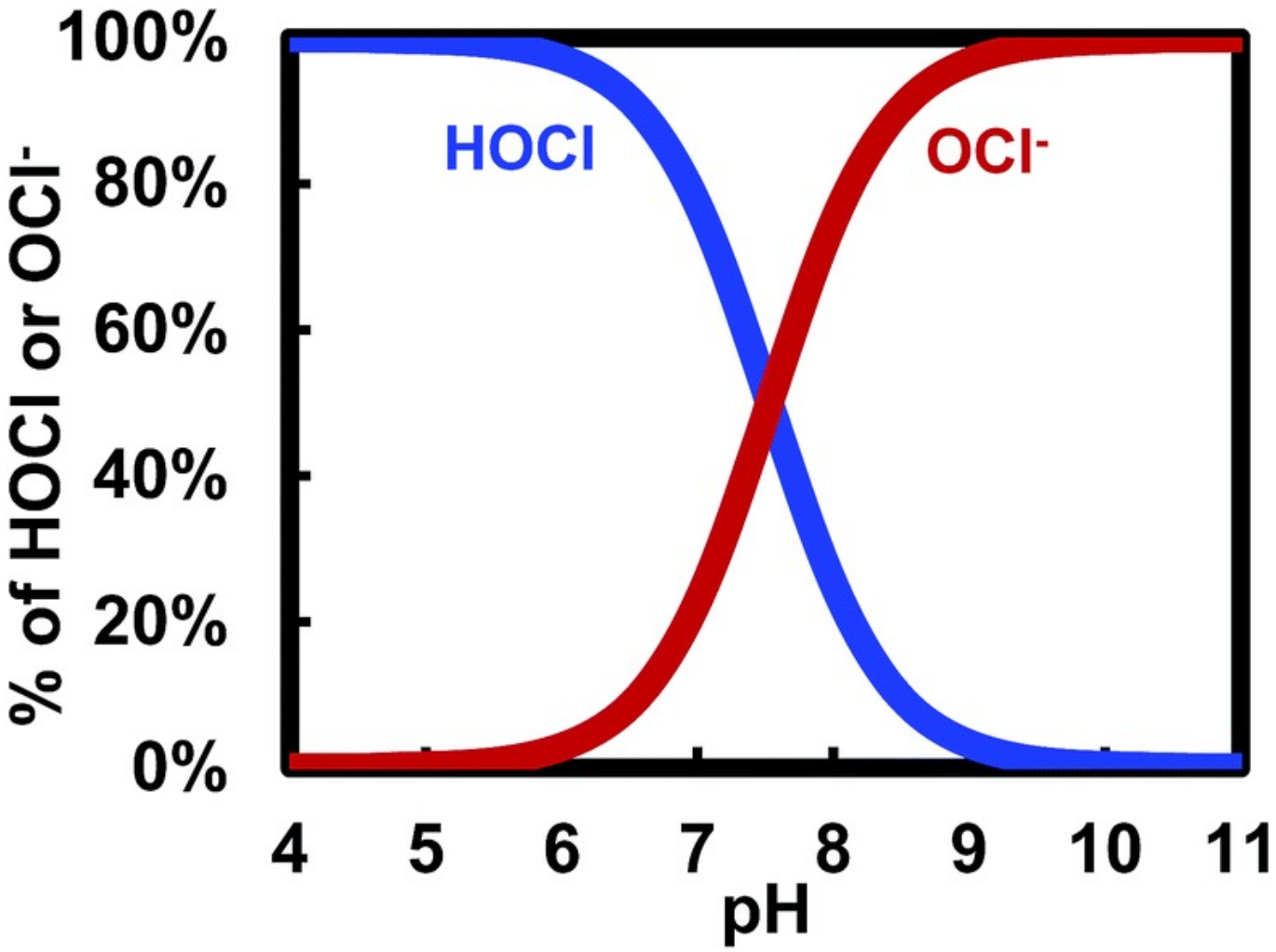


Kiamco, Mia Mae & Zmuda, et al. (2019). Hypochlorous-Acid-Generating Electrochemical Scaffold for Treatment of Wound Biofilms. Scientific Reports. 9. 10.1038/s41598-019-38968-y.

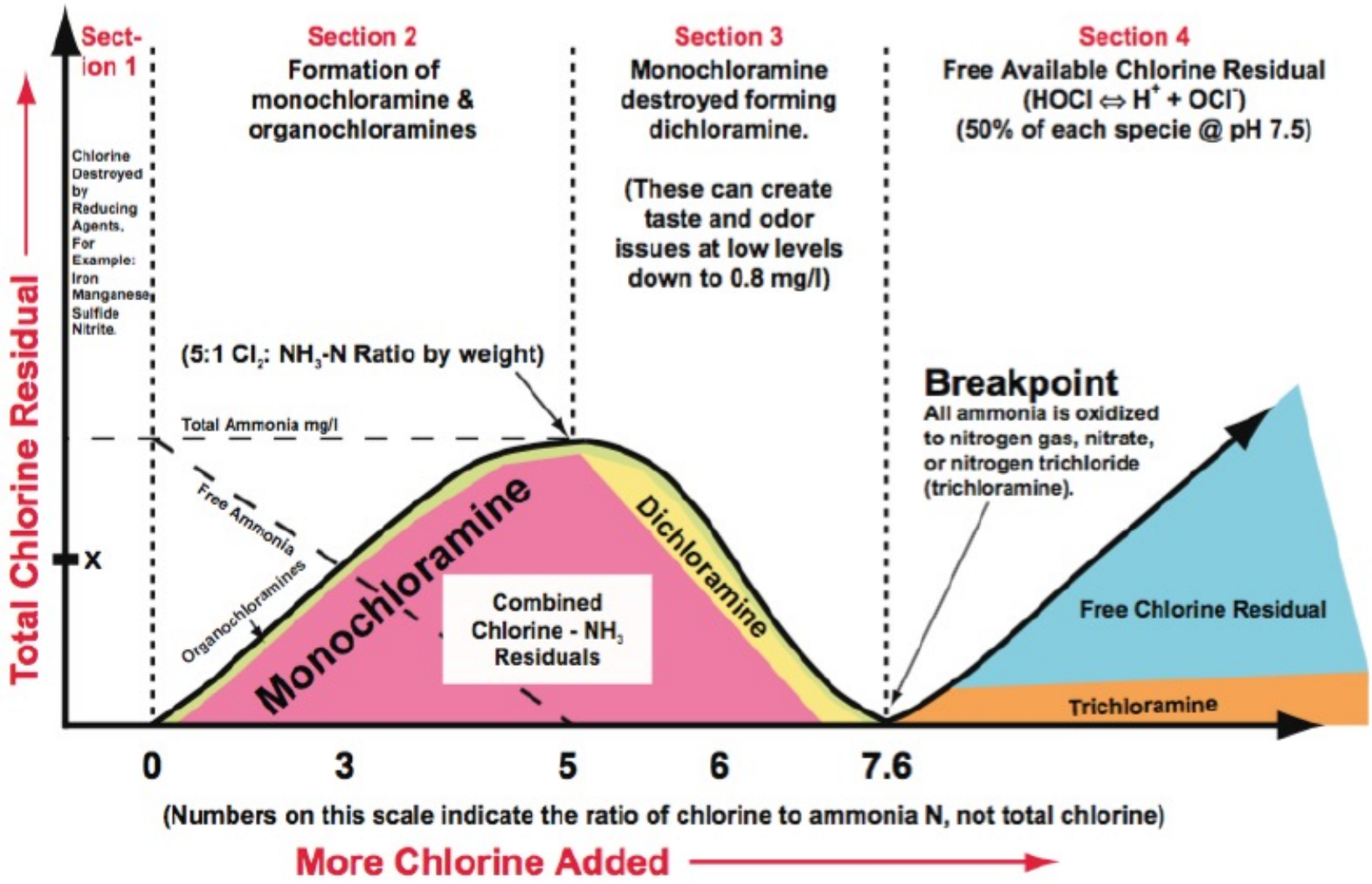
Chlorination

When free chlorine is in water, the following reaction occurs:

- $HOCl \leftrightarrows OCl^- + H^+$
- HOCl is a strong disinfectant
- OCl^- is a weak disinfectant

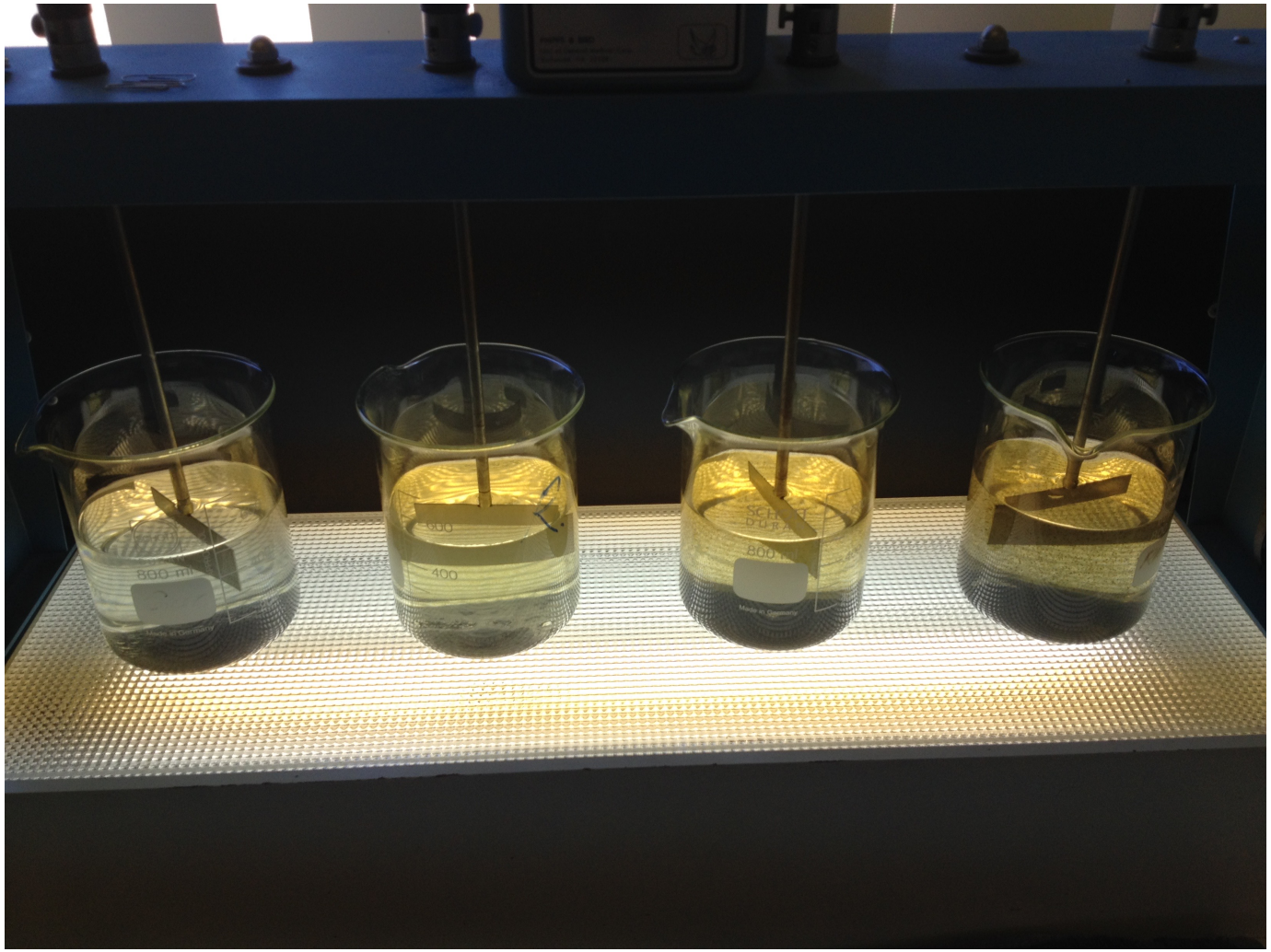


Chlorine reacts with other compounds as well



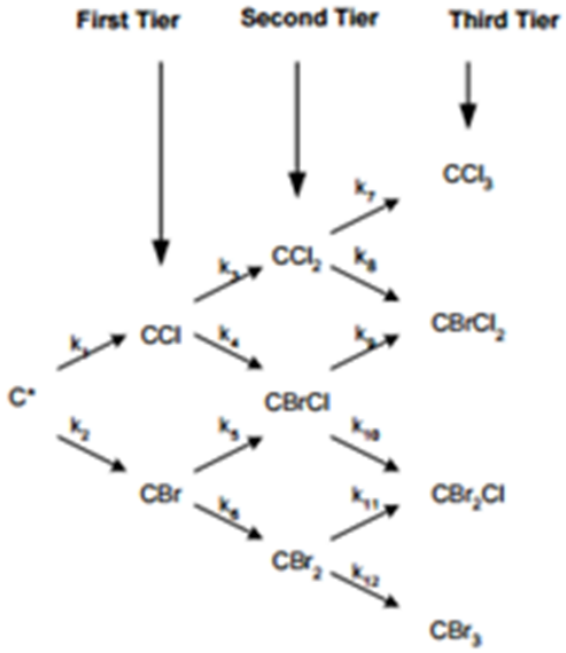
Chlorine reacts with other compounds as well

