Jar Testing Methodology

21st, 22nd, 23rd March 2017
Location: Various .

Kevin Love Irish Water

Introduction

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General Background

- The fundamental aim of jar testing is using bench scale testing to simulate / duplicate conventional treatment steps of a full-scale plant

- It is important that the conditions used in the jar test accurately simulate full-scale plant conditions as possible. Knowledge of the water treatment plants hydraulic characteristics for initial mixing / flash mixing, flocculation, and clarification are all critical (as well as translation into a batch-testing protocol). The parameters include:
  - Effective retention times in the rapid mix and flocculation basins
  - Actual retention time in basins if jar testing is being done to evaluate time dependent reactions for which full-scale reaction time influences results

Why Regular Jar Testing is Essential

- Maximum Removal of Organics
  - Reduced THM Formation
- Reduced Risk of Cryptosporidium
- Chemical Efficiency
- Optimum Clarification Process Performance
- Reduced Solids loading on to filters
  - More efficient filter runs
- Reduced Chlorine Demand
- Maintain Chlorine Residuals Longer in Network Distribution

Know what you want to get out of the Jar test

- Chemical Response to Changes in Raw Water Quality or Characteristics
- Evaluation on the effects of changes in chemical dosages and points of application;
- Choose alternative coagulants;
- Addition polymeric coagulant aids (including evaluation at different timing point and locations);
- Variation of mixing intensities and times; and
- Evaluation on removal of total organic carbon, or other water quality parameters of concern (i.e. colour, turbidity, soluble/insoluble metals).

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Equipment Required/Desirable

Item	Function
Flocculator/Jar Test Unit	6 No. jar testing unit recommended with variable speed stirrer settings (0-300rpm) and a stop watch.
6 x 500 or 1000ml Beakers (low style) (flocculator depending)	Glassware to carry out jar tests.
3 x 500/1000ml Beakers and additional glassware (1 litre and 500ml measuring cylinders) as required for filtration and sample collection	Raw water sample collection and for collecting filtered samples.
Micro-Pipette (10-100 µl and 1-20 µl) and dispensing tips RECOMMENDED	For dosing neat chemicals. Note: Chemical dilution should be avoided. Dilution can lead to degradation of active product and also dilution errors.
Pipettes (1ml, 5ml and 10ml) and suction pump	For dosing diluted chemicals
Whatman No.1 Filter Paper (30-50cm dia.) **(Alternate porosity filter paper should be applied if filter media porosity known to be different)**	Simulates similar filtration capability of rapid gravity filters. Porosity approximately 11µm. A suction filter could also be considered for jar test filtration as gravity filtration can be time consuming. Care should be taken not to damage or rip filter paper.
2 x larger filter funnels and funnel stand	For filtration of coagulated and flocculated samples
50, 10 and 1 ml syringes	For abstracting samples from beakers to fill bench instrument sample cells. Decanting is often difficult direct from beakers.
0.45 µm membrane discs	For filtering samples to measure true colour, dissolved metals, UVA or DOC only.
Turbidity meter (with sample bottles and cleaning oil)	Turbidity measurements. Periodic calibration to manufacturer standards recommended.

Equipment Required/Desirable (Contd.)

Photometer and Colorimeter	**For measuring colour, total metals (iron, aluminium or manganese – site specific). Suitable reagents as recommended my manufacturer instructions should be purchased in advance of any tests.**
pH meter (and standard solutions for calibration – buffers pH 4, 7 and 10)	Measuring pH change and preparing jars to a fixed pH for enhanced coagulation tests. Ensure pH probes are properly maintained, stored in the correct ionic strength potassium chloride buffer solution and calibrated frequently to a minimum of 2 points (pH 4 and pH 7). Probes should never be stored in deionised water or bulbs allowed to dry out.
Magnetic stirring plate and stirrer flea	Mixing and preparing samples (i.e. polyelectrolytes, lime slurry and soda ash).
Electronic balance scales	Weighing – recommended to use a calibrated device to 3 decimal places.
Sample bottles and labels from analytical labs	Samples that are considered to be optimised from jar tests and works sample points should be compared and evaluated for a given set of parameters.
Coagulant solution	Aluminium sulphate, polyaluminium chloride, ferric sulphate, ferric chloride - All neat coagulant solutions should where possible be taken from site storage tanks and replaced on a weekly basis. It is recommended that MSDS from chemical suppliers be obtained in advance of any tests from Irish Water or chemical supplier.
pH adjustment chemicals **(For all chemicals it is essential to note concentration (% w/w) and specific gravity.**	Caustic soda (sodium hydroxide), soda ash (sodium carbonate – may require batching (5% w/w recommended), lime (for lime slurry 1.5% w/w recommended), sulphuric acid, hydrochloric acid. Maintain good laboratory practice and keep acid and bases separate in a chemical safe box. All bottles should be clearly labelled and dated.
Polyelectrolyte	Poly solution where possible should be sampled daily or every other day from site day tanks. Alternatively, powder solutions should be carefully prepared to 0.1 – 0.2 % w/v (or equivalent plant strength) every other day.

