Chlorate Working Group

Drinking Water Treatment

V0 1

May 2016

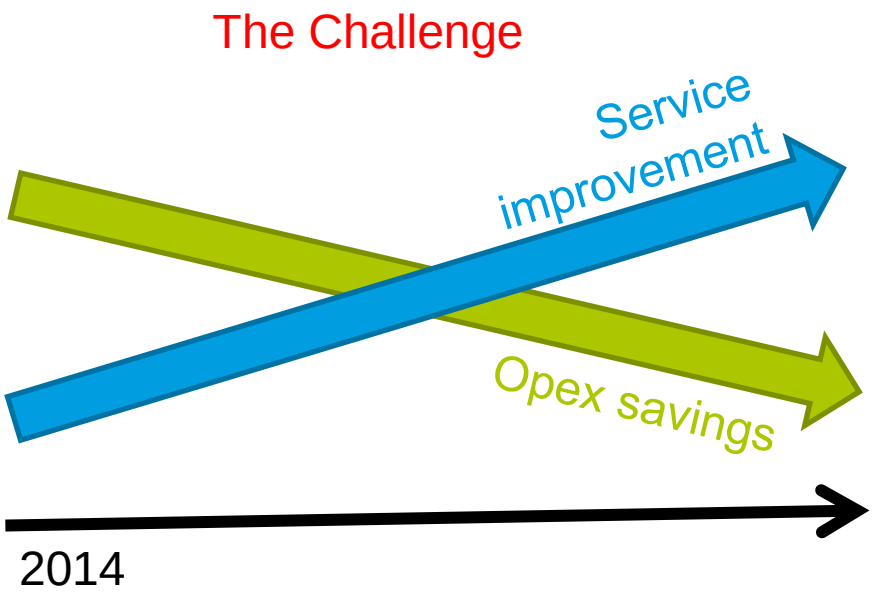
Why Our journey

Jan 2015:

- 23,000 people on a BWN
- 121 WSZs on RAL
- 49% UFW
- Over 33% of our WTPs do not have 15% headroom

What brought us to this point:

- Constrained funding leading to underinvestment
- Fragmented industry structure (31LAs)
- Inconsistent O&M standards
- Aging and poor quality infrastructure



What

Current Asset Management

Current:

- Priority – reduce OPEX
- Investment – driven by EU Directives
- No long term strategies
- Limit understanding of risk

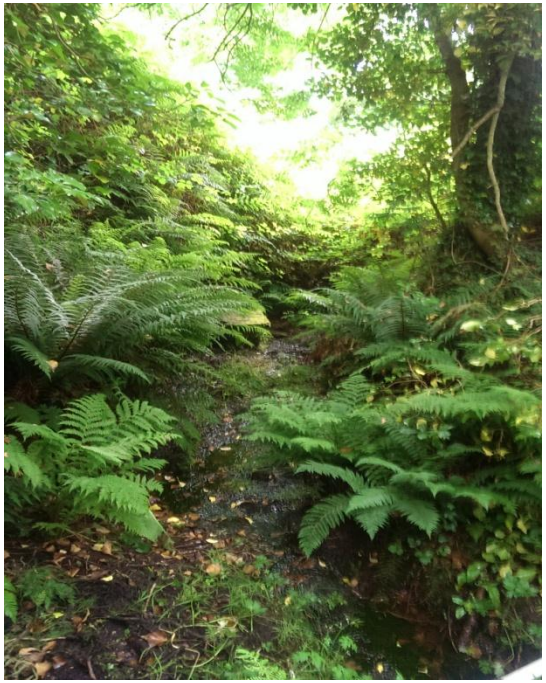
Service improvement

Effective decision making:

- Evidence-lead decisions
- Asset intelligence (better data)

Ra w Water				Filtration							Disinfection	
Category	Sources	CFC	%	SSF	Mem/Cart	RGF	GAC	Mang	**Total**	%	Chlorine	UV
G1	1	0	**0**	0	0	0	0	0	**0**	**0**	1	0
G2	5	0	**0**	0	0	0	0	1	**1**	**20**	5	1
G3	433	5	**1**	0	1	51	2	10	**64**	**15**	372	110
G4	33	0	**0**	0	0	6	2	0	**8**	**24**	30	11
G5	45	4	**9**	1	2	9	3	0	**15**	**33**	42	18
S1	2	0	**0**	1	0	0	0	0	**1**	**50**	2	0
S2	236	75	**32**	30	5	91	7	1	**134**	**57**	231	50
S3	168	104	**62**	22	1	114	6	4	**147**	**88**	164	26
Subtotal	**406**	**179**	**44**						**282**	**69**		
Total	**923**	**188**		**54**	**9**	**271**	**20**	**16**	**370**	**40**	**847**	**216**