- Organics from algae and leachate
- Different compounds impact chlorine demand differently
- Some organics will oxidise more slowly



WHO Water quality Guidelines

Guideline values	
	Chloroform: 0.3 mg/l (300 µg/l)
	Bromoform: 0.1 mg/l (100 µg/l)
	Dibromochloromethane (DBCM): 0.1 mg/l (100 µg/l)
	Bromodichloromethane (BDCM): 0.06 mg/l (60 µg/l)



THM reaction path; Nokes et al. (1999)

Potential for Trihalomethanes

- Chloroform an ‘carbon/organic species’
- bromodichloromethane (BDCM) a ‘bromated species’
- dibromochloromethane (DBCM) a ‘bromated species’
- bromoform a ‘bromated species’

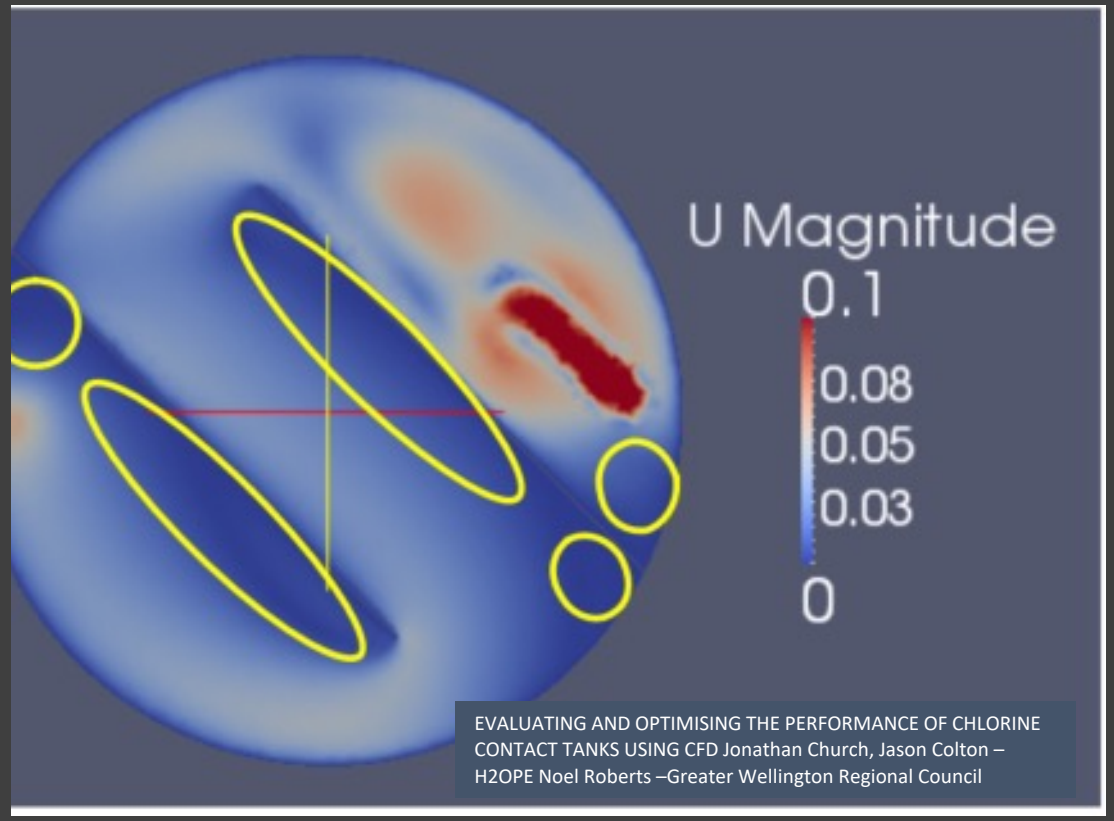
Disinfection – Free Chlorine

Table 4.3 Recommended Ct values for 99% (2-log) inactivation

	Temperature (°C)	pH	Ct (mg.min L^{-1})
Bacteria	<2	7	0.08
	<2	8.5	3.3
Viruses	<5	7 – 7.5	12
	10	7 – 7.5	8
Giardia	0.5	7 – 7.5	230
	10	7 – 7.5	100
	25	7 – 7.5	41

Parameter	Disinfection Performance
Temperature ↑	Better ↑
pH ↑	Worse ↓
Turbidity ↑	Worse ↓
Contact Time ↑	Better ↑

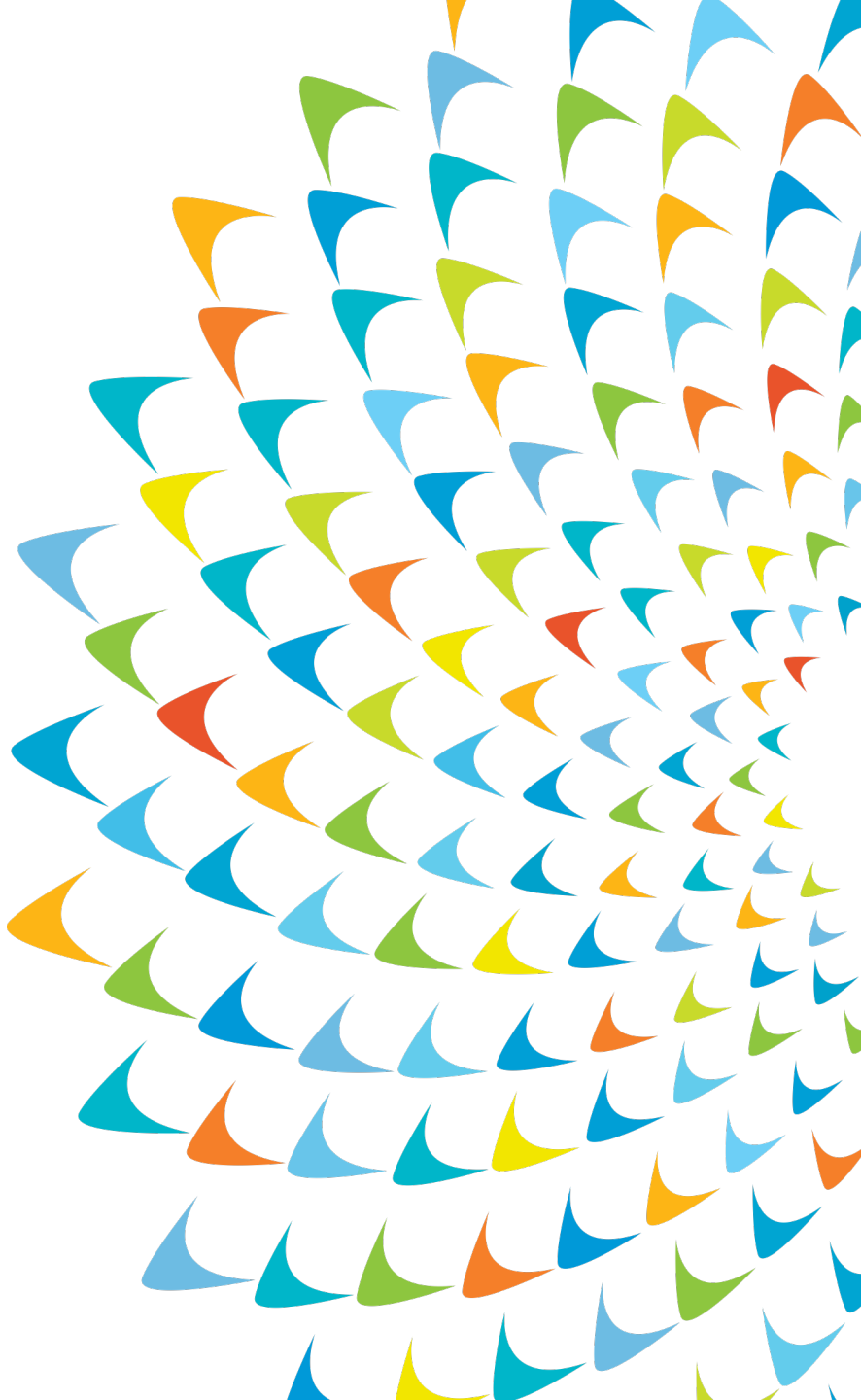
How much contact time do you have?



Baffling Condition	Baffling Factor	Baffling Description
Unbaffled (mixed flow)	0.1	None, agitated basin, very low length to width ratio, high inlet and outlet flow velocities.
Poor	0.3	Single or multiple unbaffled inlets and outlets, no intra-basin baffles.
Average	0.5	Baffled inlet or outlet with some intra-basin baffles.
Superior	0.7	Perforated inlet baffle, serpentine or perforated intra-basin baffles, outlet weir or perforated launders.
Perfect (plug flow)	1.0	Very high length to width ratio (pipeline flow), perforated inlet, outlet, and intra-basin baffles.

Source: 2003 USEPA Disinfection Profiling Manual

Sodium Hypochlorite

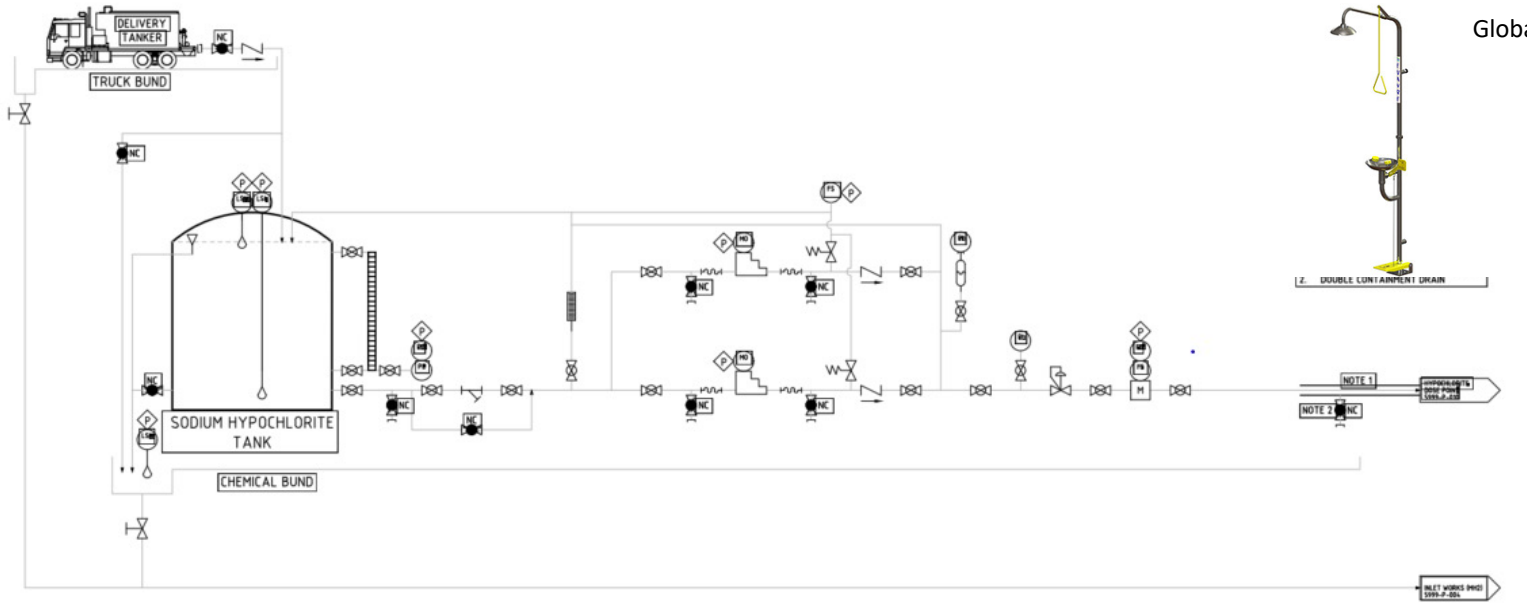


Basics of the chemistry

- Solution of ~12.5 % w/w free chlorine
- Reaction in water = $NaOCl + H_2O = OCl^- + OH^-$
- Deliveries, 15L, 20L, 200L, 1,000L and bulk