Jar Test Procedure

Irish Water

ENGINEERING SPECIFICATION: CFC EVALUATION AND JAR TESTING (CLEAN WATER)

Document No: IW-TEC-XXX-XX

Revision: 0.1 (2016)

Irish Water Jar Test Specification

ID No.: OP23/WI1 | Date: Aug 08

Drinking Water

Selection of Coagulant and Flocculant Dose Rates

Rev: 3

Approved by: Eamon Nunan | Page 1 of 1

Stage A: Determination of raw water characteristics.

Measure pH, TDS, colour (true and apparent), turbidity, alkalinity, UVA, UVT and temperature.

Stage B: Preparation of Working Solutions.

Coagulant: Prepare a 1:10 w/v dilution of coagulants from commercial products using treated water where possible. **Prepare daily.**
By weight: 10gms dissolved in 100 mls of water.
By volume: mls of liquid coagulant made up to 100mls

Liquid Alum	Ferric Sulphate	Ferric Sulphate HA	Chemifloc 101	Chemifloc 103	PAC
7.6	6.5	7.0	7.4	7.7	8.3

1 ml of working solution = 100mg (ppm) of Product.

Flocculant: Prepare a 1g/l solution of the flocculants by dissolving 0.2 gm in 200 mls of D.I. Water. Allow to mix for 40 minutes. **Prepare daily.**
1 ml of working solution = 1mg (ppm) of Product

pH Control:
1N Sulphuric Acid solution; 1 ml added to 500 mls of water = 98 mg/L.
1N Sodium Hydroxide Solution: 1 ml added to 500 mls of water = 80 mg/L.
10% w/v Soda Ash Solution: 1 ml added to 500 mls of water = 200 mg/L.

Stage C: Determination of best dosage of coagulant.

1) Pour 500 mls of raw water into beakers and place on gang stirrer.
2) Agitate at 200 rpm.
3) Add required coagulant dose to each beaker (Range 40 – 260 mg/L) by injecting 0.1 mls of working solution for every 20 mg/L required.
4) Agitate at 200 rpm for 2 minute.
5) Agitate at 30 rpm for 13 minutes.
6) Determine the optimum dose and coagulant by visual appreciation of growing flocs during slow agitation phase.
7) Monitor pH values after addition of coagulant and determine pH adjustment dosage as required.
8) Repeat evaluation until the optimum coagulant, dose rate and coagulation pH has been determined.
9) Run test at the required pH and coagulant dose rates.
10) Evaluate and record the level of floc formation.
11) Allow to settle for 30 minutes and record settlement rates.
12) Filter supernatant using a No. 40 Whatman filter paper and test for turbidity.
13) Filter supernatant using a 0.45µm filter and test for colour, UVA, UVT and dissolved metal i.e. Aluminium, Iron.

Chemifloc Jar Test Procedure

Basic Principles Same for Each Procedure

- Pour 500ml/1000ml Raw Water into 6 Beakers
- Turn Flocculator on to 200 rpm
- Add the required amount of pH Correction Product
- Add the desired Amount of Coagulant (60-200ppm)
  - One jar should be used to reflect current plant set points for comparison/reference
- Allow to mix for 1-2 mins dependant on local site conditions
- Reduce Flocculator Speed to 30 rpm
- Allow to mix for 15 mins
- Record Flocculation pH
- Switch of Flocculator and Allow to stand for 30 minutes
- Draw of supernatant and test for turbidity as an indication of the clarification process
- Draw of supernatant from the beaker, filter through a 1.0 um syringe filter and test for UVA, UVT and Residual Coagulant
- Select dose that gives maximum organic carbon removal (Highest UVT) or Lowest Turbidity

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Jar Testing Template Examples

Plant Name:		Date:	
Technician:		Time:	

Raw Water Analysis:

Coagulant dose versus Colour (PtCo)

Raw Water Sample taken from:	
Raw water THMFP (µg/l)	

RAW WATER DATA			Colour			Chemical									
Temp.	pH	Alkalinity	Apparent	True (0.45µm filtered)	Turbidity	Iron	Manganese	TDS	UVT (0.45µm filtered)	TOC (if known)	DOC (if known)	Conductivity	WTP coagulant dose (if known)	WTP poly dose (if known)	WTP dosed raw water pH (if known)
°C		mg/l	PtCo	PtCo	NTU	ug/l	ug/l	mg/l	%	mg/l	mg/l	us/cm	mg/l	mg/l	pH