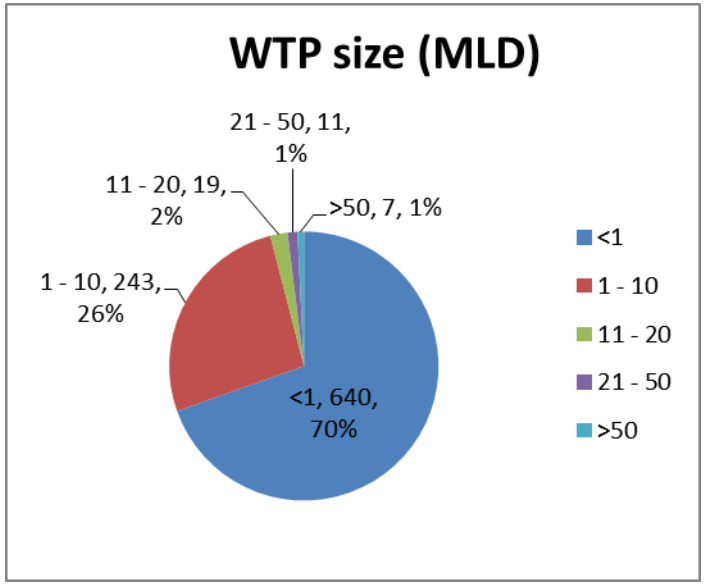
What

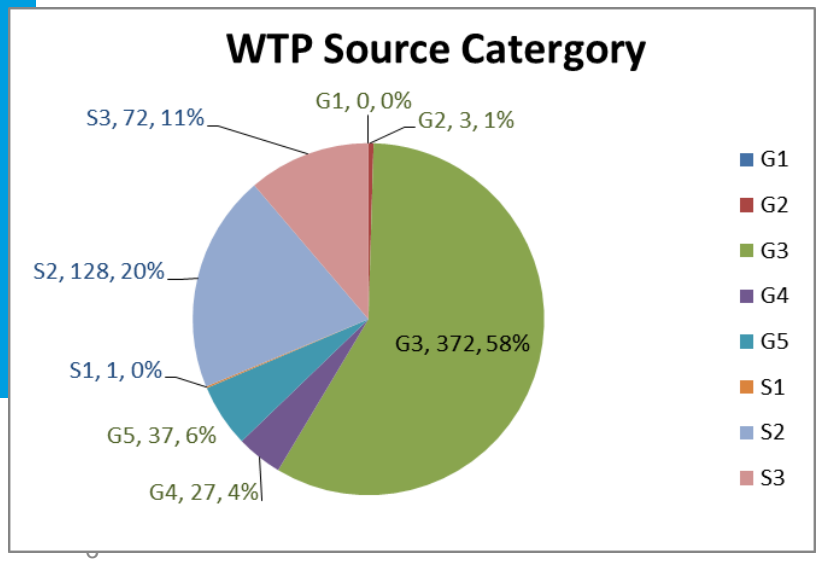


What

How

Rationalisation





Current:

- 860+ WTPs
- 70% of WTPs < 1.0MLD
- 31% of WTPs abstract from surface water sources
- 70% of population supplied from WTPs abstracting from surface water

Scottish Water:

- 400 WTPs (2002) ➡ 235 WTPs (2013) [41% ⬇]

Region	2015	PRW1 Option 3
Southern	548	184 (66% ⬇)
East Midlands	226	53 (76% ⬇)
North West	161	84 (48% ⬇)
Total	**935**	**321**

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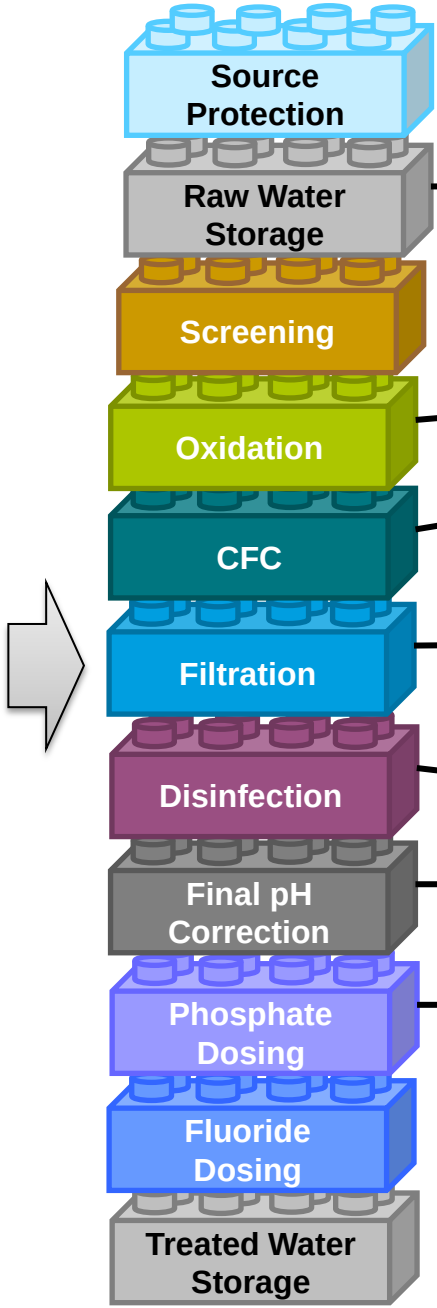
The Disinfection Strategy

Water Treatment Process Chain

Water Treatment Strategy



S (river) - Bank-side storage

G1 (low risk) – Iron, Manganese, Ammonium

S1-3 + **G2-5 (high risk)** - Protozoa, THMs, Colour, Algae, Cadmium, Nickel, Odour, Pesticides, Taste, TOC

S1-3 + **G2-5 (high risk)** - Protozoa, THMs, Colour, Algae, Cadmium, Nickel, Odour, Pesticides, Taste, TOC, Iron, Manganese, Aluminium
GW (low risk) – Iron, Manganese, Ammonium

S1-3 + **G2-5 (high risk)** - Protozoa, Bacteria, Viruses
G1 (low risk) – Bacteria, Viruses

