

The Provision of Safe and Secure Drinking Water

Drinking Water Safety Challenge

Asset Planning (Water Treatment)

March 2017





V0 3



Coagulation Control Workshop - Agenda

09h00 – 09h30: Registration

09h30 – 10h15: Provision of safe drinking water [Victor van der Walt, IW] 10h15 – 11h00: Coagulation chemistry [David Speers, Jacobs]

11h00 – 11h30: Tea/Coffee

11h30 – 12h15: Jar testing best practice [Kevin Love, IW]12h15 – 13h00: History of coagulation control [John Clark, Chemtrac]

13h00-14h00: Lunch



14h00 – 15h00: CoagSense Coagulation Control [John Clark, Chemtrac] 15h00 – 16h00: Practical Implications of Coagulation Control [Mike Riding, PI]

Why Drinking Water Safety Challenge

Traditional approach (monitoring the end product)

- Monitoring of coliform bacteria, turbidity and disinfectant residuals has been demonstrated insufficient for the prevention of waterborne outbreaks (Payment *et al.*, 1993)
- Waterborne outbreaks have been documented in regions where the drinking quality was met with existing microbiological criteria (Melnick and Gerba, 1979; Craun, 1981; Lippy and Waltrip, 1984; O'Neil *et al.*, 1985)



The presumed close correlation between pathogen occurrence and the detection of indicator organisms may not always be present, especially in the case of *Cryptosporidium* (Teunis *et al.*, 1995)

Galway (EPA 2012)

- New approach required
- Outbreak of Cryptosporidium in Galway City in 2007 (242 cases of illness)
- Compliance with micro, chemical and indicator parametric values was 99.1% the previous year.
- Monitoring did not tell us whether the supply was safe and secure

HOW Drinking Water Safety Challenge cont.

New approach (health based targets and microbial risk assessment)

 New WHO approach focuses explicitly on risks posed by waterborne pathogens in individual sources of drinking water (WHO Guidelines for drinking water quality, 4th ed., 2011)





212° the extra degree

At 211 °F, water is hot At 212 °F, water it boils, And with boiling water, comes steam. And steam can power a train

AND ... IT IS THAT ONE EXTRA DEGREE

that makes all the difference! (Sa

(Sam Parker, 2005)

DWSP Approach - by making small changes we can significantly improve the safety and security of drinking water we supply!



WHO Risk Assessment and Risk Management Approach – a new way of working

JISC REANN



HOW

HOW Challenges with health based target approach

Development/implementation of risk-based approach:

Australia, Canada, Netherlands, New Zealand, Sweden, Norway, USA

Implementation challenges [UKWIR, 2016]:

- Recognised that a health target is not practical for assessing the microbiological safety of drinking water. Instead it has been converted to a performance target for water treatment, (i.e. specified log reductions for particular pathogens).
- Limited to assessing robustness of water treatment processes. No corresponding assessment for water in distribution systems.
- Log reduction targets are unsuitable for operational monitoring. In practise, verification of process performance requires checking of surrogate parameters.

WHO [2017]:

7

 Achieving specified turbidity targets at well-designed filtration plants that have been optimised to achieve particle removal is a critical component of demonstrating pathogen reductions (Table 4).

Treatment type	Turbidity target	Crypto reduction	Virus reduction	
CFC+RGF	≤0.3NTU in 95%	3-log	2-log	WATER

Step B.3.2 - Protozoa Log Credit Compliance Criteria – CFC + RGF (enhanced individual filtration)



- To obtain 4.0 protozoa log credits for CFC + RGF used as a coagulation, clarification and filtration process, the following requirements must be met during periods when treated water is being produced:
 - *a)* All water must pass through the full CFC and filtration process (no bypass or mixing of water without CFC + RFG);
 - *b)* The filters must be operated at a steady flow rate. Maximum rate of change of flow 1.5%/minute;
 - *c) Measurement of turbidity of the filtered water leaving each filter must satisfy the following conditions:*
 - i. Shall be less than or equal to 0.1 NTU for at least 95% of each filter cycle. The filter cycle is the period between the filter being returned to supply following backwashing and being taken out of supply for backwashing;
 - ii. Individual filtrate shall not exceed 0.3 NTU for the duration of any 15-minute period;
 - iii. Individual filtrate shall not exceed 0.5 NTU for the duration of any 3-minute period; and
 - iv. Filter run to waste until below 0.1 NTU filters shall be capable of directing filtered water to waste immediately following a backwash for a period of time until the filtrate turbidity value is below 0.1 NTU.
- Protozoal compliance monitoring requirements for CFC + RGF are as follows (separation between data records must be less than 1-minute):