Beaker No.	1	2	3	4	5	6	Target
Initial Jar pH							
Coagulant	**Aluminium Sulphate 8%**						
Coagulant Dose as product (mg/l)	80	90	100	110	120	130	
pH Adjustment Product	**Sulphuric Acid 96%**						
pH Adjustment Dose (mg/l)							
pH measured	6.0	6.1	6.2	6.3	6.4	6.5	
Polyelectrolyte	**Flopam AN 910**						
Poly Dose (mg/l)							
Poly Dose time after coagulant addition (mins)							
Rapid Mixing and Flocculation Mixing							
Rapid Mix Time (mins)							
Slow Mix Time (mins)							
Floc Size from Chart at end of Slow Mix Time							
Settlement Time (mins)							
Settled Water Analysis							
Colour (PtCo) Settled							**<20**
Turbidity Settled Water (NTU)							**<2**
Aluminium (Total) Settled (ug/l)							
Iron (Total) Settled (ug/l)							
Manganese (Total) Settled (ug/l)							
Alkalinity Settled (mg/l CaCo3)							
Filtered Water Analysis (Whatman No. 1 Filtered)							
Colour (PtCo)	5.0	4.5	4.0	2.0	3.0	4.0	**<5**
pH measured							
Residual Aluminium (ug/l)	50.0	40.0	20.0	25.0	30.0	35.0	**<200**
Residual Iron (ug/l)							**<200**
Manganese (ug/l)							**<50**
UVT (%)	88.0%	89.0%	90.0%	93.0%	88.0%	87.0%	**>92**
Turbidity NTU	0.29	0.27	0.20	0.10	0.15	0.24	**<0.2**
TOC (mg/l)							
DOC (mg/l) (0.45µm filtered)							
% TOC Removal	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
THMFP							

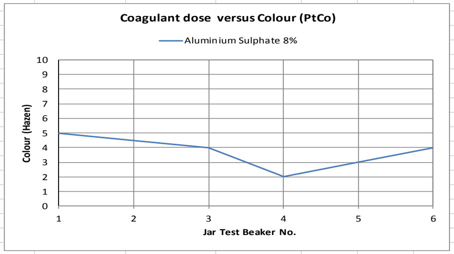
Selection of Optimum Dose is Based on the Following Assumptions. 1) Highest Filtered Water UVT, Lowest Filtered Water Iron/Alum Residual, Lowest Filtered Water Turbidity.

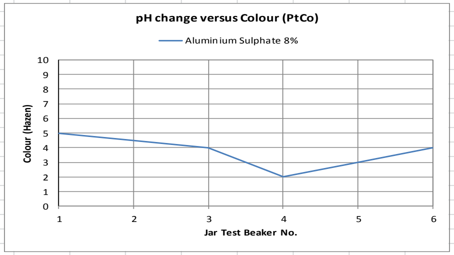
Pump Settings

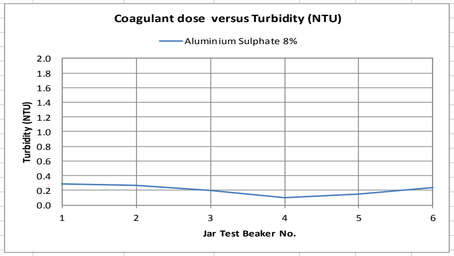
			g/l
Plant Flow (m3/hr)	200	**pH correction Concentration**	1835
Optimum PH Control mg/l	50	**Coagulant Concentration**	1320
Optimum coagulant mg/l	110	**Poly Day Tank Solution**	1
Optimum Poly Dose mg/l	0.1		

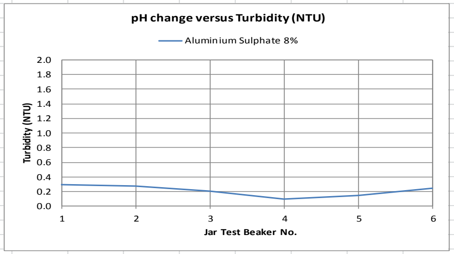
Calculate Pump Flow Rate (Flow in m^3/Dose in hr*mg/l)/Concentration g/l = l/hr

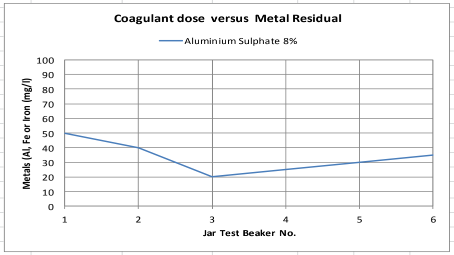
pH Control l/hr	5.4	**pH Adjustment Pump Stroke**		Speed	
Coagulant l/hr	16.7	**Coagulant Pump Stroke**		Speed	
Poly l/hr	20.0	**Poly Pump Stroke**		Speed	

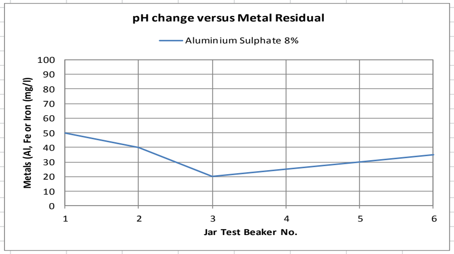












Irish Water Jar Testing Specification Template

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Appendix 1

Jar Test Record Sheet

Date:	**12/10/16**	Weather:	**Dry/sunny**
Plant Name:	**Achill Water Treatment Plant**		
Raw Water Source:	**Lough Acorrymore**		