S1-3 + **G2-5 (high risk)** + **G1 (low risk)** – pH, Plumbosolvency control

S1-3 + **G2-5 (high risk)** + **G1 (low risk)** – Plumbosolvency control

S – surface water, G – ground water

Application of Disinfection Technologies

Consideration	Chlorine	Chloramines	Ozone	Chlorine Dioxide	UV
Complexity of technology	Low	Low	High	Medium	Medium
H&S	Low *	Medium	Medium	High	Low
Efficacy against bacteria	Good	Good	Good	Good	Good
Efficacy against viruses (Adeno)	Good	Medium	Good	Good	Medium
Efficacy against protozoa (Crypto)	Poor	Poor	Good	Poor	Good
By-product formation	THM, HAA	NDMA	Bromate	Chlorite, Chlorate	
pH dependency	High	High	None	Medium	None
Persistent residual	High	High	None	Medium	None
O&M	Low	Moderate	High	Moderate	Moderate
Applicability in Ireland		Increased metal corrosivity	Very large Ct required at <5°C	Very large Ct required at <5°C	UVT > 70% Turbidity ≤1.0 NTU

* High H&S concerns for chlorine gas

Primary disinfectant	Log Inactivation for *Cryptosporidium*	Required Ct (mg.min/L) at water temperature of 5°C
Ozonation	3.0	47
Chlorine dioxide	3.0	1,288

Process Decision Chart

UISCE ÉIREANN : IRISH WATER

Start

Primary disinfection (inactivation of pathogens)

Mandatory
All supplies must use chlorination for pathogenic bacteria and virus inactivation – min. 4-log inactivation

Use IW Ct calculation worksheet

To achieve compliance, effective Ct ≥ target Ct, free chlorine residual should be ≥ 0.5mg/L at end of contact time (t)

Is supply low risk ground water (G1)?

N

Surface water (S1-3) or high risk groundwater (G2-5)

Provide treatment (filtration and/or UV) for pathogenic protozoa removal/inactivation

Protozoa log credit assessment

1. Determine **protozoal log credit requirement** for supply – default = 4-log *Cryptospridium* removal/ inactivation (see Tables D.1 or D.2)
2. Determine **protozoal log credit for treatment options** (see Table D.3)

To achieve protozoal compliance, sum of log credits for each process ≥ log credit requirements for supply

Y

Secondary disinfection (maintaining quality in distribution network)

Mandatory
All supplies must use chlorination to maintain water quality in distribution system