http://www.sciencemadness.org/smwiki/index.php/Sodium_hypochlorite

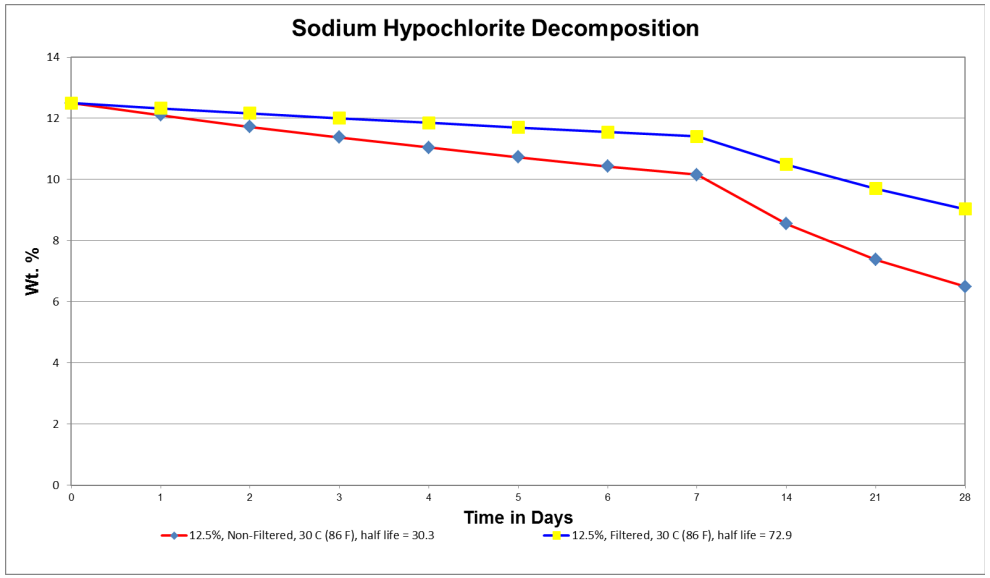
Typical System

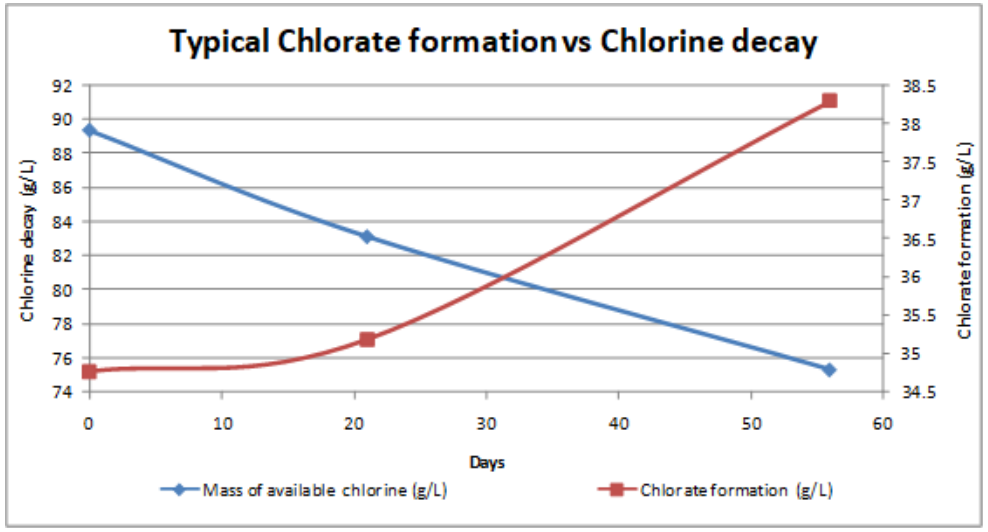


Global Spill Control

Decay

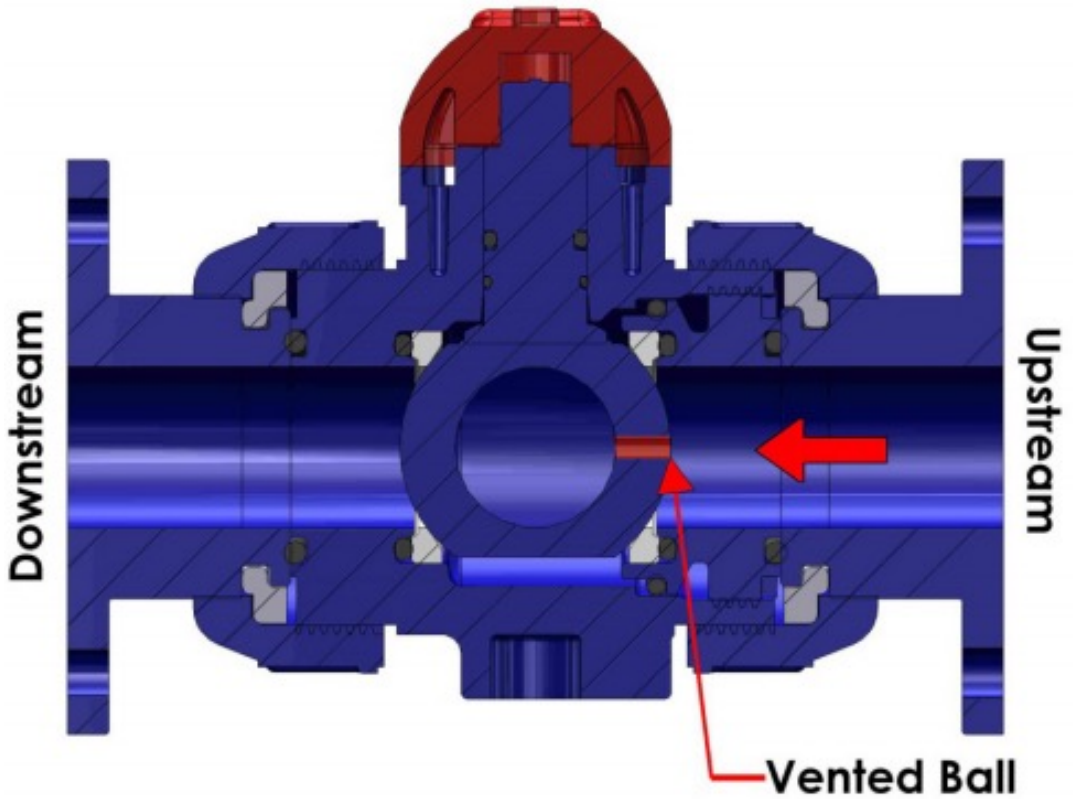
- $3\ ClO^- + H+ \rightarrow HClO_3 + 2\ Cl$
- WHO Guidelines for Chlorate (ClO_3^-) of 0.7 mg/L
- UV light, higher temperatures and pH all impact degradation
- Dilution Is the solution, 50% dilution = 25% of the decay rate





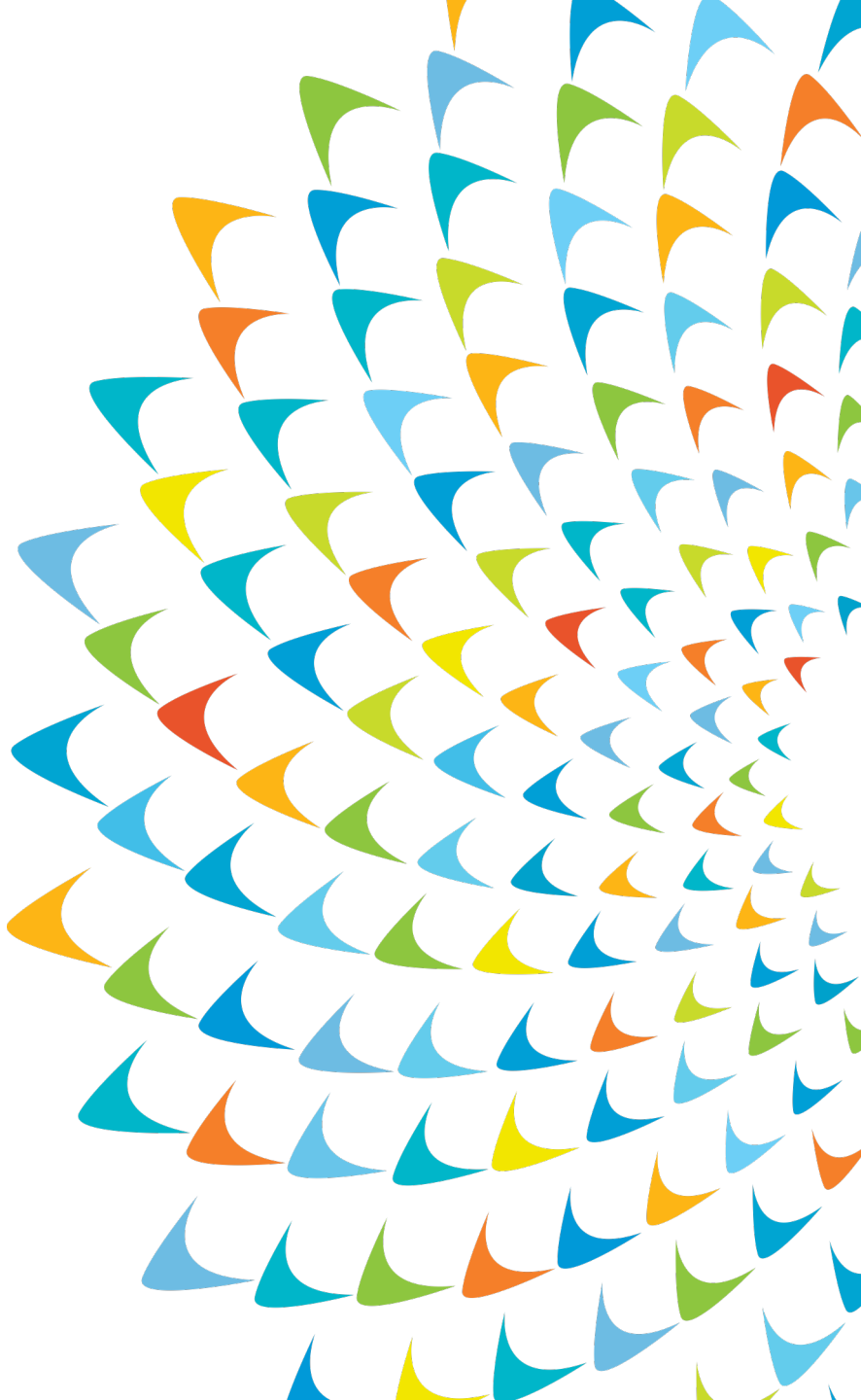
Safety

- Need correct PPE when handling:
  - Face shield
  - Gloves
  - Safety glasses
- Reacts to form chlorine gas when mixed with acid
- Appropriate materials for pumps, pipes and tanks
- Vented ball valves, safety showers, containment
- Appropriate training and procedures
- Refer to AS 3780 for design standards



Asahi America - https://www.asahi-america.com/images/x-assets/PDF/Type-21_Ball_Valve_for_Sodium_Hypochlorite.pdf

