Royal Society of Chemistry

Water and Wastewater Treatment

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Where Do We Operate?

Geographically the **largest** of the water and wastewater companies in England and Wales.

Region **stretches** from the Humber to the Thames estuary, and from Buckinghamshire to Lowestoft.

Challenges

Population Growth

Up 20% in last 20 years but we still supply same amount of water as we did in 1990

Driest Region of England and Wales

2/3 average rainfall and only 1/3 of effective rainfall (what's left after evaporation and transpiration)

Flat, Low-Lying Region

Energy intensive to pump water and wastewater

Flooding

Quarter of land in our area below sea level

Anglian Water by Numbers

Potable Supply 4.5 million

Wastewater 5 million

Domestic and commercial customers

1.1 billion

Litres of water supplied every day

140

Water treatment works

37,000

Kilometres of water mains

Our long-term goals

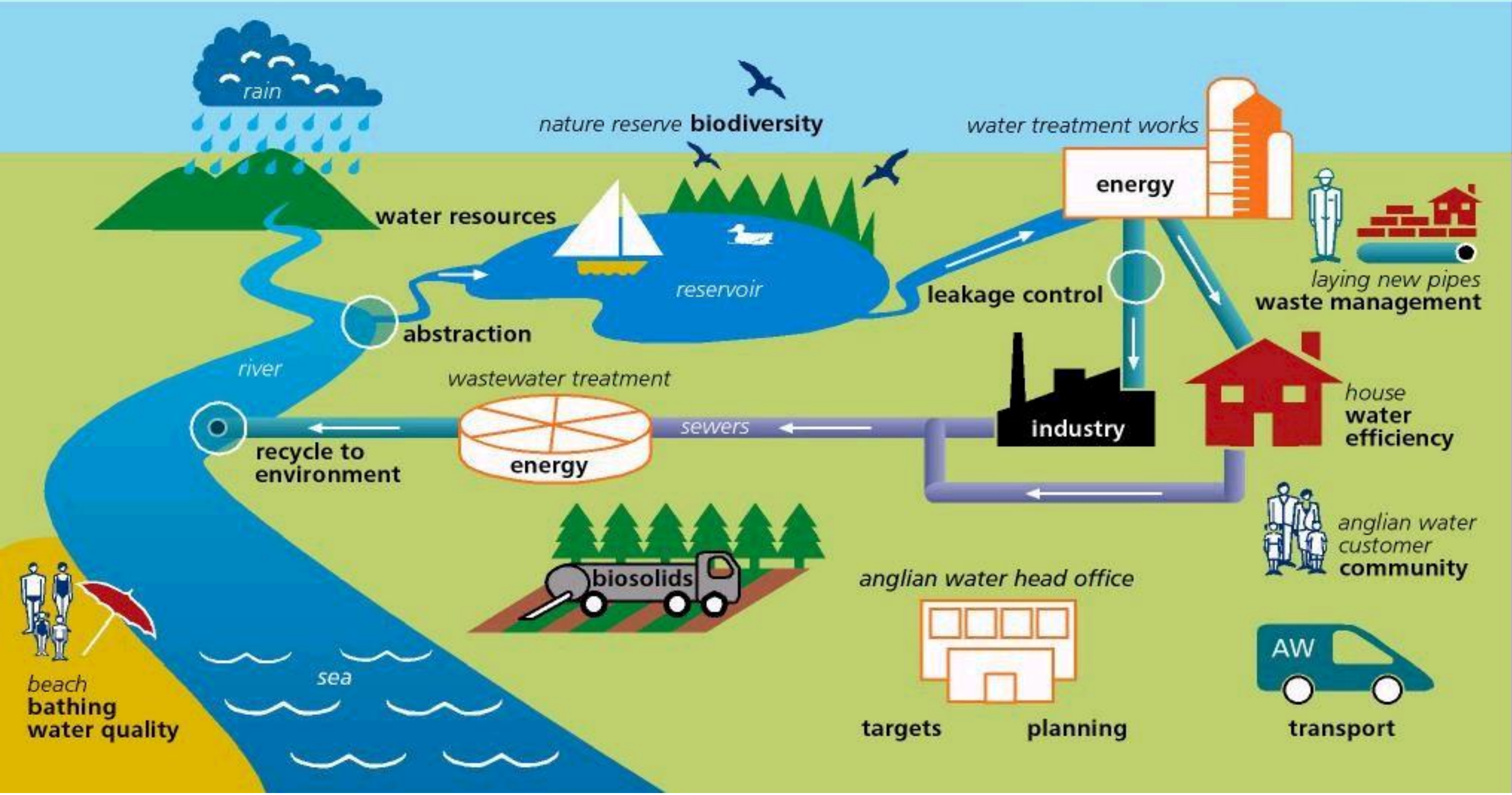
Business goals:

- These are our 12 ambitious goals for AMP 6.

