**Bibliography**

**An Advanced Approach to Automatic Coagulant Control (2016)**<http://www.swig.org.uk/wp-content/uploads/2016/01/Roger-Powell-2016.pdf>

This presentation briefly discusses the Com::pass coagulation control unit. There is no audio to the presentation, so it is not the best source of information, however it was a good starting point to introduce me to the topic.

**Effective Coagulation Control (2012)**  
<https://www.youtube.com/watch?v=n9-AjDjSnd0>

This presentation discusses effective coagulation control and is made by Julian Edwards, 25 years within the UK water industry and 10 years working with automatic coagulation control systems.

(THESE NOTES ARE STRAIGHT FROM THE PRESENTATION – DON’T COPY THEM)

* Useful text in description – DON’T COPY IT!
* Proper coagulation is essential for good clarification and filtration performance and for the control of pathogens and disinfection by-products
* Improper coagulation can cause:
  + High residuals of coagulant in treated water (aluminium)?
  + Post-treatment precipitation of particles causing turbidity, deposition and coatings of pipes in the distribution system
  + *Micro-organisms/pathogens* such as cryptosporidium entering the water supply (this is a real nasty one (<http://dwi.defra.gov.uk/consumers/advice-leaflets/crypto.pdf)>)
* Increasing disposal costs and land filling restrictions has put pressure on water utilities to minimise sludge

An optimised coagulation process –

* Maximises removal of particles, turbidity and micro-organisms/pathogens
* Maximises removed of TOC (total organic carbon) and DBP (disinfection by-products) (<https://en.wikipedia.org/wiki/Disinfection_by-product>)
* Minimised residual coagulant concentrations (can overdose coagulant but *can’t underdose* therefore overdosing can be used when the plant isn’t manned*)*
* Maximised filter performance
* Minimised sludge production
* Minimised operating costs

NOM (Natural Organic Matter)

* Affects colour, taste and odour
* Reacts with most disinfectants, reducing disinfection power
* Produces DBPs
* Heavily influences coagulant demand
* Affects biological regrowth in distribution systems
* Reduces effectiveness of GAC (granular activated carbon filter) (<http://www.health.state.mn.us/divs/eh/hazardous/topics/gac.html>)

Cryptosporidium Parvum (ask Kate if this is a problem for her)

* A protozoan (single-cell microscopic animal) parasite than can cause outbreaks of diarrhea when it contaminates a municipal water supply
* Can be found in any surface water source
* Resistant to chlorine (!!!!!)
* Recognized by the World Health Organization as a significant global health threat

Analytical Instrumentation for the Water Industry (ask Kate what she uses)

|  |  |
| --- | --- |
| **Physical Monitors** | Turbidity  Conductivity |
| **Organic Monitors** | UV organics  Colour |
| **Inorganic Monitors** | pH/ORP  Dissolved Oxygen  Ammonia  Nitrate  Phosphate  Chlorine  Aluminium  Iron  Manganese |

Summary

* Optimization of the coagulation process is central to the drinking water industry’s ability to meet goals for particulate (turbidity) and NOM (natural organic matter) removal
* Accurate, reliable and representative information on the performance of the coagulation, clarification and filtration stages is paramount to successful performance of the WTW
* More time and thought should be given to the front end of a WTW i.e. ensuring that the coagulation/clarification stages can be easily optimised and controlled – ‘if you get the front end right the back end of the process will normally take care of itself’

More points

* The correct dosing of coagulants and flocculants provides an added safeguard against the risk of waterborne diseases such as cryptosporidiosis

**Coagulation and Flocculation (not a reference, just for me to learn from!)**  
<https://www.youtube.com/watch?v=lHIk57r40ik>

* The main goal of the coagulation/flocculation process is to reduce turbidity in the water
* Turbidity is a measure of the amount of suspended particles in a sample, which cause cloudiness
* Removing turbidity can remove unwanted taste and odour compounds
* Lower turbidity allows for higher rates of disinfection
* A coagulant is a chemical that is added to water that causes small particles to come together to form larger particles than can settle due to gravity – the predominant coagulant used is aluminium sulfate (<https://en.wikipedia.org/wiki/Aluminium_sulfate>)

1. Coagulant is added to turbid water
2. Coagulant forms precipitate called ‘flocks’, trapping impurities
3. These flocks then settle down to the bottom, leaving the water clear