Gas Chlorination



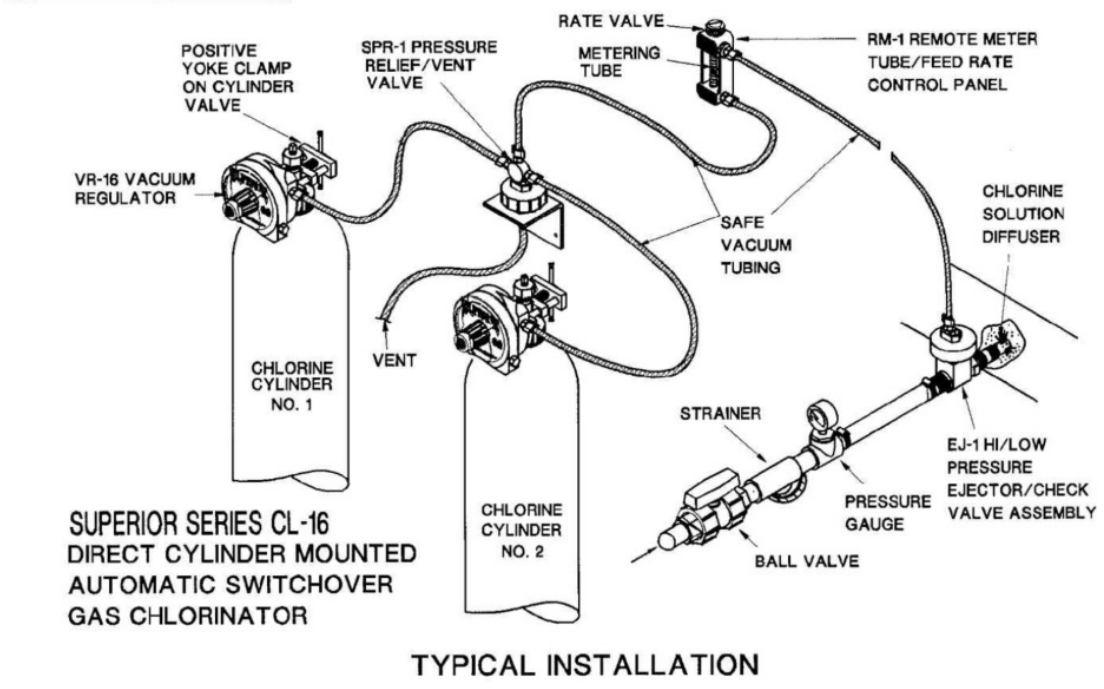
Basics of the chemistry

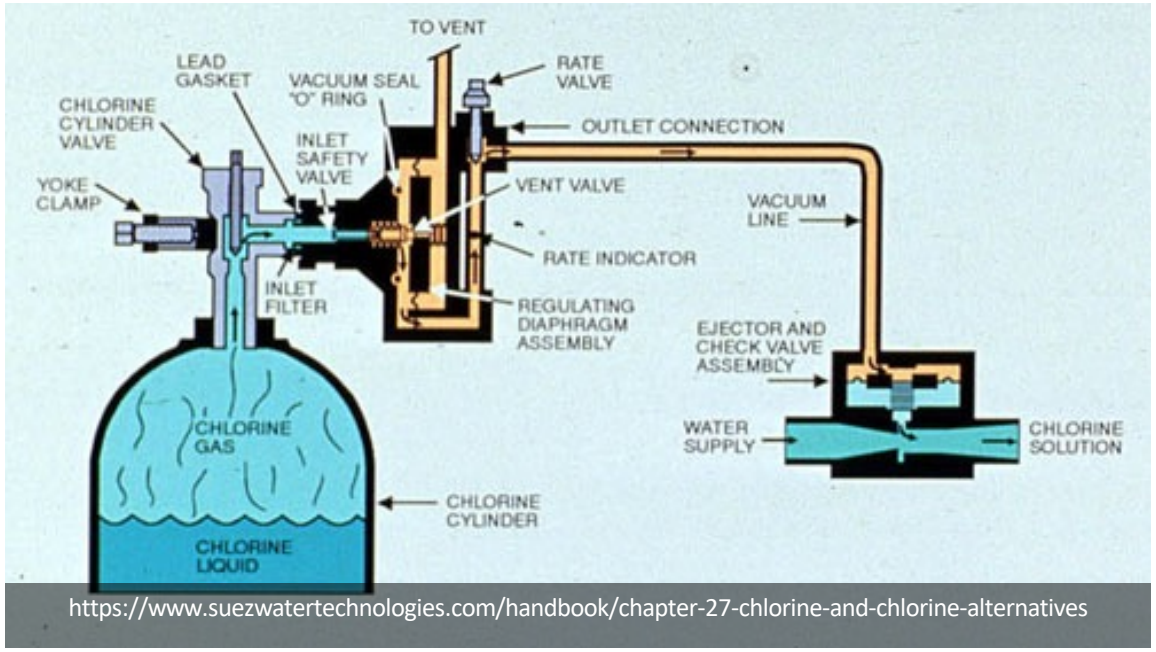
- Dense gas, yellow in colour
- $Cl_2 + H_2O = HOCl + HCl$

Then

- $HOCl \leftrightarrows OCl^- + H^+$

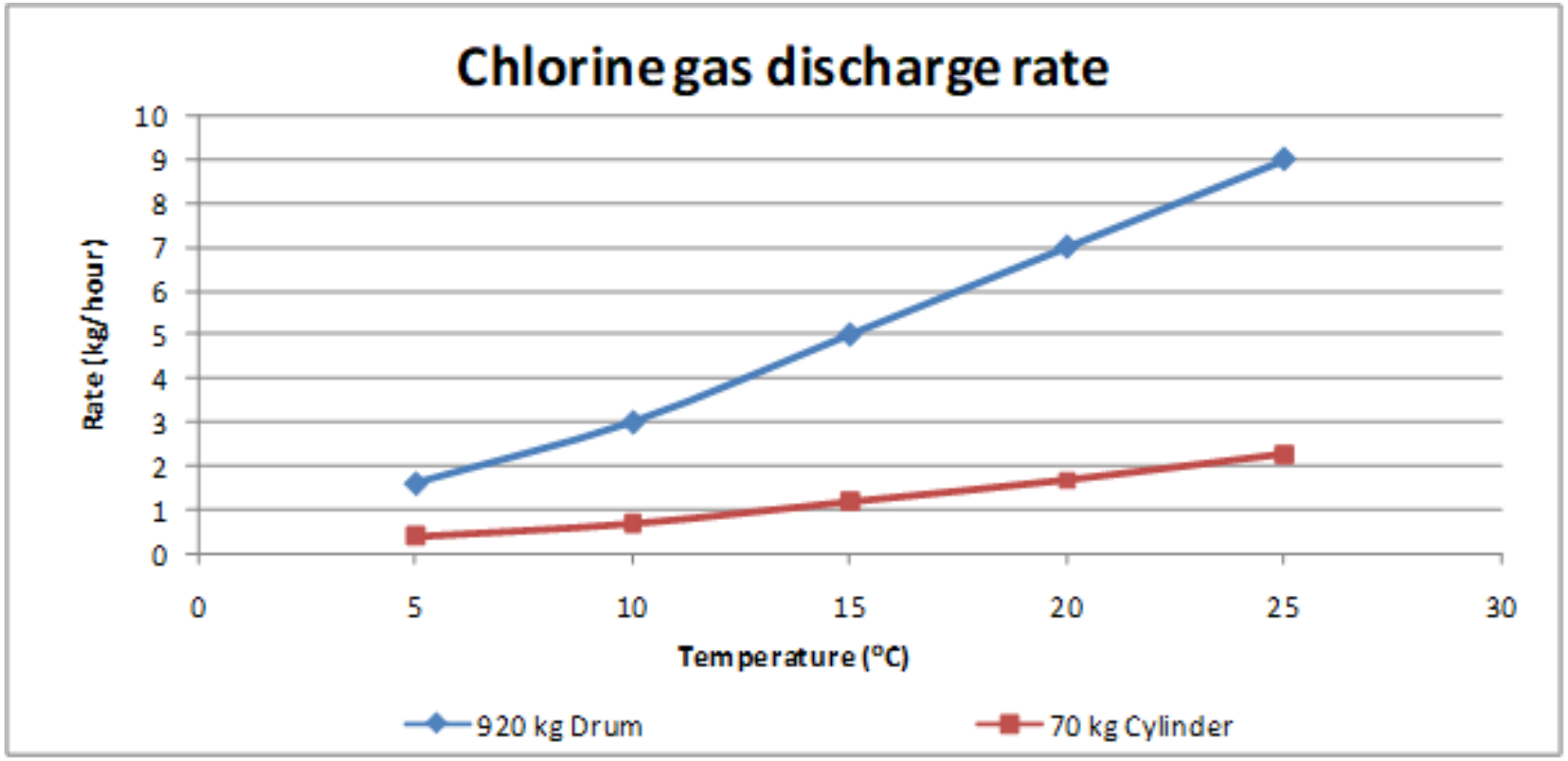
Typical System





https://www.suezwatertechnologies.com/handbook/chapter-27-chlorine-and-chlorine-alternatives

Maximum draw off

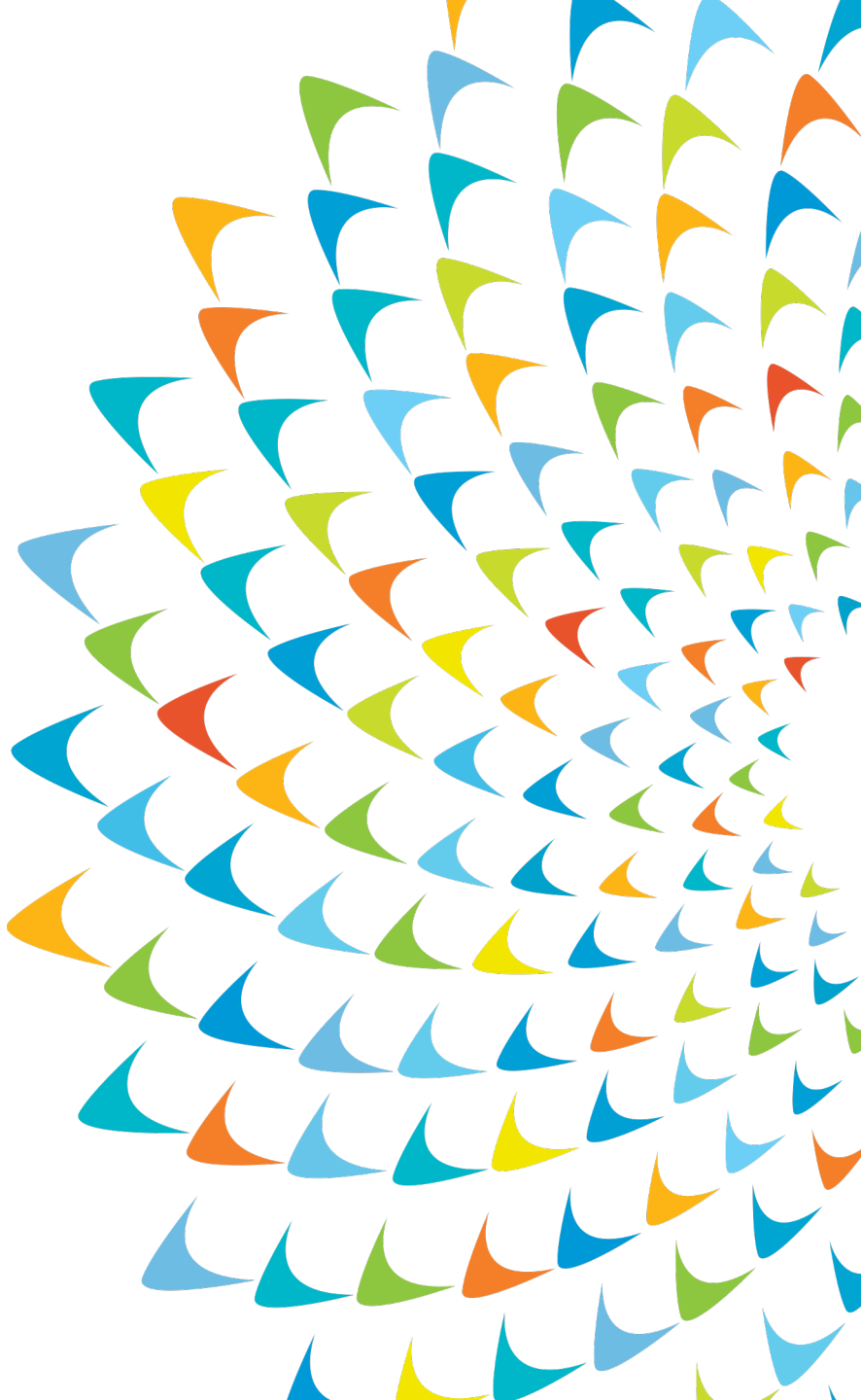


Safety

- Chlorine gas can be deadly
- Gas monitoring for leakage
- Windsocks for wind direction
- Ventilation
- Training and procedures
- Appropriate PPE
  - Gas detector
  - Gloves and goggles
  - Ammonia bottle
- Automatic isolation
- Emergency procedures
- Refer to AS 2927 for design standards

Prominent Fluid - https://www.prominent.com/en/Products/Products/Metering-Systems/Metering-Systems-for-Chlorine-Gas/p-dulco-vaq-automatic-emergency-shut-off-system.html

Other forms of chlorination



Chloramination

- Both chlorine (sodium hypochlorite or gas chlorine) and ammonia added to water.
- As chlorine is added, it reacts with the ammonia to form monochloramine.
- Less effective disinfectant than free chlorination.
- Chloramines are stinky.
- Monochloramine:
  - Contribute less to taste or odour (than di and tri).
  - Is more stable in solution than free residual chlorine.
  - Can be used to minimise THM disinfection byproducts.
- Free ammonia left in the water is a nutrient for microorganisms (bad).