Key strategic priorities 2010–2035:

- Increase the resilience of our water and wastewater services.
- Secure and conserve water resources.
- Plan and invest for growth in our region.
- Improve the environment in our region.
- Mitigate and adapt to climate change impacts.
- Improve our efficiency and flexibility.
- Meet the needs of our customers and keep bills at current affordability.

our role in the water cycle



Water Industry Regulators

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Ofwat (Office of Water Services)

Economic regulator involved in regulating charges to customers

OFWAT

CONSUMER COUNCIL FOR Water

Consumer Council for Water

Ensuring that companies deliver excellent service to customers

Environment Agency

Regulation of water abstraction and discharges to the environment

Environment Agency

dwi

Drinking Water Inspectorate

Guardians of drinking water quality

Water Treatment and Management

Catchment → Treatment → Storage → Distribution → Consumer

Water Sources

Key

source of supply
groundwater

surface water
reservoir
bankside storage
direct abstraction

areas in which we provide sewerage services only
1 Severn Trent Water
2 Thames Water
3 Cambridge Water
4 Three Valleys Water
5 Essex and Suffolk Water
6 Tendring Hundred Water

Raw Water Quality

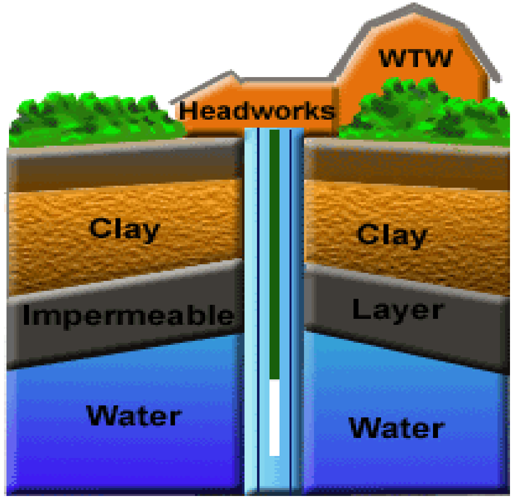
Groundwaters

- Pathogens
- Iron
- Manganese
- Nitrate
- Sulphides
- Heavy metals
- Pesticides
- Ammonia

Surface Waters

- Pathogens
- Trace organics - Pesticides
- Suspended solids
- Algae
- Ammonia
- Taste and odour
- Colour
- Zoo plankton

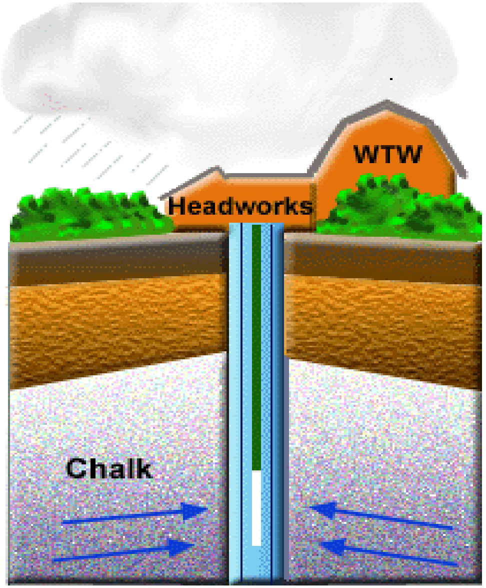
Groundwater?



- ‘Confined’ groundwater:
  - ‘Older water’.
  - Can contain iron and manganese (these cause orange/brown and black discolouration if not removed).
  - May contain nickel, arsenic, selenium.
  - Anaerobic (no oxygen) – often smells of hydrogen sulphide (rotten eggs!)

Groundwater?