**Automatic Coagulation Control at Water-Treatment Plants in the North-West Region of England (1990 is that too old?)**  
<http://onlinelibrary.wiley.com/doi/10.1111/j.1747-6593.1990.tb01467.x/abstract>

**Flocculation (NOT A REFERENCE – JUST FOR ME TO LEARN)** <https://www.youtube.com/watch?v=5uuQ77vAV_U>

* Small floating particles in water can make you sick – there are two types inorganic (clay, silt, mineral oxides) and organic (algae, bacteria, protozoa). The bacteria once ingested by humans can sometimes be fatal. All of these small particles float as they are not heavy enough to settle to the bottom
* Suspended particles that are too small to settle are called colloids – these colloids cause Turbidity.
* There is a correlation between turbidity and risk of disease – toxic compounds can adsorb (stick to) the surface of the suspended colloids, more colloids = more toxic the water can become
* One of the practical ways to clean turbid water is flocculation – the process in which colloids aggregate to form larger particles called Flocks by addition of a chemical called a flocculant, a typical example is Alum (Aluminium sulfate)
* Water isn’t potable straight after flocculation – it will require skimming and filtration

**Coagulation**[**https://www.youtube.com/watch?v=zAh8vZj5aSI**](https://www.youtube.com/watch?v=zAh8vZj5aSI)

* Strictly defined as a method to alter colloids so that they will be able to flocculate and form larger particles (coagulation is not flocculation)
* Direct sand filtration was first developed around 1885 and is largely ineffective at removing bacteria, viruses, soil particles, and colour (NOM). These are all negatively charged substances)
* Colloids are suspended in solution and cannot be removed by sedimentation or filtration

The challenge

* Colloids are stable due to their small size and *negative charge*, which causes them to repel each other upon collision
* Because colloids are so small, their motion is controlled by *Brownian motion* (random movement)
* In order to destabilize colloids, their charge must be neutralised

The General Practice

* Add positively charged ions (*coagulants)* to the solution to neutralize the charge of colloids, these positive ions are attracted to the negatively charged colloids and come together to form larger particles called ‘flocs’
* These coagulants (i.e. chemicals) must be effective, non-toxic and insoluble so that the coagulants can be removed

Jar Tests:

* In order to determine the coagulation dose and efficiency for a given water sample, jar tests are performed
* First, the pH is systematically varied with a given coagulant dose
* Second, the coagulant dose is varies with a given pH
* Line up 5 or 6 jars with increasing pH OR dose – if pH is increasing, the dose is constant and vice versa. The clearest jar is the right dose.
* To graph this – x axis dose (mg/L) and y axis (Turbidity NTK(?))

*Coagulant: Alum (Aluminium Sulfate)*

* Al3+ is added to water as aluminium sulfate
* It is supplied as a liquid with ~51.2% water to avoid crystallization)
* Optimum pH is 5.5 to 6.5 (depends on source water)

When alkalinity is present:

Al2(SO4)3 • 14H2O – 6HCO3 → 2Al(OH)3 • 3H2O(s) + 6CO2 + 8H2O + 3sO4-2

Aluminium Sulfate (combined in a hydrated form with 14 moles of water) – alkalinity (bicarbonate)

→

Precipitant (solid) (aluminium hydroxide) + 6 moles carbon dioxide + sulphate

*There’s very little pH change with this reaction*

When alkalinity isn’t present:

Al2(SO4)3 • 14H2O → 2Al(OH) • 3H2O(s) + 2H2O + 3H2SO4

Alum dissociates and combines with water (isn’t shown here) →   
forms aluminium hydroxide precipitant + water + sulphuric acid

If this happens, significant pH drop (acidic)

Coagulant Aids

|  |  |
| --- | --- |
| pH Adjusters | Sulfuric acid (lowers pH)  Lime Ca(OH)2 (raises pH) (has hydroxide ions)  Soda Ash Na2CO3 (raises pH) |
| Activated Silica | Activated silica has a negative charge in solution that can interact with the positive charge of coagulant precipitates to form larger, denser particles that have a greater chance of interacting with colloids |
| Clay | Functions like activated silica, particles are slightly negative and can add weight to flocs |
| Polymers | Long-chained carbon compounds with many active sites and charges, create interparticle bridging to produce large flocs that settle well |

Activated silica, clay and polymers are going to optimise coagulation   
(clay is really cheap, polymers are made to order and are synthetic but are v expensive and so added in very small quantities)

<https://www.ncbi.nlm.nih.gov/pubmed/26994797>