Chlorine dioxide

ONSITE GENERATION SYSTEMS CAN BE COMPLEX

BY-PRODUCTS ARE CHLORITE AND CHLORATE – HEALTH IMPACT

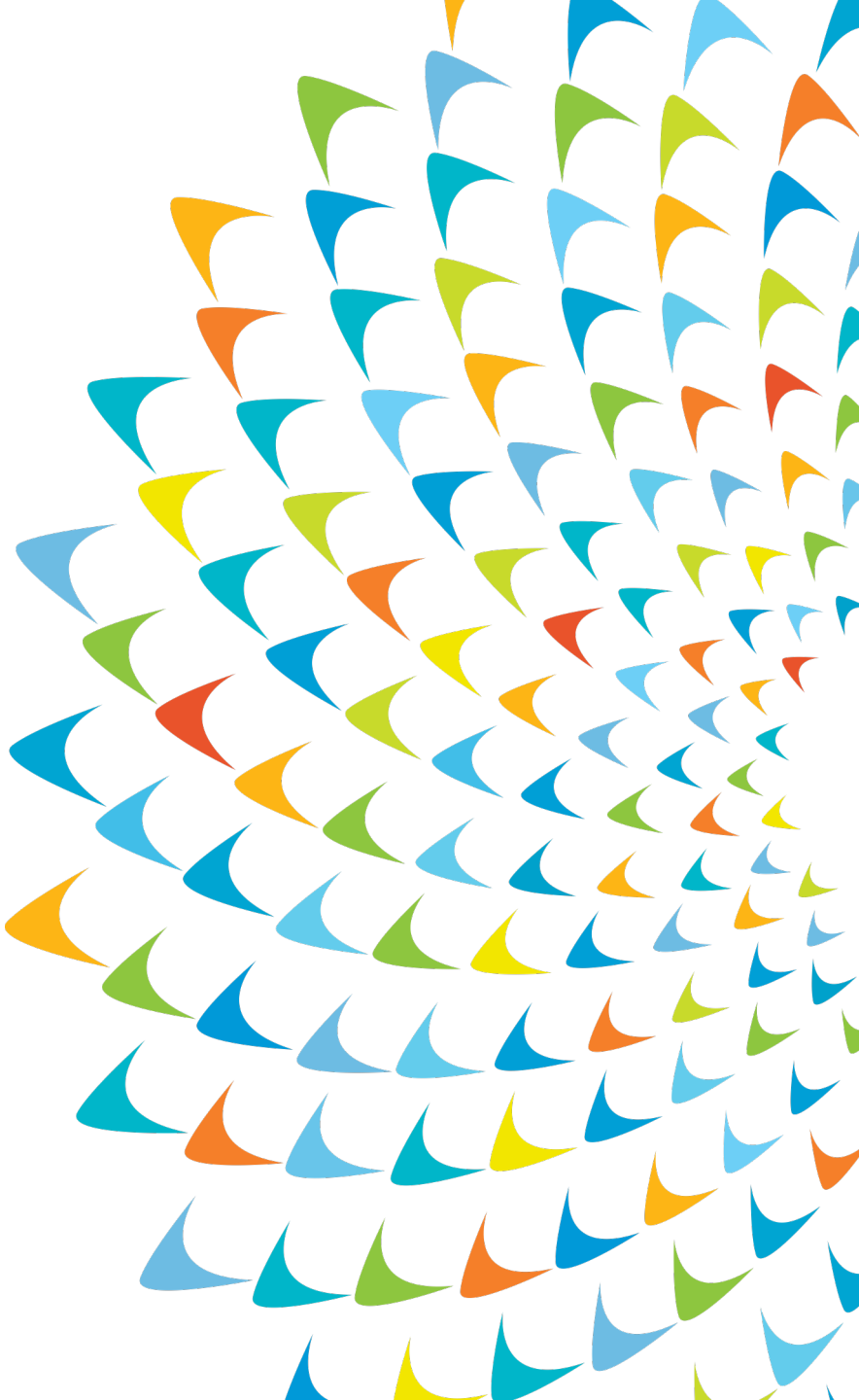
LIMITED NUMBER OF SITES USING TECHNOLOGY

Prominent Fluid – ProDos - Granular Calcium Hypochlorite Feeder System

Calcium hypochlorite

- Reacts with water as follows:
- $Ca(OCl)_2 + 2H_2O <–> 2HOCl + Ca+2 + 2OH^-$
- Difficult to control dose rates in tablet form
- Dry feed systems can be complex
- Good stability for storage

Operational Management



Operational review of chlorination systems

How often to sample and where?

- Part of the Water Safety Plan
- Representative sampling
- Uniform distribution of sample sites
- From reservoirs and in distribution
- Also, Immediately after treatment

The minimum level of analysis should therefore include testing for indicators of faecal pollution (thermotolerant (faecal) coliforms), turbidity, and chlorine residual and pH (if the water is disinfected with chlorine). (WHO Guidelines for Drinking Water Quality)

How often to sample and where

- Sample daily for physiochemical parameters immediately after treatment and in main storages

Table 4.4 Recommended minimum sample numbers for faecal indicator testing in distribution systems[a]

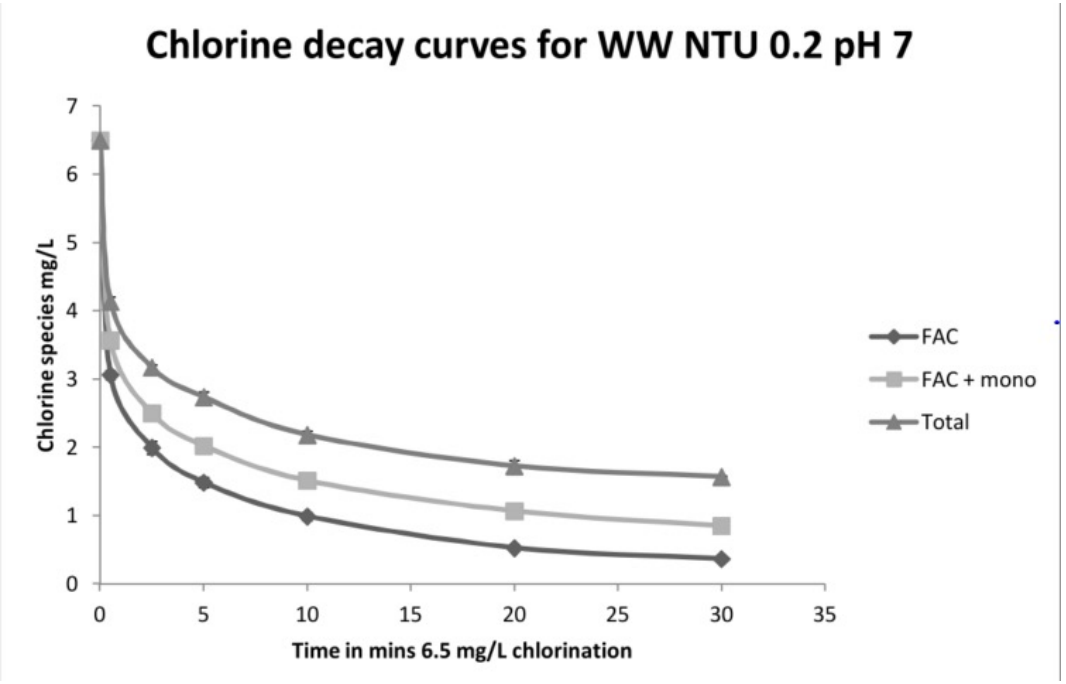
Type of water supply and population	Total number of samples per year
Point sources	Progressive sampling of all sources over 3- to 5-year cycles (maximum)
Piped supplies	
< 5000	12
5000–100 000	12 per 5000 population
> 100 000–500 000	12 per 10 000 population plus an additional 120 samples
> 500 000	12 per 50 000 population plus an additional 600 samples

[a] Parameters such as chlorine, turbidity and pH should be tested more frequently as part of operational and verification monitoring.

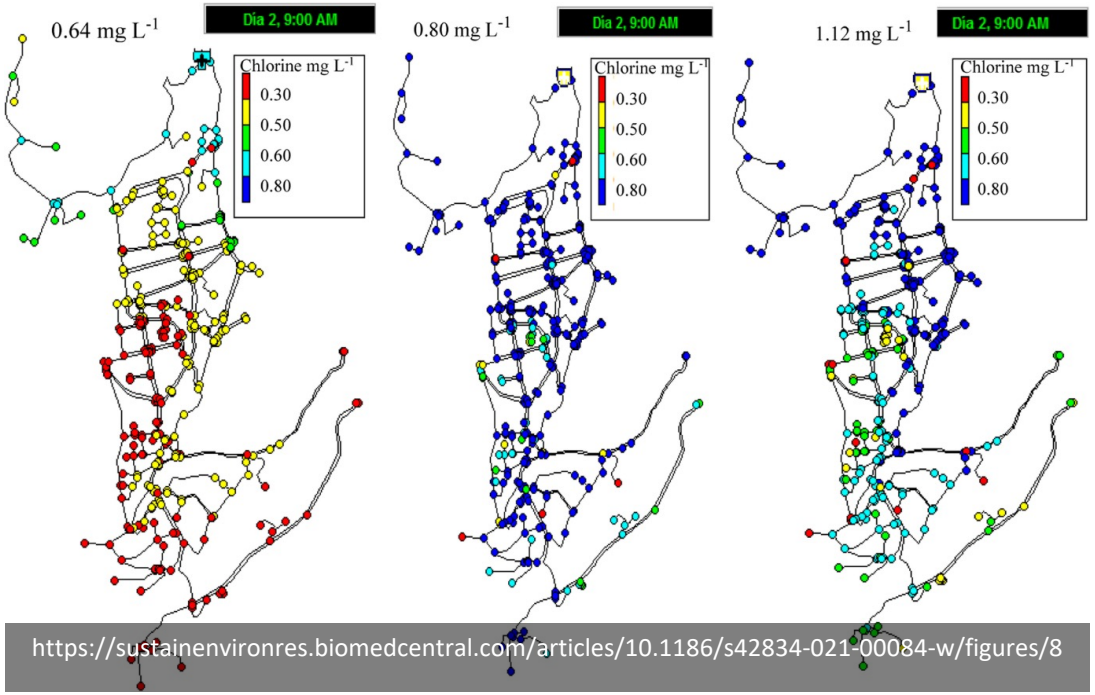
WHO Drinking Water Guidelines

Managing residual

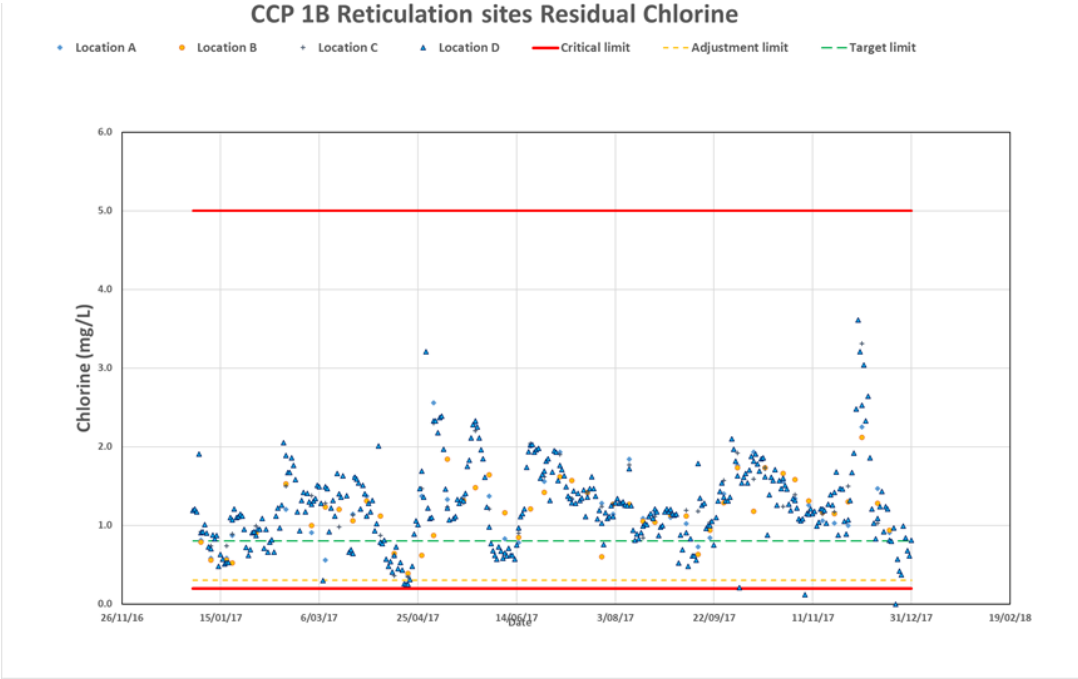
- Chlorine residual decays over time
- The rate of decay will depend on a number of factors
- Target residual of >0.2 mg/L (system specific)