- Unconfined groundwater:
  - More influenced by activity on the surface.
  - May contain nitrate (from fertilisers applied to agricultural land) and pesticides – a big issue in our region.
  - Can be microbiologically poorer in quality.



Surface water?

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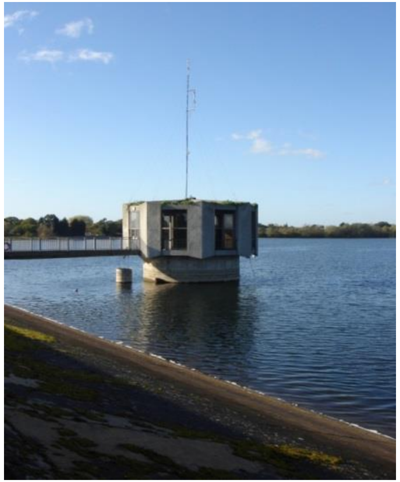
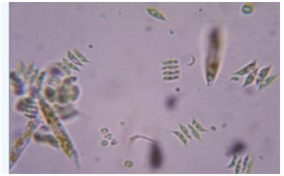
Reservoirs store water for future use, and are a key first part of the treatment process

45% of water comes via reservoirs, with 5% taken directly from rivers



Surface water?

- Pesticides and nitrate (run off from agricultural activity).



- Metals.
- Pathogens.

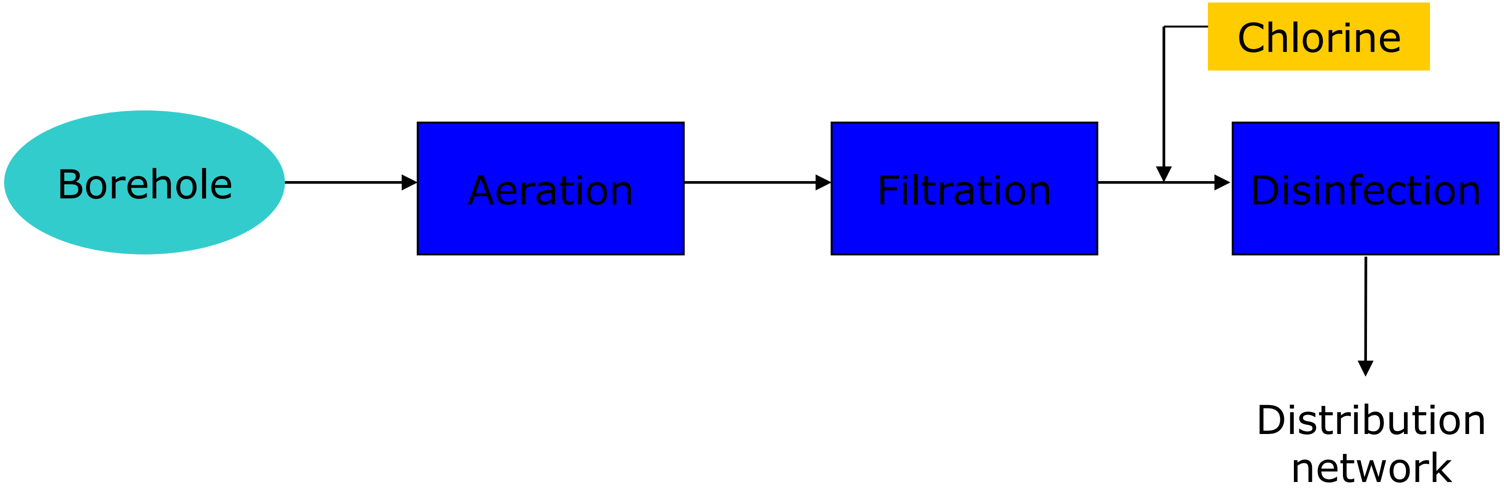
- Algae.
- Zooplankton (including killer shrimps!).

- Potential sewage effluent, dilution.
- Each present their own treatment challenge.