Raw Water Analysis

			Colour						
Temperature	**pH**	**Alkalinity**	**Apparent**	**True**	**Turbidity**	**Conductivity**	**TDS**	**UVA**	**UVT**
°C		**mg/L $CaCO_3$**	**PtCo**	**PtCo**	**NTU**	**µs/cm**	**mg/L**		**%**
16.4	5.5	<5	54	46	0.72	112	112	0.243	57.1

Jar Test 1

Beaker No	**1**	**2**	**3**	**4**	
Alum Dose (mg/L)	60	70	80	90	
Soda Ash Dose (mg/L)	45	53	60	68	
Poly Dose (mg/L)	0.1	0.1	0.1	0.1	
Floc Size	Pin	Medium	Medium	Medium	
Floc pH	6.39	6.63	6.66	6.75	
Settled Water Analysis					**Jar Test Target**
Alkalinity (mg/L CaCO3)	10	15	20	20	
Apparent Colour (PtCo)	4	2	0	0	<20
Turbidity (NTU)	0.44	0.35	0.32	0.32	<1
Filtered Water Analysis (0.45µm)					
Aluminium (µg/L)	20	24	22	23	<50
True Colour (PtCo)	Under Range				<5
Turbidity (NTU)	0.11	0.13	0.09	0.09	<0.2
UVA	0.013	0.014	0.013	0.014	
UVT (%)	96.8	96.7	96.9	96.8	>90

Achill WTP. Mayo County Council.

JAR TEST SHEET

COS Water Treatment Plant

Raw Water Source River Shannon Date: 24/01/2017

	Jar No.	**1**	**2**	**3**	**4**	**5**	**6**
	Caustic Dose (mg/L)	**0**	**0**	**0**	**0**	**0**	**0**
Rapid Mix 30 sec							
	Alum Dose (mg/L)	170	180	190	200	210	220
	Poly Dose (mg/L)	0.18	0.18	0.18	0.18	0.18	0.18
	Floc pH	6.86	6.72	6.67	6.63	6.63	6.61
Rapid Mix 2 min (Approx 250 revs)							
Slow Mix 15 min (Approx 25 revs)							
Settle 15 min	NTU	1.65	1.36	1.59	1.75	1.62	1.87
Filter through 0.45micron filter							
	Raw Water						
Alkalinity (mg/L)	98.4						
Colour (True-Filtered)	83						
Colour (Apparent)	97						
pH	7.95						
Turbidity (NTU)	2.3	0.15	0.11	0.16	0.12	0.12	0.14
UVT (%)	37.2	81.6	82.3	83.1	84.1	85.4	85.9
Aluminium							

Carrick on Shannon. Leitrim County Council

Flocculation Test

Location: ______________________________________ Date: ______________________

Raw Water Quality:-

• Colour		TOC		True Col	
• pH		DOC		App Col.	
• Temp				UV Trans	
		Alkalinity		UV Abs	

Beaker No.	**Soda/Lime**	**Alum**	**Poly**	**Floc**	**pH**	**Res. Alum**	**DOC**	**UV Trans**	**UV Abs**	**Remarks**	**TOC %Removal**
1											
2											
3											
4											
5											
6											

Add Soda - 300 RPM for 1 min.

Add Alum- 100 RPM for 30 sec.

Ad Poly - 100 RPM for 30 sec, 35 RPM for 5 min & 19 RPM for 10 min.

Current Dose.	
Soda -	
Alum -	
Poly -	
pH	

Donegal County Council

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Irish Water Jar Testing Specification

Raw Water Sample taken from:

Raw water THMFP (µg/l)

RAW WATER DATA			Colour			Chemical					
Temp.	pH	Alkalinity	Apparent	True (0.45µm filtered)	Turbidity	Iron	Manganese	TDS	UVT (0.45µm filtered)	TOC (if known)	DOC (if known)
°C		mg/l	PtCo	PtCo	NTU	ug/l	ug/l	mg/l	%	mg/l	mg/l

Beaker No.	1	2	3	4	5	6	Target
Initial Jar pH							
Coagulant	**Aluminium Sulphate 8%**						
Coagulant Dose as product (mg/l)	80	90	100	110	120	130	
pH Adjustment Product	**Sulphuric Acid 96%**						
pH Adjustment Dose (mg/l)							
pH measured	6.0	6.1	6.2	6.3	6.4	6.5	
Polyelectrolyte	**Flopam AN 910**						
Poly Dose (mg/l)							
Poly Dose time after coagulant addition (mins)							
Rapid Mixing and Flocculation Mixing							
Rapid Mix Time (mins)							
Slow Mix Time (mins)							
Floc Size from Chart at end of Slow Mix Time							
Settlement Time (mins)							
Settled Water Analysis							
Colour (PtCo) Settled							**<20**
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Aluminium (Total) Settled (ug/l)							
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Alkalinity Settled (mg/l CaCo3)							
Filtered Water Analysis (Whatman No. 1 Filtered)							
Colour (PtCo)	5.0	4.5	4.0	2.0	3.0	4.0	**<5**
pH measured							
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UVT (%)	88.0%	89.0%	90.0%	93.0%	88.0%	87.0%	**>92**
Turbidity NTU	0.29	0.27	0.20	0.10	0.15	0.24	**<0.2**
TOC (mg/l)							
DOC (mg/l) (0.45µm filtered)							
% TOC Removal	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
THMFP							

Selection of Optimum Dose is Based on the Following Assumptions. 1) Highest Filtered Water UVT, Lowest Filtered Water Iron/Alum Residual, Lowest Filtered Water Turbidity.