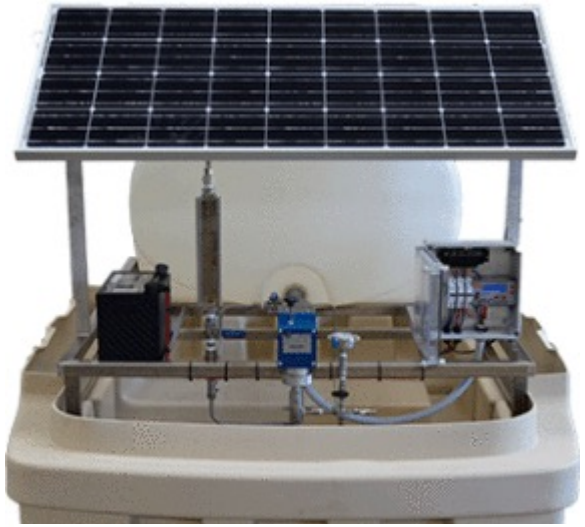
Managing water quality in network



https://sustainenvironres.biomedcentral.com/articles/10.1186/s42834-021-00084-w/figures/8



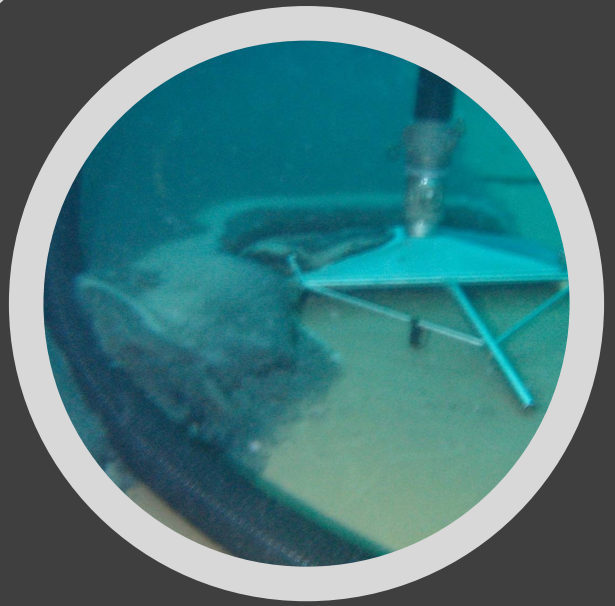
Mixing and re-chlorination



https://solarinjection.com.au/sia-pumps/solar-driven

IXOM 2021 - https://www.ixomwatercare.com/applications/potable-water-systems/distribution-system-chlorine/complete-potable-tank-mixing

- It is often necessary to boost the chlorine in a network to maintain a residual
- Mixing in reservoirs can minimize presence of dead spots. Provide more consistent residual.

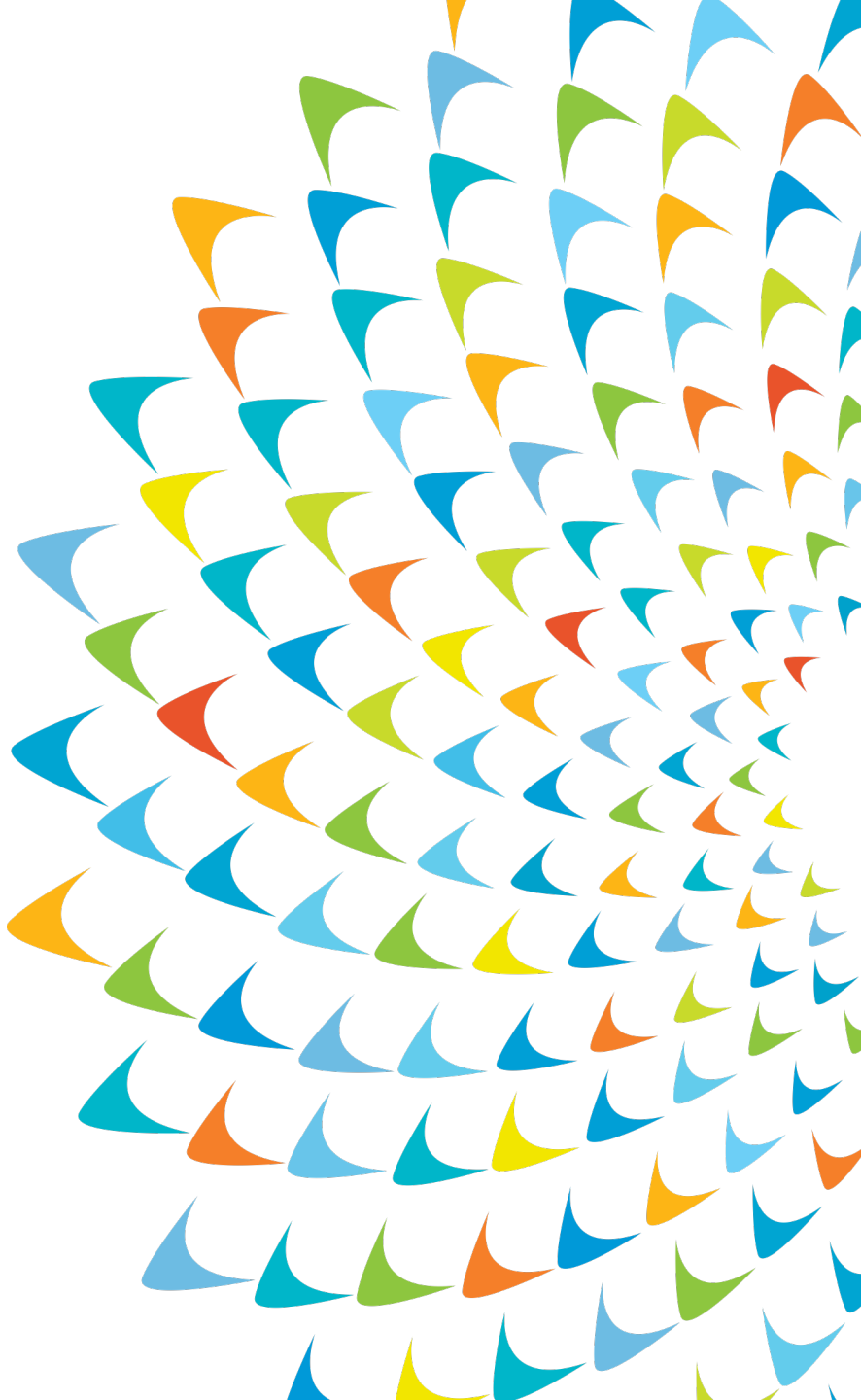


Reservoir design and maintenance

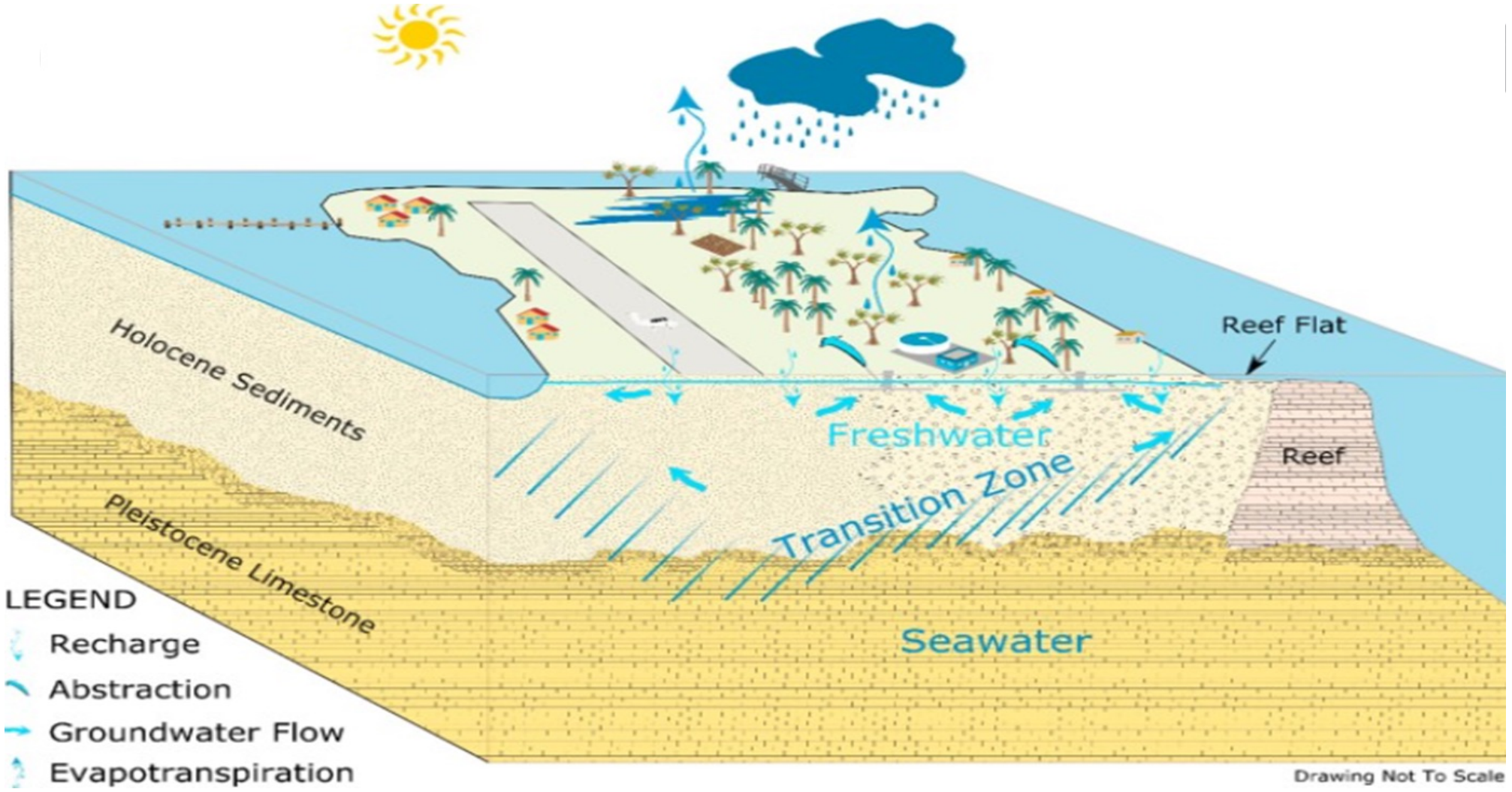
- Vermin screens
- Divert rainwater
- Minimise sunlight
- Properly sealed
- Clean every 2 years
- Draw-off 200 mm above base
- Bucket/hose test