Parameter	Location	Frequency	Critical Control Point	Alarm	Compliance duration
Turbidity	Settled water	Continuous	>2.0NTU	>1.5NTU	Any 15-minute period
	Filtered water (individual)	Continuous	>0.1NTU	>0.08NTU	Any 15-minute period
	Filtered water (individual)	Continuous	>0.5NTU	>0.45NTU	Any 3-minute period
	Filtered water (individual)	Continuous	Settled water turbidity ≥ raw water turbidity		Any 3-minute period
Flow	Filtered water (individual)	Continuous	>design filtration rate $m^3/m^2/hr$		Any 15-minute period
Headloss	Individual filter	Continuous	>0.25m	>0.20m	Any 1-minute period
Rate of change of	Filter water (individual)	Continuous	>1.5% of filtration rate		Any 1-minute period
filtration rate			through each filter/minute		
Filter cycle	Individual filter	Continuous	>48hrs	>40hrs	Any filter cycle

HOW Risk reduction: End to End



IW has adopted the **Drinking Water Safety Plans approach** to develop a more **standardised** and **consistent** set of **Policies**, **Strategies**, **Specifications**, **Standard Operating Procedures**, **Planned Maintenance**, across the organisation.







IW Raw Water Monitoring Programme

RW UVT vs. Rainfall (River source)



- Strong correlation between rainfall and RW UVT (high rainfall = low UVT)
- Grab sampling provides incomplete picture (grab sampling 58.1% vs on-line 40%)

Grab Sai	mples	UVT	Turbidity	DOC
23/03/2	016	83.3	3.68	1.3
28/04/2	016	83.8	0.54	1.3
30/06/2	016	58.1	0.44	4.3
28/07/2	016	73.4	19.8	2.8



Operational Monitoring

Pathogen Compliance Review

UISCE ^{ÉIREANN : IRISH} WATER

Primary Disinfection - Pathogen Compliance Criteria

- Removal (filtered water)
 - Turbidity
 - <1.0ntu 100%
 - 3-log Crypto <0.3ntu 95%
 - 4-log Crypto <0.1ntu 95%
- Chlorination
 - Primary (WTP final water) adequate
 Ct
- UV
 - NSF, DVGW, ONORM -40mJ/cm2
 - USEPA 3-log Crypto

ATED	Pathogen C	omplia	ince Re	view			
WATER							
Make Water Older				Country			
insri water Site:				County:			
Date:	21/01/2016			Data Source	ce:	SCADA (1 minute	inter
				Date from:		21/12/2013 15:58	
				Date to:		21/12/2015 15:58	
				No. of days	s:	730	davs
Site Processes:	DAFF + UV + Chlorination					17520	hrs
Source:	\$3		Data perio	d with plant	operating:	12039	hrs
			The	oretical tota	al run time:	12363	hrs
Primary disinfection	process'	UV		Protozoa I	on Credits	5	
Note:							
1010.		-			_		_
Recorded SCADA	Data Analysis						
* Outlier values		Raw	Raw	Raw	Treated	Treated	
excluded from		Flow	Turbidity	pH	Flow	Turbidity	
dataset analysis	Values	(m3/nr)	(NIU) 10.07	0.20	(m3/nr) 20.00	(NIU) +5.00	
	95th percentile	12.5	2.43	na	14.67	0.32	
	Min.	0.1	0.00	3.92	0.01	0.00	
	Ave.	11.0	1.19	6.86	11.31	0.12	
		UVT	UVI	Residual Chlorine	Treated		
	Values	(&)	(IINN/CIT2)	(mg/L)	рн		
	Max.	99.99	57.56	+5.00	11.58		
	5th percentile	0.09	28.42	0.46	na 3.74		
	Min. Ave.	75.63	34.71	0.00	7.29	1	
CFC+RFG Remova	al Non-compliance (Step B.3.1 requi	rements	ot met wh	en produc	ina drinkir	ng water)	_
		No. of	No. of	Max.	Ave.	% of total data	D
Parameter	Compliance Criteria	Events	Days	duration	duration	period	pe ()
Turbidity	> 0.3NTU any 15min period	369	200	24.7hrs	2.2hrs	6.8%	12
	KW turb. < TW turb. [+0.1NTU]	254	131	7.8hrs	7.5hrs	0.2%	12
Flow (TW)	> 11m3/hr any 15min period	1356	405	2.6days	4.0hrs	45.1%	12
Headloss	< 0.25m any 1min period						
P							
Rate of change							
	< 1.5% any Trnin period	•	-	-	•		
Filter cycle	< 1.5% any rmin period	•	•		•		
Filter cycle	< 1.5% any rmin period > 48 hours on-compliance (Step B.3.5 requirem	- ents not r	- - net when p	- producing	- drinking w	- ater)	
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Operational Monitoring