Water Treatment and Management

Catchment → **Treatment** → Storage → Distribution → Consumer

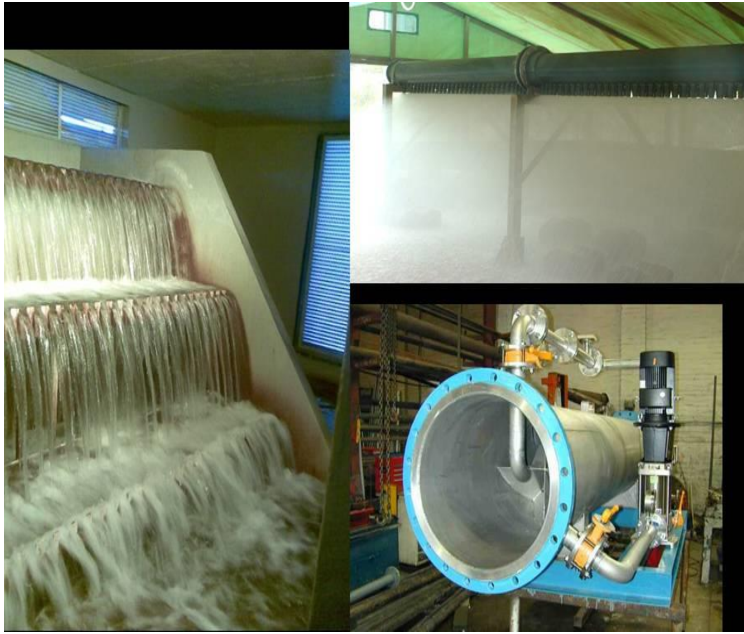
Groundwater Treatment



Iron removal

- Aeration can take various forms
  - Packed tower aerator
  - Spray
  - Cascade
  - Venturi air injection
  - Oxygen injection
  - Compressed air injection

↑ Increasing Carbon Dioxide removal



Manganese removal (groundwater)

- Manganese like iron exists in groundwaters in reduced form.
- Generally concentrations are lower than Iron.
- Similar to iron it needs to be oxidised to form a filterable precipitate.
- However, the rate of oxidation with oxygen is very slow and a more powerful oxidant is required.
- In AW we use chlorine for this oxidation and is like iron aided by increasing pH.

Manganese removal

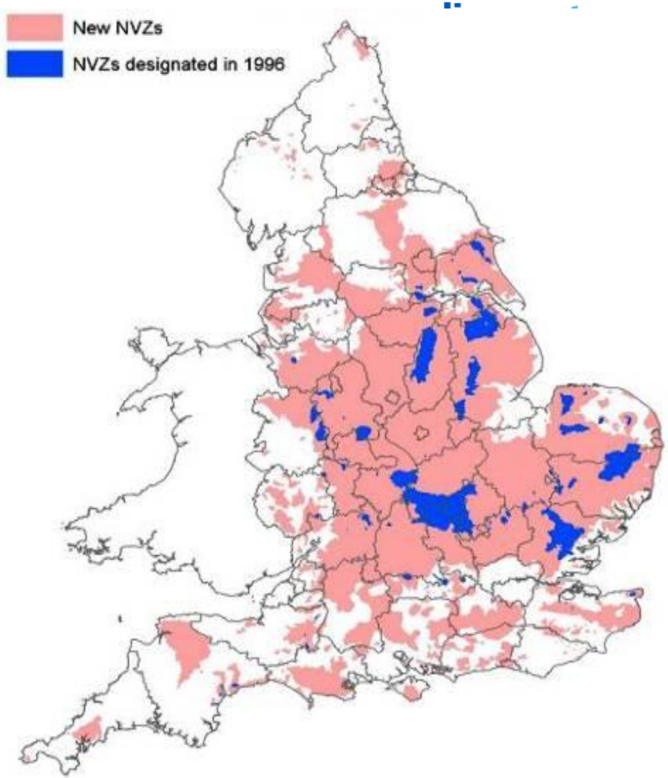
- The precipitation of the oxidised manganese is aided by having a catalyst in the filter bed.
- The catalyst used is manganese dioxide.
- This is technically called autocatalysis.
- The common trade name for this is “Polarite”.
- It is only continually effective in the presence of free chlorine hence the requirement for a free chlorine residual post filtration.