To achieve compliance free chlorine residual ≥ 0.1mg/L

Operational monitoring

Final pH Correction

Bacterial and Viral Compliance Criteria

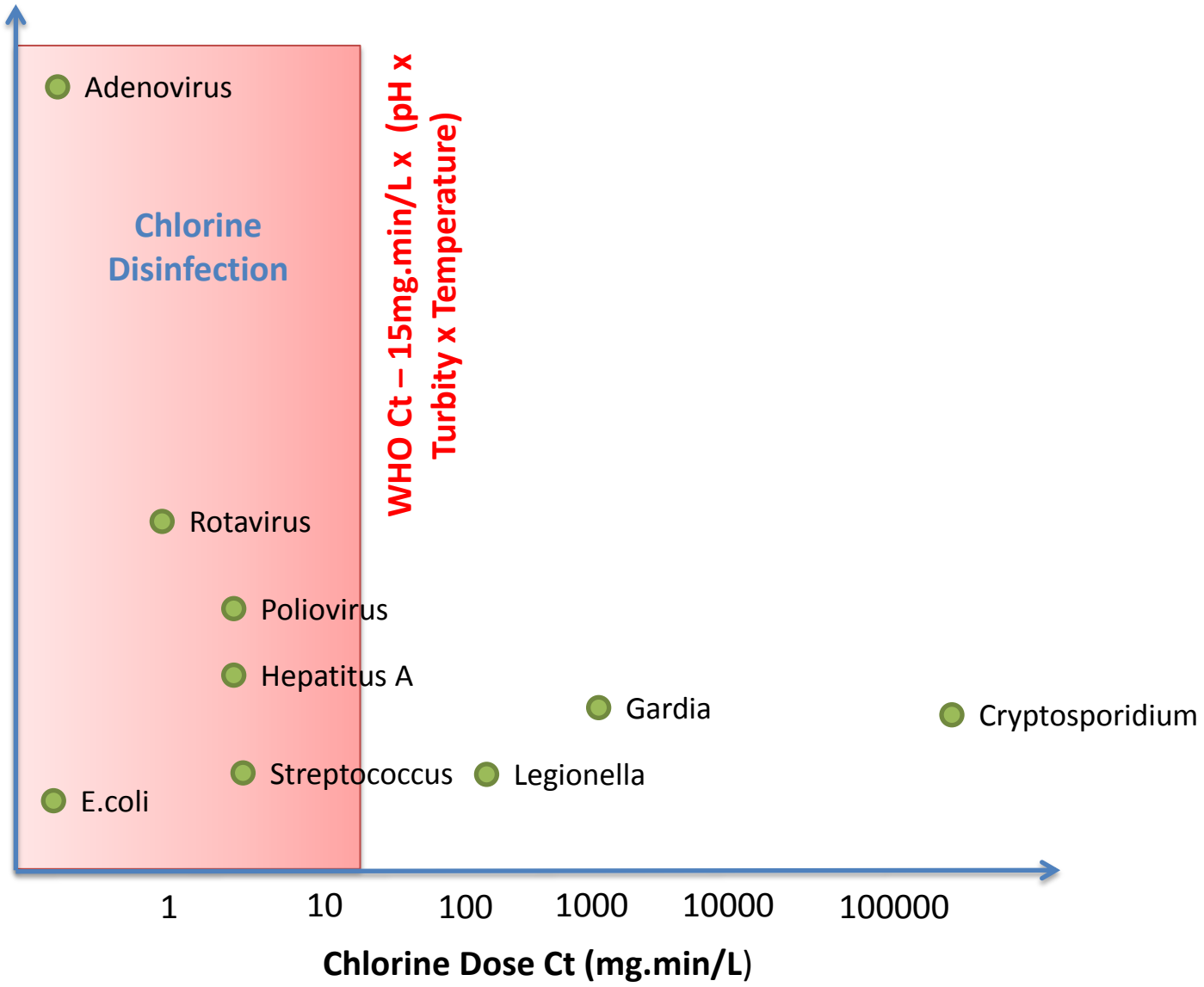
A) Bacterial and Viral Non-compliance

- A chlorination disinfection process does not achieve Target Ct determined in Steps A.1: Chlorination Validation Calculation, resulting in the treatment plant not reaching the total log credits required.

- The monitoring or operational requirements specified in Step A.2 are not met or exceeded.

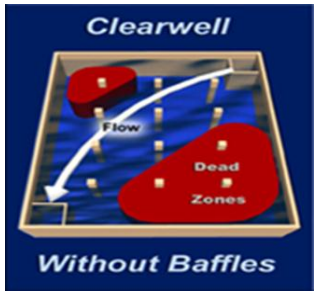
- Incorrect monitoring procedures are used (eg, inadequate sampling, incorrect standardisation of metering equipment, or analyses not carried out by a laboratory recognised for the purpose).

Primary Disinfection Option 1 – Chlorine only

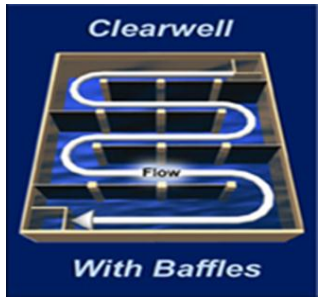


Step A.1 - Bacterial and Viral Log Credit Compliance Requirements – Chlorination

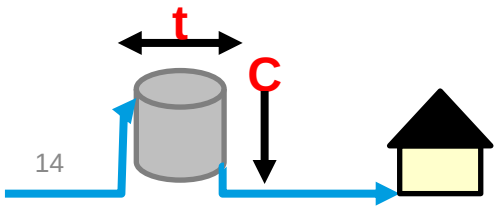
- Calculate target Ct and Effective Ct



Distribution factor =0.1



Distribution factor =0.5

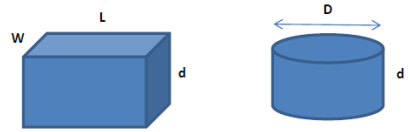


Disinfection - Chlorination Validation Calculation

Plant Details

Scheme Name:	Example Scheme
Treatment Plant Name:	Example Water Treatment Plant
Water Supply Zone Code:	WSZ000
Maximum flow	200.00 m^3/hr
Calculation prepared by:	A.N. Other
Date:	31/10/2014

Contact Tank Shapes



Target Ct

Source:	Surface Water (Lake)	
Maximum pH:	8.20	
Minimum Temperature:	5.00	°C
Maximum Filtered Water Turbidity:	0.4	NTU
Minimum Ct	15	mg.min/l
pH Factor	1.3	
Temperature Factor	1.2	
Turbidity Factor	1	
Target Ct	23.40	mg.min/l

Effective Ct - Contact Tanks

Contact Tank	No. 1	No. 2	
Tank shape	Rectangular *	Circular **	
Internal length (L) *	10.00		m
Internal width (W) *	10.00		m
Internal diameter (D) **			m
Minimum depth (d)	3.00		m
Tank volume	300.00	0.00	m^3
Flow distribution	Poor	Average	
Distribution factor	0.3	0.5	
Effective contact time (t)	27.00	0.00	minutes
Minimum free chlorine concentration after (t)	0.8		mg/l
Effective Ct after (t)	21.60	0.00	mg.min/l

Effective Ct - Pipelines

Pipe	No. 1	No. 2	
Internal diameter	0.25		m
Length	300.00		m
Pipe volume	14.73	0.00	m^3
Effective contact time (t)	4.42	0.00	minutes
Minimum free chlorine concentration after (t)	0.62		mg/l
Effective Ct after (t)	2.74	0.00	mg.min/l

Total Effective Ct after (t) 24.34 mg.min/l

Instructions : 1) Enter site specific data into blue cells. 2) Grey cells, select from drop down box.
3) Total effective Ct after (t) must be greater than target Ct.

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Step A.2 - Bacterial and Viral Log Credit Compliance Criteria – Chlorination

- To obtain 4.0 bacterial and viral log credits for chlorination used as primary disinfection process, the following requirements must be met during periods when treated water is being produced:

  a) *All water must pass through the full chlorination (primary disinfection) process [no bypass or mixing of water];*
  b) *Effective Ct must exceed target Ct (IW Chlorination Validation Calculation Worksheet) at all times;*
  c) *Measurement of free chlorine of the water leaving the contact tank must satisfy the following conditions:*
     i. Shall be greater than or equal to 0.5mg/L for the duration of any three-minute period.
  d) *Measurement of turbidity of the water entering the contact tank must satisfy the following conditions:*
     i. Shall be less than or equal to 1.0 NTU for the duration of any three-minute period;
     ii. Treated water turbidity shall not exceed the raw water turbidity for the duration of any three-minute period; and
     iii. Shall not exceed 2.0 NTU in any sample
  e) *Measurement of pH of the treated water entering the contact tank must satisfy the following conditions:*
     i. Shall be less than or equal to maximum design pH for the duration of any fifteen-minute period.