CFC+RGF Review - Example

					\frown
Values	Raw Flow (m3/hr)	Raw Turbidity (NTU)	Raw pH	Treated Flow (m3/hr)	Treated Turbidity (NTU)
Max.	30.0	19.99	11.99	48.3	+5.00
95th percentile	28.0	0.93	na	27.6	0.62
Min.	0.1	0.26	5.10	0.0	0.00
Ave.	25.9	0.58	6.80	20.4	0.21
Values	UVT (%)	UVI (W/m2)	Residual Chlorine (ma/L)	Treated pH	\bigcirc
Max.	100.0	66.0	3.81	9.36	
5th percentile	79.7	18.6	0.52	na	
Min.	29.2	0.0	0.00	3.45	
Ave.	88.6	35.2	0.87	7.23	

CFC+RFG Removal Non-compliance (Step B.3.1 requirements not met when producing drinking water)								
Parameter	Compliance Criteria		No. or Events	No. of Days	Max. duration	Ave. duration	% or total data period	Data period (hrs)
Turbidity	> 0.3NTU any 15min period		1737	379	2.2days	1.8hrs	19.6%	16167
	RW turb. < TW turb. [+0.1NTU]		3163	231	3.1days	0.3hrs	4.9%	16167
Flow (TW)	> 30m3/hr any 15min period		0	0	0hrs	0hrs	0.0%	16167
Headloss	< 0.25m any 1min period		-	-	-	-	-	-
Rate of change	< 1.5% any 1min period		-	-	-	-	-	-
Filter cycle	> 48 hours		-	-	-	-	-	-



Operational Monitoring

Removal

DWSP Water Quality Control Measures

Physical/Chemical Risk Control

Barrier 5: Interruption to supply	supply > demand
Barrier 6: DBP (THMs)	≤100µg/l at tap
Barrier 7: Lead	≤10µg/l at tap
Barrier 8: Pesticides	≤0.5µg/l at tap
Barrier 9: Nitrates	≤50mg/l at tap
Barrier 10: Aluminium	≤200µg/l at tap
Barrier 11: Iron	≤200µg/l at tap
Barrier 12: Manganese	≤50µg/l at tap
Barrier 13: Taste and odour	acceptable at tap
Barrier 14: Pollution of environment	≤ discharge limit
Barrier 15: Other	≤ limit at tap

Risk Assessment

THM Compliance Data Review



a)

Water Quality Risk Analysis

	Treate	d Water A Risk	TTHM (ma	TTHM (maximum concentration) [µg/L]			TTHM	No. of	Existing	
	Priorit	tisation	100 - 200	200 - 300	200 - 300 >300		Risk	WSZs	CFC	
2014-16							5	7	1	
751no.	ige [µg/L]	<100	2	2	3	\Box	4	7	2	
WSZs	(avera ation)	100 - 150	2	3	4		3	11	3	
	TTHM						2	91	41	
	5	>150	3	4	5		Total	116	47	

- Existing WTP deficiencies:
 - 1) No DBP precursor removal process (69no. 60%);
 - 2) Existing DBP removal and/or disinfection process not optimised (47no. 40%);
 - *3) Network exceedance after booster chlorination.*



Disinfection Policy Comparison

Irish Water

- Removal (filtered water)
 - Turbidity
 - <1.0ntu 100%
 - 3-log Crypto <0.3ntu 95%
 - 4-log Crypto <0.1ntu 95%

TTHM_t < 40 to 80μg/l (t > 24hrs)

- Chlorination (WTP final water)
 - WTP final water > 0.5mg/l
 - Customer tap = detectable FCR

Scottish Water

- Removal (WTP final water)
 - Turbidity
 - <1.0ntu 100%
 - <0.5ntu 99%
 - <0.4ntu 95%