Variations in Raw Water Quality

Optimum Flocculation pH

Floc Size, Settleability and Turbidity Removal

Best Organic Carbon Removal

- Highest UVT

Lowest Filtered Water Turbidity

Residual Alum/Iron < 50ug/l

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Irish Water Jar Testing Spec.

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Irish Water

ENGINEERING SPECIFICATION:
CFC EVALUATION AND JAR TESTING (CLEAN WATER)

Document No: IW-TEC-XXX-XX

Revision: 0.1 (2016)

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3. JAR TESTING METHODOLOGY

- Jar Test Preparation
  - Sample Collection
  - Raw Water Analysis
  - Preparation

- Optimal pH jar tests
  - Add Coagulant First
  - Addition of pH Correction Product to target pH 6.0,6.2,6.4…….

- Optimal Coagulant Jar Tests
  - Once optimum pH has been established
  - Vary Coagulant Dose

- Optimal Polymer Jar Tests
  - Polymer Selection
  - Different time intervals after addition of coagulant.

Analysis

FILTRATE BENCH ANALYSIS

- Carefully decant settled jar test water and pass through a 1µm filter paper and collect filtrate for analysis (to simulate RGF filtration stage). Measure for filtered colour, turbidity, UVT and **aluminium/iron/manganese residuals as applicable**.

- Further filter this primary filtrate through a 0.45µm filter and test for true colour, UVA, UVT and dissolved metals (if required).

- Tabulate and plot results to ascertain lowest metal and turbidity residuals. If there are several points which show equally low metal and turbidity residuals select the point with the lowest metal dose.

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3.1 RESULTS AND INTERPRETATION

- Optimise and understand the conditions for coagulant dosing and pH adjustment requirements for best organics/natural organics removal. UVT is considered an excellent indicator of coagulation performance. Effective coagulation, flocculation and clarification is also essential to ensuring that a UVA of 0.035cm^{-1} (92% UVT) is achieved in filtered water, thus removing the potential for disinfection by-product formation;

- Evaluate the potential for THM formation; and

- Understand the potential chlorine demand requirements of treated water to reflect on the likely THM formation and chlorine decay in extended supply networks.

Raw Water Requiring Alkalinity Correction

- Alkalinity Consumption

1.0 mg/l of Product	mg/l Alkalinity as $CaCO_3$ (F)
Liquid Aluminium Sulphate	0.24
Kibbled Aluminium Sulphate	0.51
Ferric Aluminium Sulphate	0.25
Ferric Sulphate Solution 12% w/w Fe	0.32
PolyAluminium Chloride	0.147

- Alkalinity Addition

1.0 mg/l of Product	mg/l Alkalinity as $CaCO_3$
Sodium Carbonate as Na_2CO_3	0.94
Sodium Hydroxide as NaOH	1.25
Sodium Hydroxide as 25% w/w NaOH	0.312
Sodium Hydroxide as 30% w/w NaOH	0.375
Hydrated Lime as $Ca(OH)_2$	1.35

- Alkalinity Suppression

1.0 mg/l of Product	mg/l Alkalinity as $CaCO_3$
Sulphuric Acid 96%	0.98
Sulphuric Acid 50%	0.49
Sulphuric Acid 30%	0.30

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Worked Example of Alkalinity Correction

- <u>Raw Water 15mg/l Alkalinity</u>
  - Optimum Jar Test Alum Dose = 120mg/l
  - Target Residual Alkalinity 10-20mg/l
  - Alkalinity Correction Required for Optimum Coagulation is:
    - (120*0.24)+20-15 = 33.8mg/l
  - 1mg/l Sodium Carbonate = 0.94 mg/l Alkalinity; Required Soda Ash Dose is 33.8/0.94= 36 mg/l

- For Sites with Raw Water Alkalinity Requiring Suppression
  - Add suggested range of alum (100-200mg/l)
  - Add Sulphuric Acid until target pH is met
  - Convert mls of acid used to mg/l
    - E.g. 8.4mls of 5g/l stock solution added to 500ml
    - 84mg/l Sulphuric Acid Dosed to meet target pH

pH Correction Proportional to Coagulant Dose

- Variable Coagulant Dose and Fixed pH Correction

	1	2	3	4	5	6
Alum	60	80	100	120	140	160
Soda Ash	30	30	30	30	30	30
pH	6.65	6.50	6.35	6.20	6.15	5.90

- Variable Coagulant Dose and Fixed pH Correction

	1	2	3	4	5	6
Alum	80	80	80	80	80	80
Soda Ash	25	30	35	40	45	50
pH	5.84	6.02	6.2	6.38	6.56	6.74