- Bacterial compliance monitoring requirements for chlorination (primary disinfection) are as follows (separation between data records must be less than 1-minute):

Parameter	Location	Frequency	Critical Control Point	Alarm	Compliance duration
Turbidity	Treated water	Continuous	>1.0NTU	>0.8NTU	Any 3-minute period
	Treated water	Continuous	>2.0NTU	>1.5NTU	Any 1-minute period
	Treated water	Continuous	Treated water turbidity > raw water turbidity		Any 3-minute period
Total chlorine	Treated water (before contact tank)	Continuous	<0.4mg/L	>0.5mg/L	Any 3-minute period
Free chlorine	Disinfected water (after contact tank)	Continuous	<0.5mg/L	>0.6mg/L	Any 3-minute period
pH	Treated water	Continuous	> Maximum design pH	>0.8 Maximum design pH	Any 15-minute period
Flow	Treated water	Continuous	>maximum design flow m^3/hr		Any 15-minute period

Protozoal Compliance Criteria

Principle

- *Cryptosporidium* is the most infectious and most difficult protozoan to remove or inactivate.

- The protozoal compliance criteria are constructed on the principle that if the treatment process deals successfully with *Cryptosporidium*, they will also deal successfully with other protozoa.

IW Protozoal Compliance Criteria

- Cumulative log credit approach - acknowledges any additive effect of successive different treatment processes on the removal/inactivation of protozoa where more than one treatment process is used.

- Uses overseas data, chiefly from the United States Environmental Protection Agency (USEPA) (USEPA 2006a), on the log-removal/inactivation efficacy (a measure of the percentage of organisms removed/inactivated) of *Cryptosporidium* for a range of treatment processes.

- Specifies the use of validated equipment (where appropriate), monitoring programmes and treatment performance measures.

B) Protozoal Non-compliance

- A treatment process does not satisfy the conditions required to achieve the log credit specified in Steps B.1.1 or B.1.2: Log credit assessment, resulting in the treatment plant not reaching the total log credits required.

- The monitoring or operational requirements specified in Steps B.3.1, B.3.2, B.3.3, B.3.4, B.3.5, B.3.6 or B.3.7 are not met or exceeded.

- Incorrect monitoring procedures are used (eg, inadequate sampling, incorrect standardisation of metering equipment, or analyses not carried out by a laboratory recognised for the purpose).

Step B.1.1 - Protozoal Compliance Requirements

- **Option 1** (Inadequate monitoring)
  - *Characteristics of source are assessed against catchment and groundwater categories.*

Table D.1: Log credit requirements for different catchments and groundwater categories

	Goundwater	Surface water	Log credit requirement
	G1 Low risk (no microbiological contamination) – sealed bored well with source protection, water drawn from deeper than 30m	Not applicable	0
Removal and/or Inactivation	**G2** High risk (with microbiological contamination) – sealed bored well with source protection, water drawn from deeper than 30m	Not applicable	2
	G3 High risk (with microbiological contamination) – sealed bored well with source protection, water drawn between 10m to 30m (Groundwater default)	**S1** Upland catchment - no agricultural activity in immediate vicinity or upstream	3
	G4 High risk (with microbiological contamination) - spring or bored well, water drawn <10m, in upland catchment with low concentration of cattle, sheep, horses or humans in immediate vicinity or upstream	**S2** Upland catchment - low concentration of cattle, sheep, horses or humans in immediate vicinity or upstream (Surface water default)	4
Removal + Inactivation	**G5** High risk (with microbiological contamination) - spring or bored well, water drawn <10m, in lowland catchment with high concentration of cattle, sheep, horses or humans in immediate vicinity or upstream or waste treatment outfall upstream	**S3** Lowland catchment – high concentration of cattle, sheep, horses or humans in immediate vicinity or upstream or waste treatment outfall upstream	5