– TTHM < 40μg/l

- Chlorination (WTP final water)
 - WTP final water > 0.5mg/l
 - Reservoir outlet > 0.25mg/l
 - Customer tap = detectable FCR



CFC Optimisation

Draft IW Jar Testing and THMFP Specification

- Preliminary design stage (before preparation of documents):
 - a. Jar test:

Risk

Assessment

- i. pH/alkalinity control (acid or base)
- ii. coagulation (alum and PACL)
- iii. flocculation (no polymer)
- iv. sedimentation
- v. filtration
- b. THMFP (8mg/I Cl dose with THM measured at 72-hrs)

2)Contractor design stage (after contract award):

- a. Jar test:
 - i. pH/alkalinity control (acid or base)
 - ii. coagulation (alum and PACL)
 - iii. flocculation (polymer)
 - iv. sedimentation
 - v. filtration
- b. THMFP (8mg/I Cl dose with THM measured at 72-hrs)

3) Jar testing and THMFP testing frequency:

- a. RW UVT ±5% change;
- b. RW true colour ±10PtCo unit change; or
- c. RW turbidity ±10NTU unit change



C





Jar Testing and THMFP

TTHM Monitoring - 2007 to 2014

No. of Samples	No. of Samples > 100µg/L	Average concentration (µg/L)	Max. concentration (µg/L)	
81	57	159	312	

Risk

Assessment



TTHM Monitoring - 2007 to 2014						
No. of Samples	No. of Samples > 100µg/L	Average concentration (µg/L)	Max. concentration (µg/L)			
32	6	69	132			



RH. EPS 2016

RW

0.45

13.76

24.4

Portumna WSS – Jar Test THMFP



- PACL removes more TOC;
- Alum removes more THM precursors.



Risk

Portumna WSS – CFC Upgrade

TTHM Monitoring - 2007 to 2014

No. of Samples	No. of Samples > 100µg/L	Average concentration (μg/L)	Max. concentration (µg/L)	
81	57	159	312	

	RW	TW (JT)	% Improvement
Turbidity (NTU)	0.53	0.13	75%
TOC (mg/l)	7.87	4.43	44%
UVT (%)	52.8	87.6	66%

	RW TOC (mg/l)	TW TOC (mg/l)	% improvement
14/02/2017	8.06	3.67	55%
16/02/2017	9.00	4.05	55%





Jar Testing and THMFP



RW UVT	Alum dose	Sulphuric acid dose	THM (μg/l)	Alum + acid chemical unit OPEX/m3	Alum + acid chemical OPEX/day	Alum + acid chemical OPEX/yr
63.6	160	0	83.3	€0.02	€504	€183,960
61.6	160	70	79.46	€0.02	€725	€264,443
57.8	200	0	68.76	€0.02	€630	€229,950
52.7	220	70	68.7	€0.03	€914	€333,428
47.5	160	110	93.8	€0.03	€851	€310,433
40.5	260	100	75.75	€0.04	€1,134	€413,910

Risk

Assessment

WTP Upgrade Solutions







IW Coagulation Control Guidelines

Coagulation Control Upgrade Rollout



- Upgrading works (improvements to coagulation control) <u>must</u> pass the following business test:
 - a. Reduce DWSP risk (i.e. effect Barriers 4 and 6); and/or
 - b. Economic (payback < 5-years)
- 2. In addition, Process Ops team will carryout a review of proposed upgrading works and make a recommendation, before AS approval.

Example – AMP business test







SCM - Design

1. SCM correlates with turbidity/organic removal, especially when charge neutralization is the dominant coagulation mechanism.

Key benefit – provides information more rapidly than a jar test and under most conditions will inform Operator in which direction the coagulation dose should be adjusted.

Increasing negative signal indicates excess of negatively charged particles, {i.e. deterioration in raw water.}

2. Proper function of SCM is dependent on proper installation, in particular, location of sampling point. A sample point free of abrasive grit and resistant to clogging must be assured.

SCM – Design cont.