https://watersmarine.com.au/reservoir-maintenance/

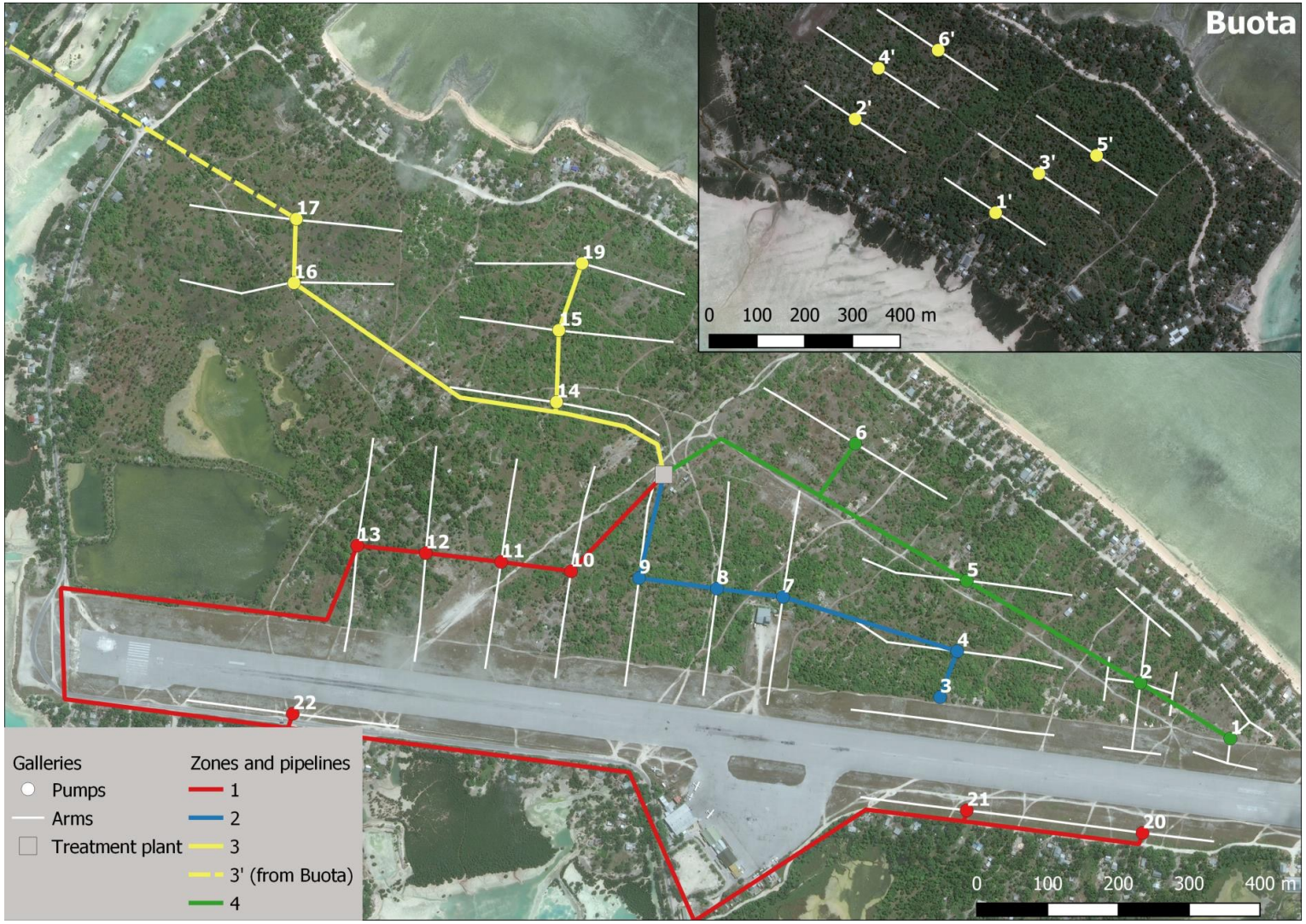
Example of challenges



Overview of PUB Water Supply



Bonriki Water Reserve



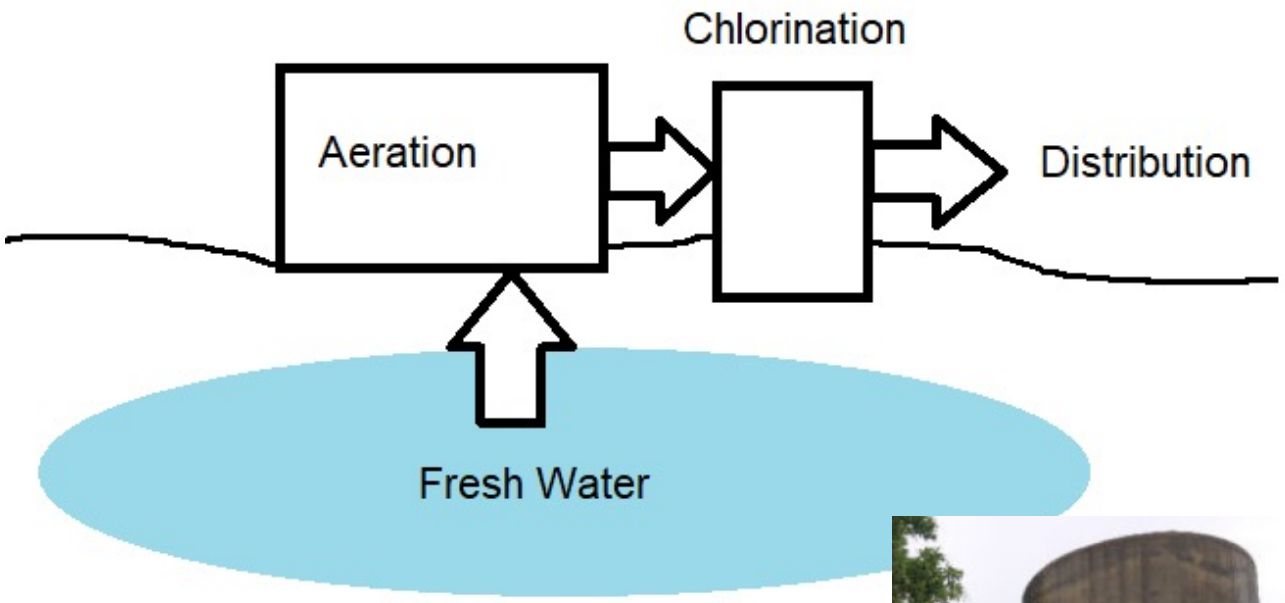
Availability

- Average annual rainfall: **1,740 mm/yr**
- Estimated annual recharge: **947 mm/yr (1,992 m³/d)**
- Average abstraction rate : **1,480 m³/d**
- Design Yield: **1,660 m³/d**

Quality

- Maximum EC recorded at the Trunk Main: **1,200 µS/cm** with up to 3,800 µS/cm at individual galleries
- EC water quality threshold at the trunk main **1,500 µS/cm**
- Ecoli Contamination (0-100 orgs/100ml)

Kiribati – The treatment process

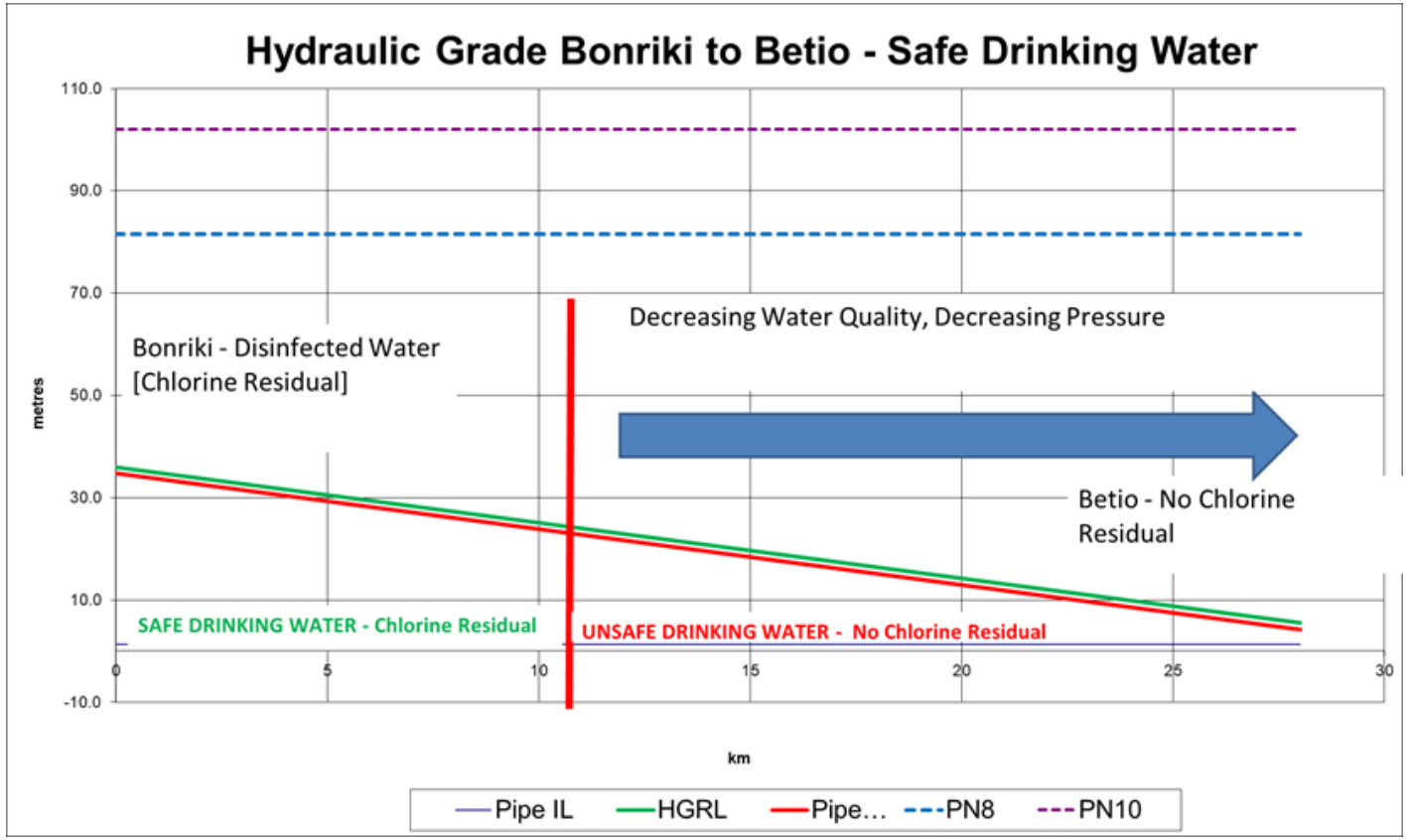


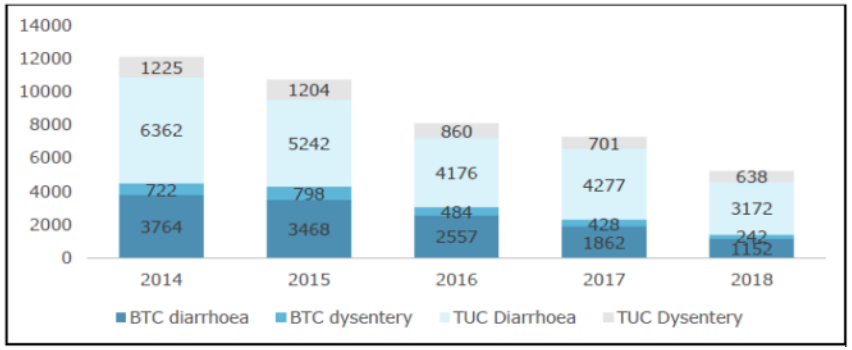
- Low water volumes
- Intermittent supply
- Highly contaminated ground water (widespread e-coli)
- Aged infrastructure (Chance of failure is high)

Kiribati – The pathogen risks

WORLD BANK 2018

"Water borne diseases could rise to devastating levels, and the potentiality of an outbreak of cholera will be imminent".