- pH/Alkalinity Elevation Proportional to Coagulant Dose

	1	2	3	4	5	6
Alum	60	80	100	120	140	160
Soda Ash	20	25	30	35	40	45
pH	6.18	6.21	6.19	6.20	6.14	6.07

- pH/Alkalinity Suppression Proportional to Coagulant Dose

	1	2	3	4	5	6
Alum	60	80	100	120	140	160
Sulphuric Acid	75	70	65	60	55	50
pH	6.1	6.09	6.12	6.06	6.12	6.08

Consistency in Stock Solutions

Examples of Stock solution used:

10g/l stock solution with 500ml beakers

- 1ml of this equals 20mg/l coagulant dose

1ml of product into 500ml equals 25mg/l

- 12.5g/l solution
- Requires calculation if you're looking for 80mg/l (3.2ml)

- For consistency stock solutions should be:
  - 5g/l Stock Solution Strength for 500ml Jars or 10g/l Stock Solutions for 1L Jars
    - Where 1ml of each stock solution equals 10 mg/l
    - Avoids factoring up/down dependent on stock solution Strength
  - This applies to all pH correction product and coagulants.

- Polyelectrolyte is the exception:
  - Required Stock Solution is 0.05g/l for 500ml Jars and 0.1g/l for 1L Jars
    - Where 1ml of each stock solution is 0.1mg/l

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Preferably use a micro-pipette

Range of pipettes available

8% Liquid Alum
60mg/l = 22.73µl
80mg/l = 30.30µl
100mg/l = 37.88µl
120mg/l = 45.45µl
140mg/l = 53.03µl

5% Soda Ash
5mg/l = 50µl
10mg/l = 100µl
15mg/l = 150µl
20mg/l = 200µl
25mg/l = 25µl

0.1% Poly
0.1mg/l = 50µl
0.15mg/l = 75µl
0.2mg/l = 100µl

All uls listed are for 500ml samples. X2 for 1L Beakers

E.g. 100mg/l Alum Dose

$$\frac{100mg/l * 500ml}{1320000mg/l} = 0.0227ml$$

Or 22.73 µl

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Making Stock Solutions

Target 1ml of stock solution is equal to 10mg/l of product for coagulation and pH correction

- Required strength to achieve this is **5g/l** or (5000mg/l) for 500ml jars (10g/l for 1 litre jars)

  Calculation for **5g/l**: $\frac{1ml * 5000mg/l}{500ml} = 10mg/l$

  10g/l Solution $\frac{1ml * 100000mg/l}{1000ml} = 10mg/l$

- To make up a 5g/l solution of alum as **coagulant** put 3.78ml into a volumetric flask and make up to 1 litre

  $\frac{5g/l * 1000ml}{1320g/l} = 3.78ml$

  Ferric Sulphate 120 = 1550g/l i.e. 3.22ml
  PACL (10%) = 1205g/l i.e. 4.149ml
  Chemifloc 101 = 1356 g/l i.e. 3.678ml

- To make up a 5g/l solution of soda ash for **pH correction** put 100ml from day tank into a volumetric flask and make to 1 litre (assuming a 5% solution)

  $\frac{5g/l * 1000ml}{50g/l} = 100ml$

- Sulphuric Acid and Caustic Soda is made up similar to alum at 5 g/l and using the following g/l strengths:
  - 96% Sulphuric Acid 1835g/l
  - 50% Sulphuric Acid 1395g/l
  - 30% Caustic Soda 1330g/l
  - 25% Caustic Soda 1275g/l

- To make up a 0.05g/l solution of **polyelectrolyte** put 50 ml from day tank into a volumetric flask and make to 1 litre (assuming a 0.1% solution)