Nitrate

- Nitrate from fertiliser into water courses or soil infiltration
- Nitrate has adverse health implications
  - Methaemoglobinaemia/stomach cancer?/ diabetes??
- Rainfall has a direct impact on nitrate leaching
- Nitrate Standards as NO_3.
  - WHO - 50 mg/l
  - EC Limit - 50 mg/l
  - AWS Target - 45 mg/l
- Nitrate Vulnerable Zones imposed by EA + WFD

Nitrate trends

- Affected aquifers
  - Cambridgeshire chalk
  - Lincolnshire limestone
- Levels rising in mid-1980s with predicted maximum of 150 - 200 mg/l
- Concentrations dropped in 1990’s, now showing signs of increasing
- AMP 4 – 23 Schemes
- AMP 5 – 3 for treatment
- AMP 6 - More



Nitrate Removal Approaches

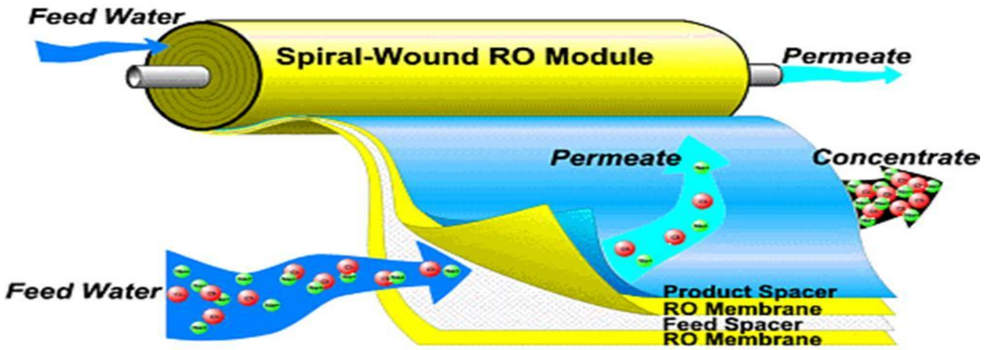
- **Ion Exchange - IEX**
  - Pros - Known technology, low capex, DWI, S/stream & blend, 1.5% W.S.
  - Cons - Calcification, high opex, effluent chem:EA, dezinc
- **Blend**
  - always preferred choice
- **Reverse Osmosis - RO**
  - Pros – S.stream & blend, low capex/opex, experience, less problematic w.stream cf IEX
  - Cons – Aggressive water, high 5 to 10% w.stream, pre-treatment of raw water
- **Electrodialysis Reversal - EDR**
  - Pros – Low opex/capex, easy control of NO_3 output, less problematic W. Stream than IEX.
  - Cons – 50% removal single stage, treat all the flow, 5 to 10% w.stream cf IEX
- **Biological**
  - Pros – Env.sustainable, minimal w.stream discharge
  - Cons - carbon source cost and control, turbidity, DWI approval, political social, automation, start up

Conventional Nitrate Removal - Ion Exchange

- Minimum of 3 shells
- Dezincifiction
- Complex valve arrangements – regen
- Operational maintenance
- Fluctuating Quality
- 1.5 ->2% waste stream