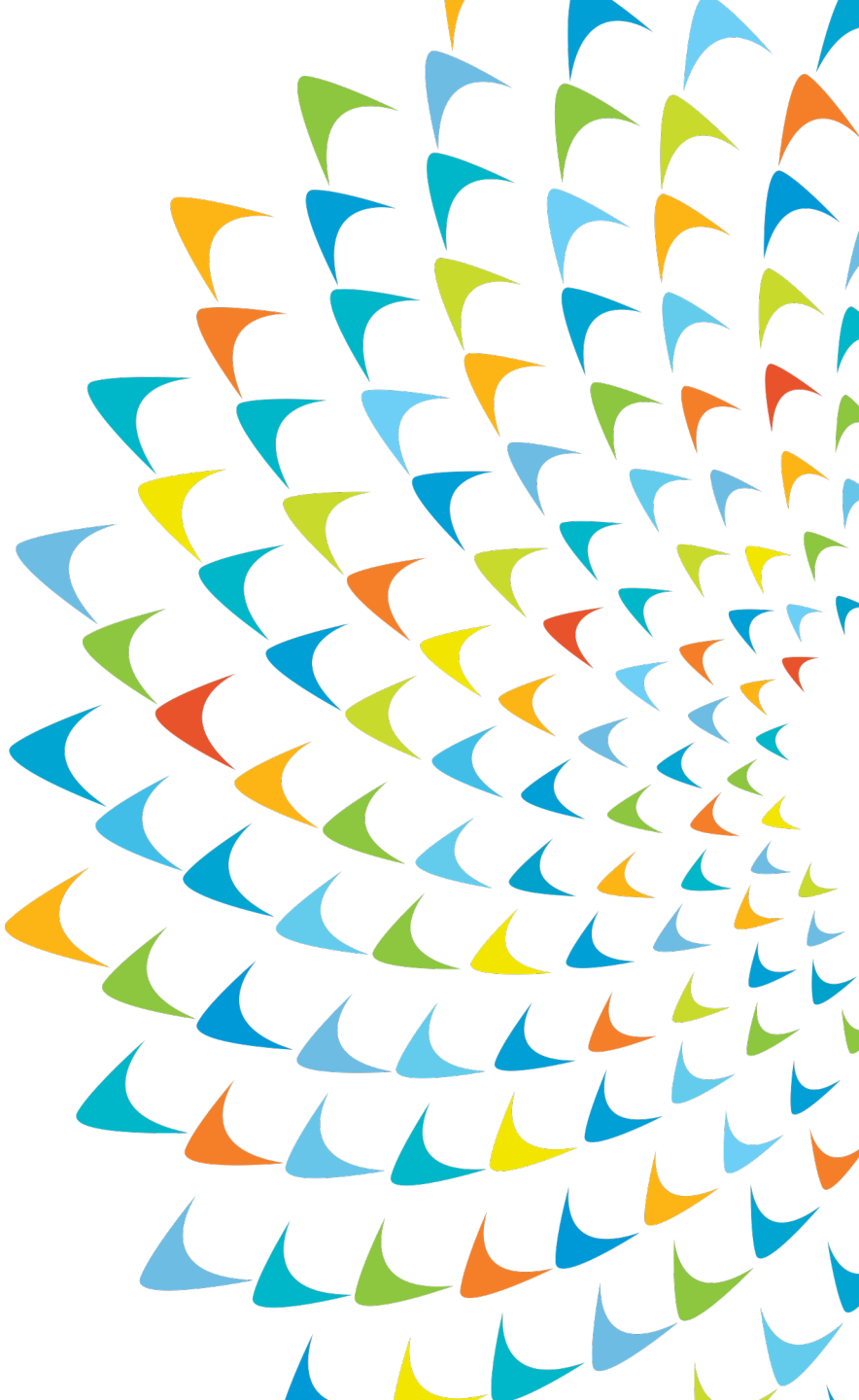


Kiribati – The proposed approach

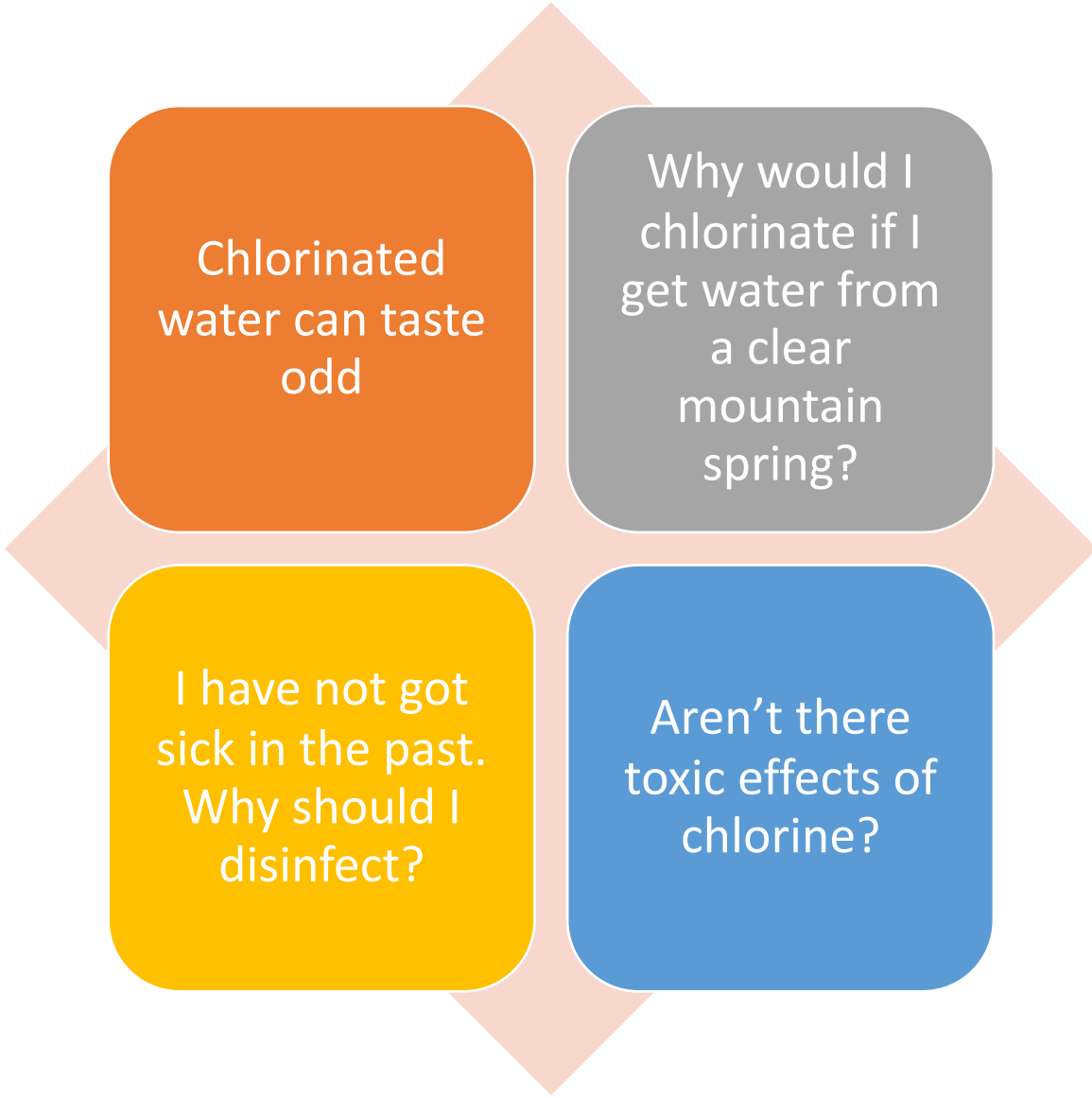
- Maximize Chlorination at the Bonriki Disinfection Station
- Install Booster Station at Betio
- Focus on repairs and maintenance
- Backflow prevention
- Surveillance of Chlorination levels
- Boil Water Alerts and Community Education

- South Tarawa Water Supply Project (desalination plants and new distribution system)

Community consultation



Typical concerns



Community engagement

- Understand the water quality risks
- Develop the preferred disinfection approach
- Determine how you will engage with the community
  - Fact sheets and FAQ
  - Community workshops
- Commence consultation
- Progress design and procurement
- Keep the community up to date
- Issue alerts when required:
  - Boiled water
  - Loss of supply
- Keep open the channels for communication

Possible responses

01

Answering questions on the taste of water:

- Control the chlorine residual to prevent concentrations from being too high in the distribution network.
- Reduce concentration of contaminants which react with chlorine to create taste and odour issues.

02

Discussing community risk:

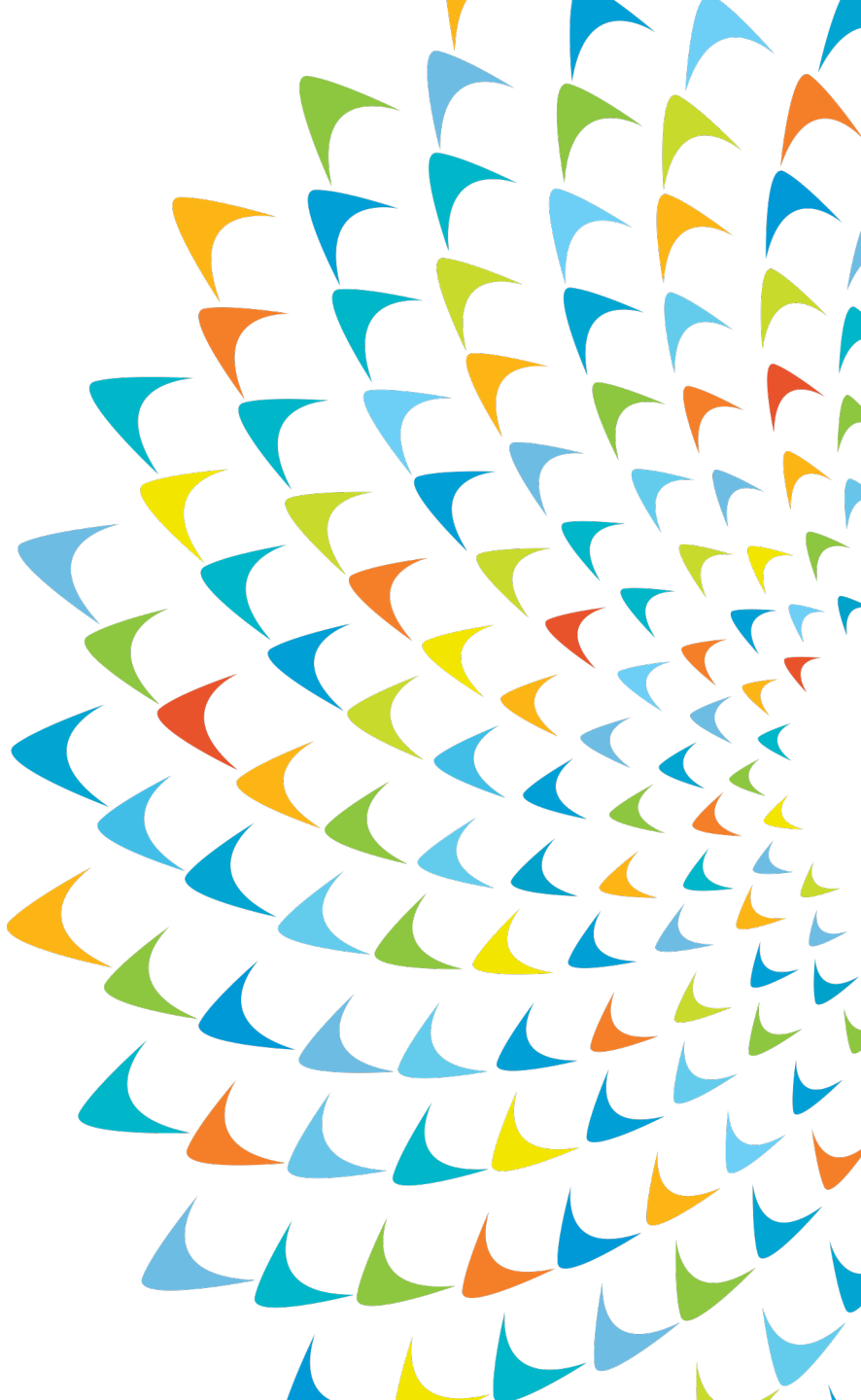
- Discuss changes in the catchment as well as growth in the local area.
- Provide analysis results if available which identify contamination.

03

Answering questions on toxicity:

- Highlight methods which will be used to control chlorine dosing.
- Highlight how toxic by-product production (i.e. THMs) will be limited.

Discussion



Thank you.