  $\frac{0.05g/l * 1000ml}{1g/l} = 50ml$

  $\frac{1ml * 50mg/l}{500ml} = 0.1mg/l$

Floc Size Comparator

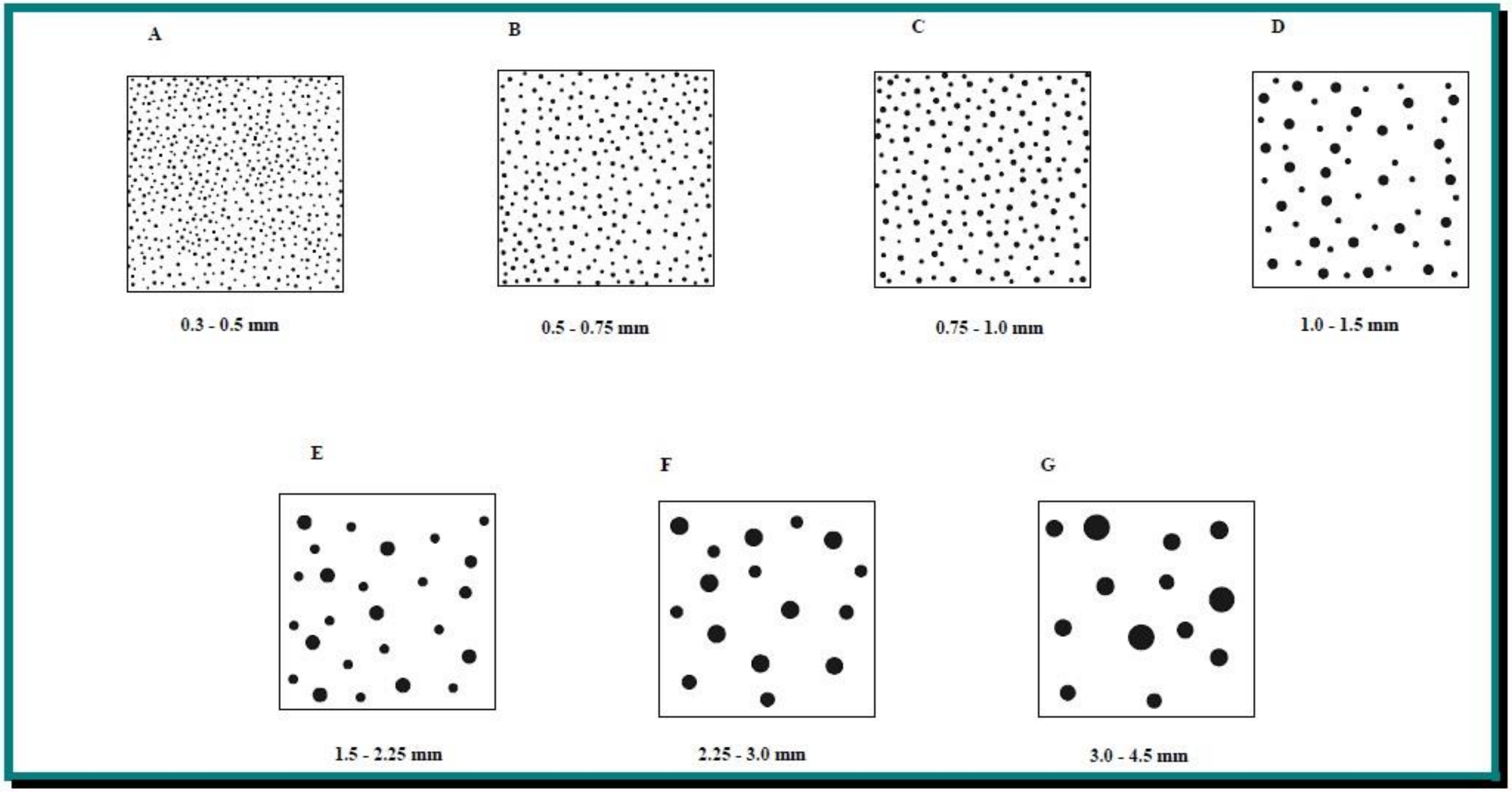


Figure 16: Comparator for the Evaluation of Floc Size Index in Coagulation Tests

Risk: Good floc formation but poor organic carbon removal
Filter Supernatant and analyse for optimum dose over visual Assessment

mg/l as Product or mg/l as Al or Fe

- How to convert from mg/l Al to mg/l product.

Product	Chemical formula	% alumina content as Al2O3	% Al content	% Fe content	spec grav
Liquid Aluminium Sulphate 8%	**Al2(SO4)3nH2O**	**8.25**	**4.25**	**0.00**	**1.32**
Chemifloc 103	Al2(SO4)3nH2O.nH2SO4	6.00	3.00	0.00	1.29
Polyaluminium Chloride 10%	Aln(OH)mCl3n-m	10.00	5.00	0.00	1.21
Chemifloc 101	xAl2(SO4)3.(1-x)Fe2(SO4)3.nH2O	-	4.00	3.20	1.35
Ferric sulfate 12%	Fe2(SO4)3.nH2O	0.00	0.00	12.00	1.50
Ferric chloride	FeCL3.nH2O	0.00	0.00	13.10	1.40

E.g. Liquid Aluminium Sulphate 8%

Percentage Alum Content is 4.25%

100/4.25 * mg/l Al = mg/l Product

23.5 * 4.55mg/l = 100mg/l

Conversion factors (mg/l)	
Al_2O_3 to Al^{3+}	÷ 0.5294
Aluminium Sulphate liquid to Al^{3+}	÷ 23.6111
$Fe_2(SO_4)_3$ to Fe^{3+}	÷ 8.3333
$FeCl_3$ to Fe^{3+}	÷ 6.8965
Fe^{3+} to Al^{3+}	÷ 2.0666