Step B.2 - Protozoal Treatment Options

Table D.3: Protozoa treatment options and credits

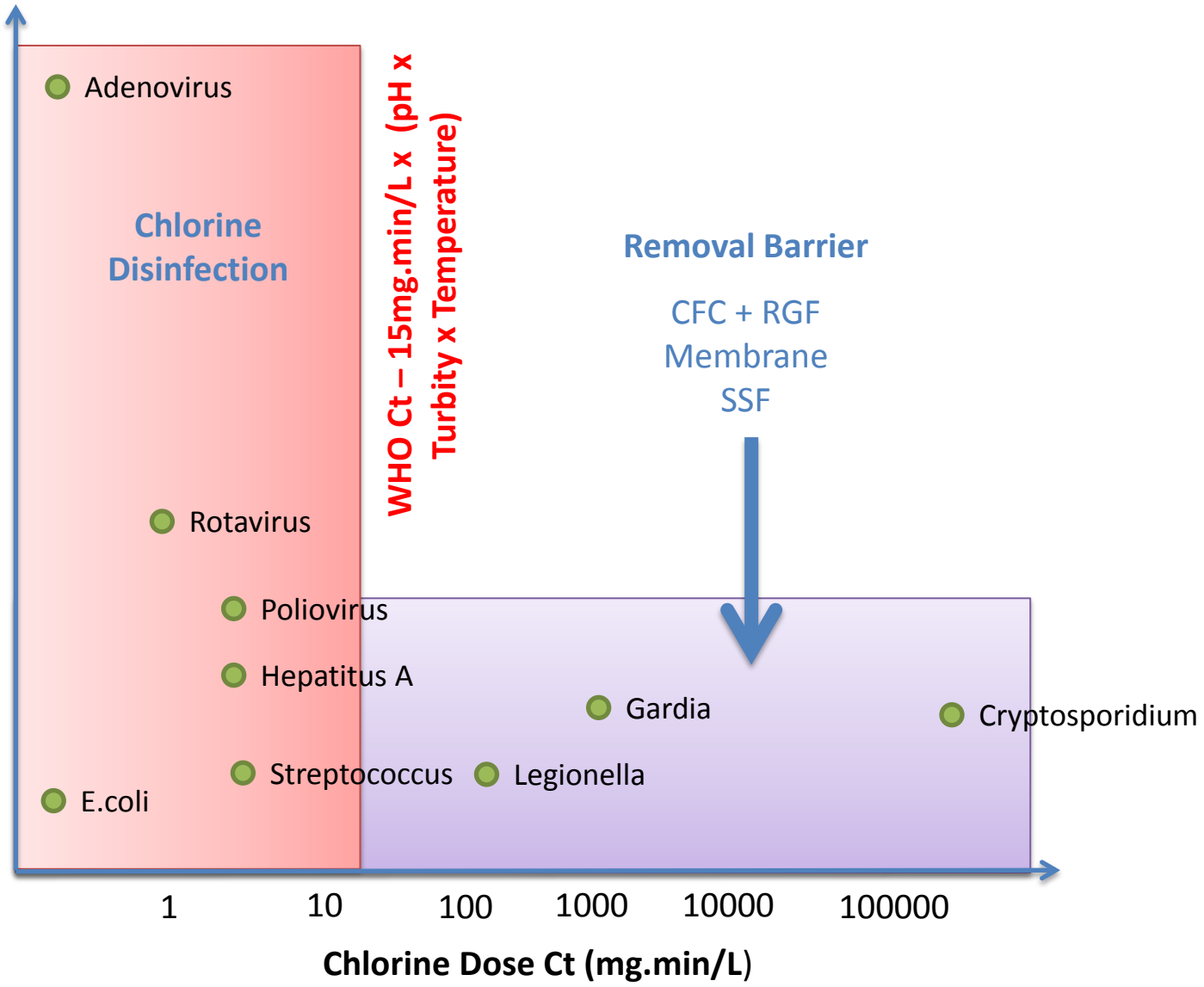
Treatment	Log credit
Filtration (physical removal)	
Coagulation, flocculation, clarification and rapid gravity filtration	3.0
• Additional log credit for enhanced individual filtration	1.0
Slow sand filtration	2.5
Direct filtration *	2.5
Membrane filtration *	Log credit demonstrated by challenge testing and verified by direct integrity testing
Cartridge *	2.0
Bag *	1.0
Disinfection (inactivation)	
UV	Dose dependent (max 3.0)

* selection of these filtration processes should be referred to Asset Strategy (Water Treatment) before proceeding with procurement

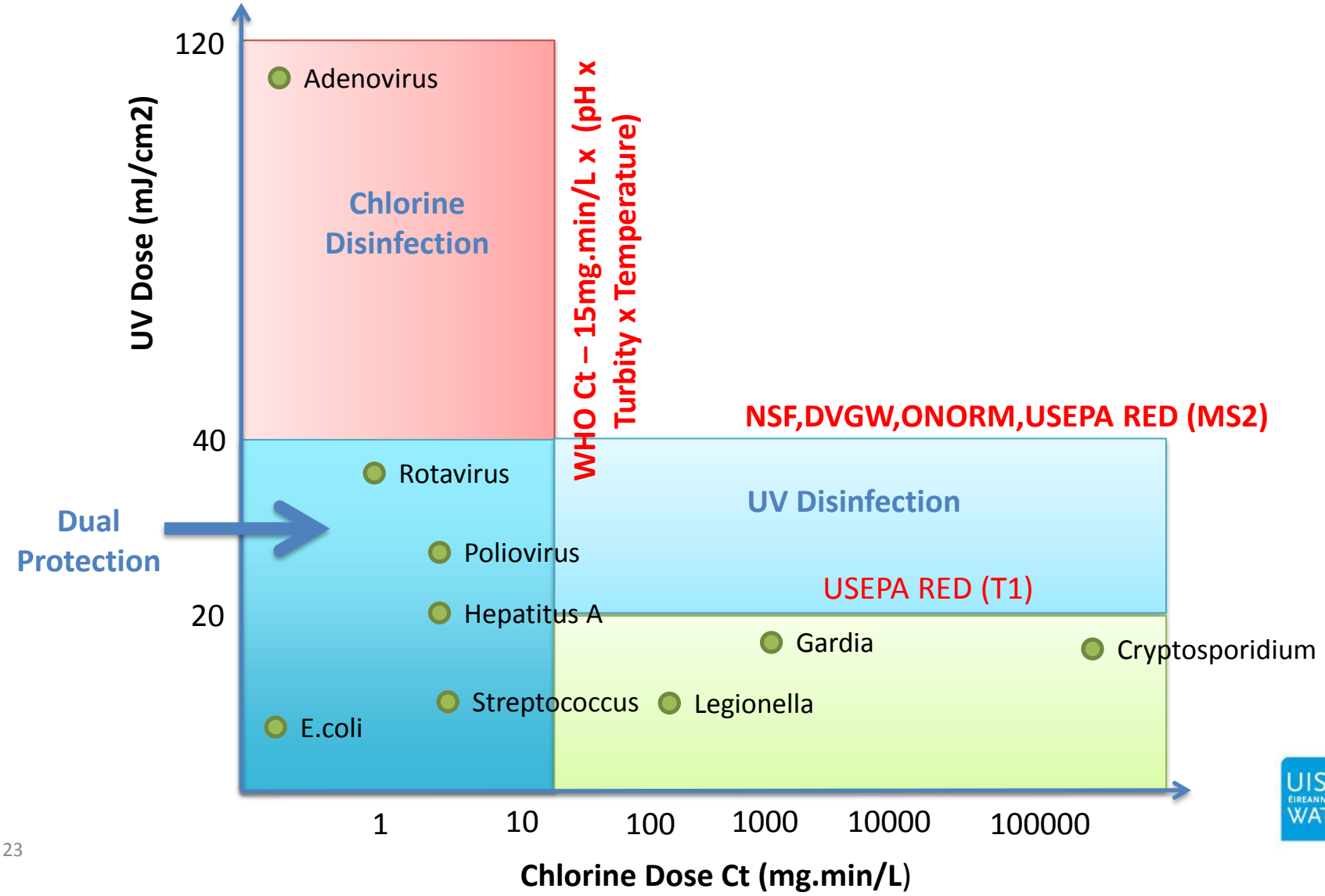
Note:

- Must consistently meet Steps B.3.1, B.3.2, B.3.3, B.3.4, B.3.5 or B.3.6 protozoa treatment compliance criteria (operational requirements); and
- Total inactivation log credit must not exceed 3.0.

Primary Disinfection Option 2 – Chlorine only



Primary Disinfection Option 3 – Chlorine + UV



WTPs with chlorine gas

County	No. of WTPs	Chlorine gas		County	No. of WTPs	Chlorine gas
Carlow	14	3		Limerick	39	
Cavan	17			Longford	7	
Clare	17			Louth	13	2
Cork	175			Mayo	21	4
Cork City	1			Meath	59	6
DLR	3			Monaghan	13	3
Donegal	39			Offaly	28	
Dublin City	3	2		Roscommon	13	3
Fingal	2			Sligo	7	4
Galway	34			South Dublin	1	
Galway City	1			Tiperary	56	3
Kerry	63			Waterford	115	
Kildare	7			Westmeath	4	
Kilkenny	22	2		Wexford	34	5
Laois	26	2		Wicklow	55	1
Leitrim	4	2				
				Total	**893**	**42**

Example: Sodium Hypochlorite vs chlorine gas

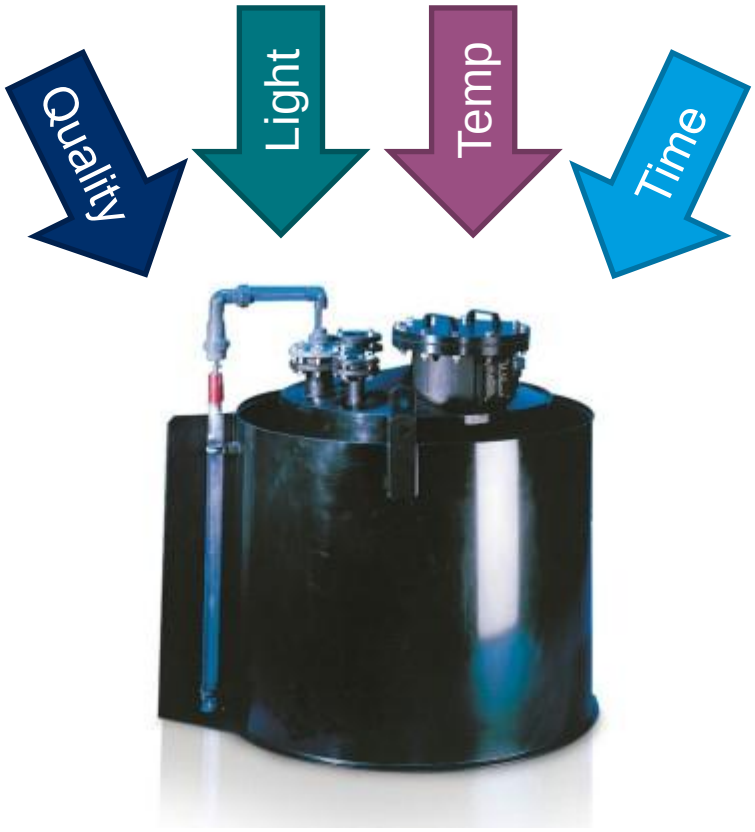
- Deficiencies of existing chlorine gas disinfection system:
  - Manual dose adjustment (no flow proportional or chlorine residual control
  - No automatic chlorinator changeover
  - Gas cylinder changeover panel no longer being manufactured
  - CAPEX upgrade cost = €108,803
- New Sodium Hypochlorite disinfection system:
  - CAPEX upgrade cost = €74,544