- The design of SCMs under the following conditions must be referred to Asset Strategy(Process Optimisation) for prior approval:
 - a. Stable raw waters conditions (lakes) [less likely to save appreciable amounts of chemicals, chemical reduction low (average 15%) high payback period];
 - b. High coagulant dose (alum dose >150mg/l);
 - c. High alkalinity (>100mg/l);
 - **d**. Very low pH and turbidity (i.e. sweep flocculation coagulation is required);
 - e. UVA/UVT for forward feed control (raw water turbidity > 8.0NTU);
 - f. Use of lime for pH adjustment;
 - g. Recirculation of liquid residuals (filter backwash, etc.). Residual metal hydroxides are positively charged;
 - h. Occasional use of powdered activated carbon (PAC); and
 - i. Control of dose rates for high molecular weight polymers (coagulant aids or flocculants).



SCM - Installation and commissioning

- 1. Manufacturer's assistance is required in installation and establishment of correct sampling point, (i.e. evaluation of 3 or more sampling locations may be required to find best sampling point);
- 2. Manufacturer's assistance is required during commissioning period (min. 12 months). Commissioning period should cover periods when coagulation difficulties will be encountered, (i.e. high/low turbidity, organics, temperature, etc.);
- 3. SCM set point should be established by initial use of jar tests, followed by observation of plant performance as a function of SCM reading, (i.e. increasing/reducing coagulant dose vs settled water quality [turbidity, true colour or UVA/UVT]); and
- 4. Manufacturer to provide cost/benefit analysis and performance assessment report (before and after SCM installation):
 - a. Plant operational data for stable and transient conditions (flow, chemical use, raw and settled water quality [pH, temperature, turbidity, true colour and/or UVA/UVT]); and
 - b. Plant and equipment failure and out of service.

An evaluation of streaming current detectors, (AWWRF)



SCM - Operation and maintenance

- 1. SCM is not a substitute for good operation and maintenance. Periodic comparison with jar tests is essential. The set point should be re-evaluated periodically to ensure optimum settled water quality (turbidity, true colour or UVA/UVT.) Set points will become less accurate with large variations in temperature, turbidity, organics, colour, pH, etc. Set points may vary monthly, day and night, etc.;
- 2. Establishment of preventative maintenance schedule is key to performance. Waiting for signs that instrument is dirty may result in the production of poor water quality. Experience indicates that cleaning requirements could vary from 2 days to 3 months, depending on concentration of raw water contaminants and type of coagulant used;
- **3**. High iron or manganese in raw water may increase operational difficulties; and
- 4. Lime addition may increase operational difficulties.

Draft CFC Specification amendments



1. CFC control process –



Draft CFC Specification amendments cont.



- 2. Pg 79: Control mechanism:
 - a) Manual or automatic (preferred option);
 - b) Feed forward turbidity, UVA/UVT (or true colour)
 - c) Feedback SCM (optional)
 - d) Tables 31 to 33:

Coagulation Control	Turbidity	тос	Coagulation pH	Alkalinity
Turbidity	> 8ntu	<2		
UVA/UVT	< 8ntu	>2		
SCM 📛			< 7.5	> 100mg/l

3. Pg 80+: Replace SUVA with UVA/UVT

Draft CFC Specification amendments cont.



4. Protozoa log credit compliance criteria - CFC:

- To obtain protozoa log credits for CFC + RGF used as a coagulation, clarification and filtration process, the following requirements must be met during periods when treated water is being produced:
 - a) All water must pass through the full CFC and filtration process (no bypass or mixing of water without CFC + RFG);
 - b) The clarifiers must be operated at a steady flow rate;
 - *c)* Measurement of turbidity of the clarified water must satisfy the following conditions:
 i. Shall be less than or equal to 2.0 NTU for at least 95% of each 24-hour period.
- Protozoal compliance monitoring requirements for CFC process (part of CFC+RGF) are as follows (separation between data records must be less than 1-minute):

Parameter	Location	Frequency	Critical Control	Alarm	Compliance duration
			Point		
Turbidity	Raw water	Continuous	>8.0NTU	>7.0NTU	Any 15-minute period
	Clarified water	Continuous	>2.0NTU	>1.5NTU	Any 15-minute period
pН	Before coagulation	Continuous	>Target pH	>0.8 Target pH	Any 15-minute period
UVT/UVA	Raw water	Continuous	< Coag design limit	< 1.2 Coag design limit	Any 15-minute period
SCM (optional)	After coagulation	Continuous	< SCM set-point	< 1.2 SCM set-point	Any 15-minute period
Flow	Raw water	Continuous	>maximum design flow m ³ /hr	>maximum design flow m3/hr	Any 15-minute period

CFC Control Summary



UISC