Application of jar tests results onto the plant

Optimum Alum dose identified 100 mg/l

Plant Flow Rate 350 m3/hr

Specific Gravity of Alum = 1.32 or 1320g/l

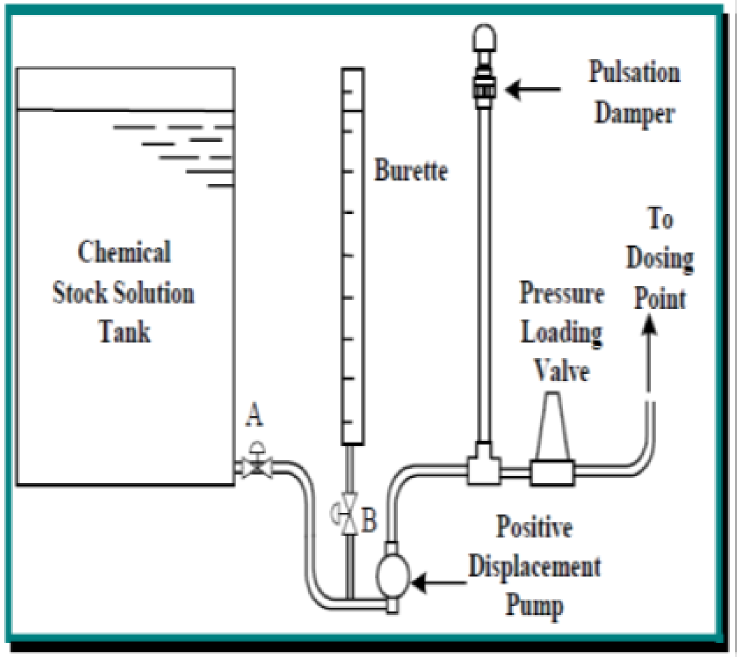
Pump Dosing Rate = $\frac{350m3/hr * 100mg/l}{1320g/l}$ = 26.5l/hr

26.5l/hr = 441 mls/min.

Perform Pump Draw Down

Monitor:

- Flocculation pH on site
- Clarification Process Outlet Turbidity
- Filtered Water Turbidity
- Final Water UVT



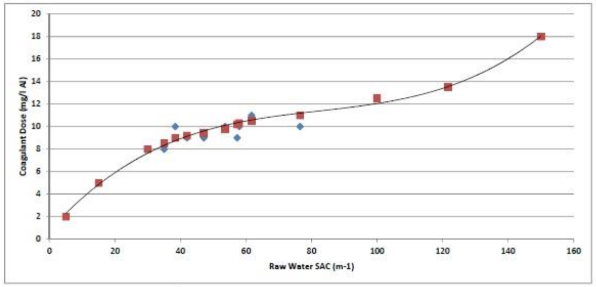
Multiple Jar Test Results -v- Time

- Use historical jar tests as a prediction of future doses based on raw water organics
- Plot Raw Water UVT/UVA -v- Alum Dose
- Plot Optimum Alum Dose -v- Flocculation pH
- Plot Optimum alum dose -v- Filtered Water UVT/Turbidity

Outcome: Eventual Feed Forward Coagulant Dosing Curve based on raw water UVT/UVA or TOC

Examples of Automatic Coagulant Dosing Curves

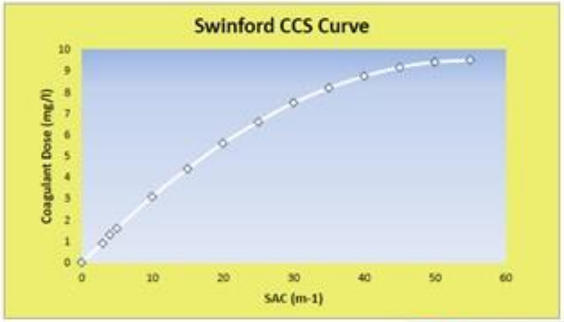
Carrick on Shannon Automatic Alum Dosing Curve



SAC	Corrected Dose	Corrected Dose
m-1	mg/l Al	mg/l Product
5	2	47.2
15	5	117.9
30	8.0	188.7
35	8.5	200.5
38.4	9.0	212.3
42	9.2	217.0
47.1	9.4	221.7
53.6	9.8	231.1
57.3	10.2	240.6
57.9	10.3	242.9
61.7	10.5	247.6
76.5	11.0	259.4
100	12.5	294.8
121.6	13.5	318.4
150	18	424.5

Swinford Automatic PACL Dosing Curve

SAC	mg/l
0	0
3	0.9
4	1.3
5	1.6
10	3.09
15	4.4
20	5.6
25	6.6
30	7.5
35	8.2
40	8.75
45	9.17
50	9.42
55	9.51



Jar Test Tables and Graphs for Interpretation

Water Test Sheet

Location	Raw Water Source	Tested by:	Date
Carrick on Shannon WTP	River Shannon	Eamon Nunan	19/03/2015

Coagulation Test 1

Parameter		Jar 1	Jar 2	Jar 3	Jar 4	Jar 5	Jar 6
pH Control							
Dose as mg/l							
Coagulant							
Dose as mg/l							
Flocculant							
Dose as mg/l							
Notes							
pH							
Temperature °C							
Total Dissolved Solids as mg/l							
Alkalinity as mg/l $CaCO_3$							
True Colour as units PtCo							
Apparent Colour as units PtCo							
Turbidity as NTU							
UV Abs 254nm							
UVT as %							
Total Organic Carbon as mg/l C							
Dissolved Organic Carbon as mg/l C							
SUVA as L/mg-m