Disinfection By-products

Chlorination By-products

- Organic
  - *Reaction between chlorine and organic matter in water*
  - *THMs, HAAs*
- Inorganic
  - *Arise due to production and storage*
  - *Bromate, chlorate and chlorite*

Sodium Hypochlorite Degradation



- IW Standards
  - *Concentration ≤ 10%*
  - *Storage < 50 days*

Table 4.2 Illustrative examples of chlorine decomposition in hypochlorite solution @ 20°C

Initial concentration	After 20 days	After 100 days
15% available chlorine	13%	10%
13% available chlorine	12%	8%
10% available chlorine	9%	8%
6.5% available chlorine	6.2%	6%

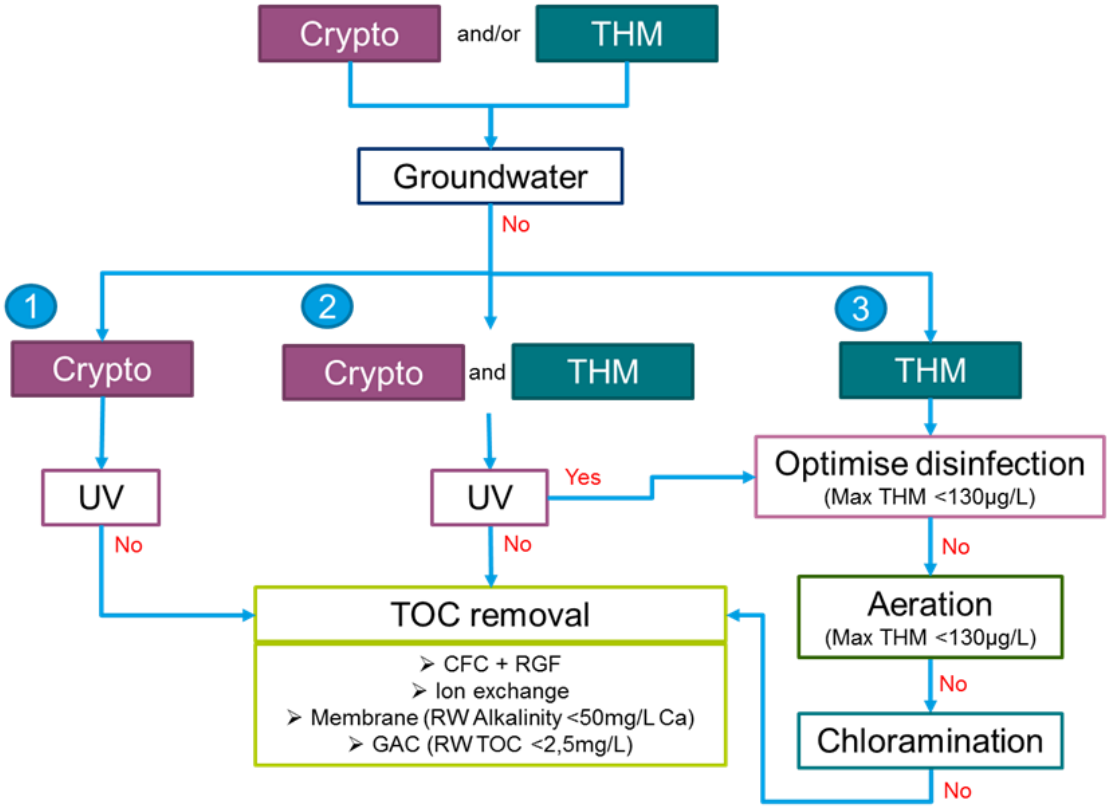
Standards for chlorine chemicals

Table 4.5 Chlorination chemical standards: limits for chlorite, chlorate and bromate

Contaminant	Maximum contaminant per mg Cl_2 dosed		
	Chlorine gas *IS EN 937: 1999	**Commercial Sodium Hypochlorite** *IS EN 901:2007	**Sodium Hypochlorite from OSE** *IS EN 14805:2008 (salt)
Chlorite	Insignificant	Insignificant	Insignificant
Chlorate	Insignificant	0.042 mg	Insignificant
Bromate	Insignificant	2.5 to 5 µg	**1.2 to 2.4 µg

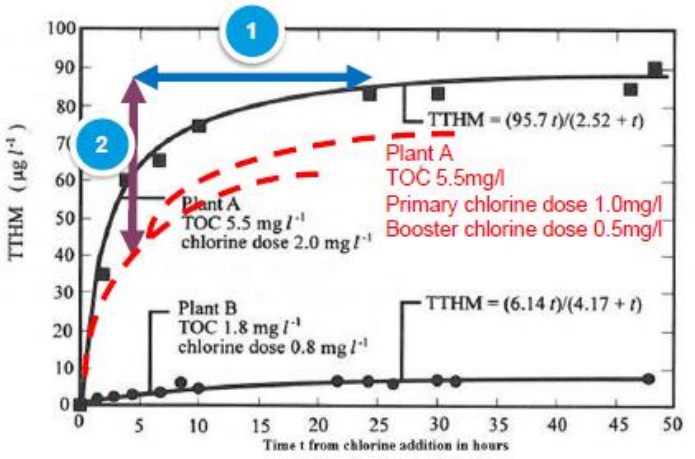
* IS EN = European standard incorporated into Irish standards, where a range is given this relates to the different product specifications allowable under the standard.

THM Reduction Strategy



Optimise disinfection:

1. Reduce contact time
2. Reduce chlorine dose



50% reduction in THMs formed at primary disinfection stage