Membranes

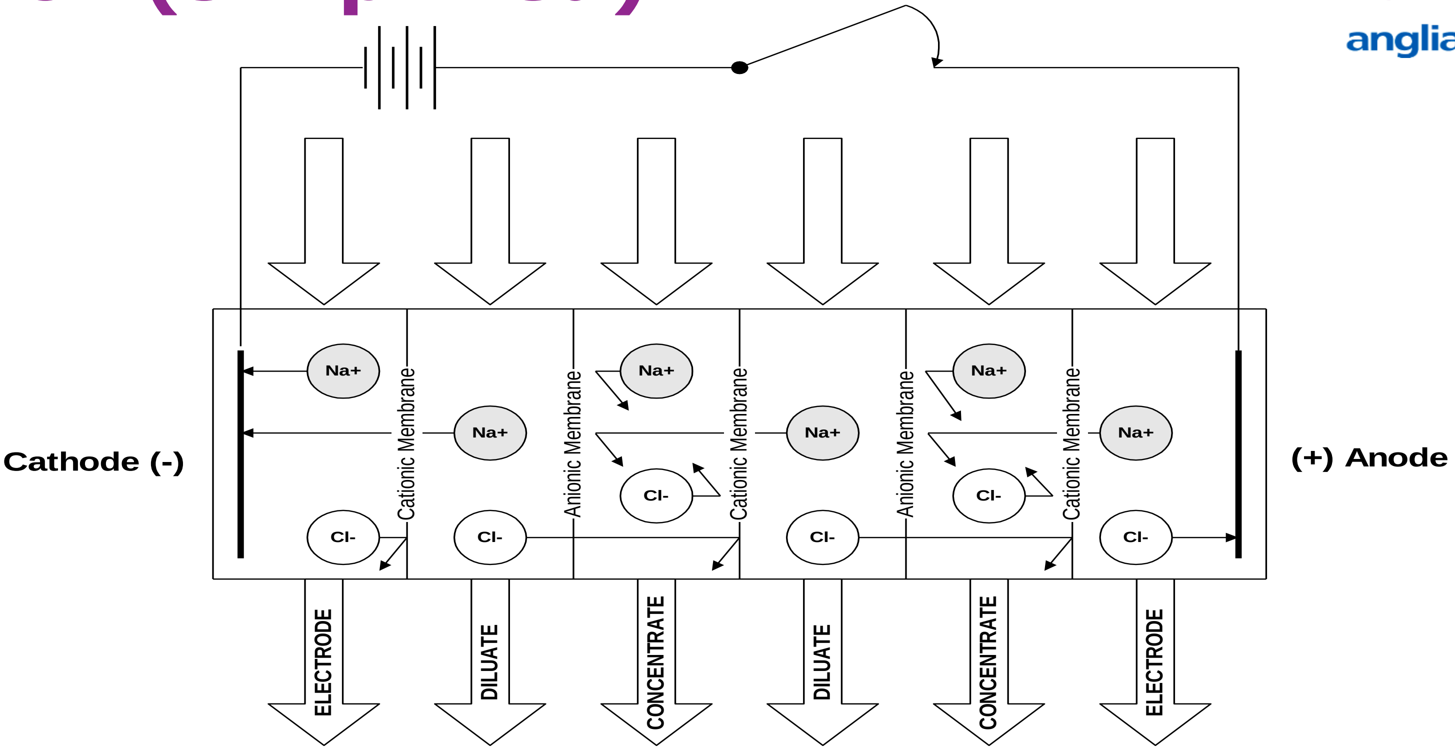
- Ultrafiltration (UF) – does not remove nitrate
- Nanofiltration(NF) – does not adequately remove nitrate
- Reverse Osmosis – very fine, removes salts, membrane looks like paper
  - CTA – Cellulose Triacetate
    - Chlorine tolerant
  - TFC – Thin Film Composite
    - High solids
    - Not chlorine tolerant
    - Bacteria resistant
    - Better rejection rates
    - Better flow rates
  - **DWI Approval**



Electrochemical

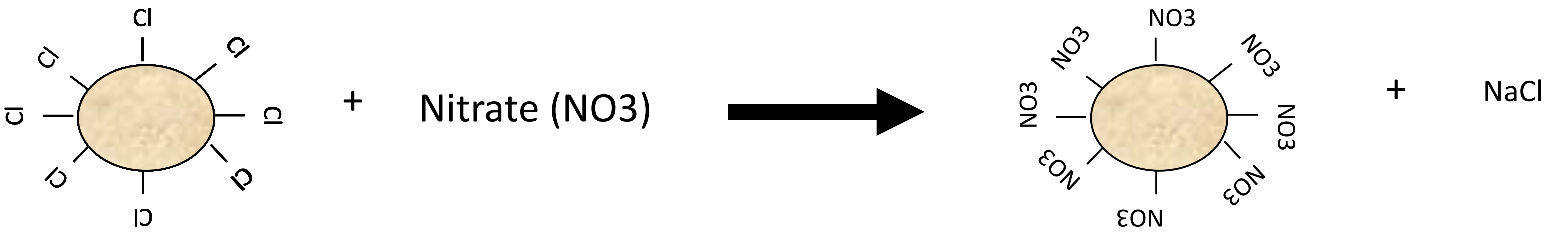
- Electrodialysis (ED) is an electrochemical process in which ions are transferred through membranes from a less concentrated to a more concentrated solution as a result of the flow of direct electric current
- Electrodialysis reversal (EDR) is ED with alternating polarity of the electrodes
  - Reduced membrane fouling
- Electrochemical Nitrate Destruction – minimal waste stream

Schematic of an Electrodialysis Stack (simplified)



Resins

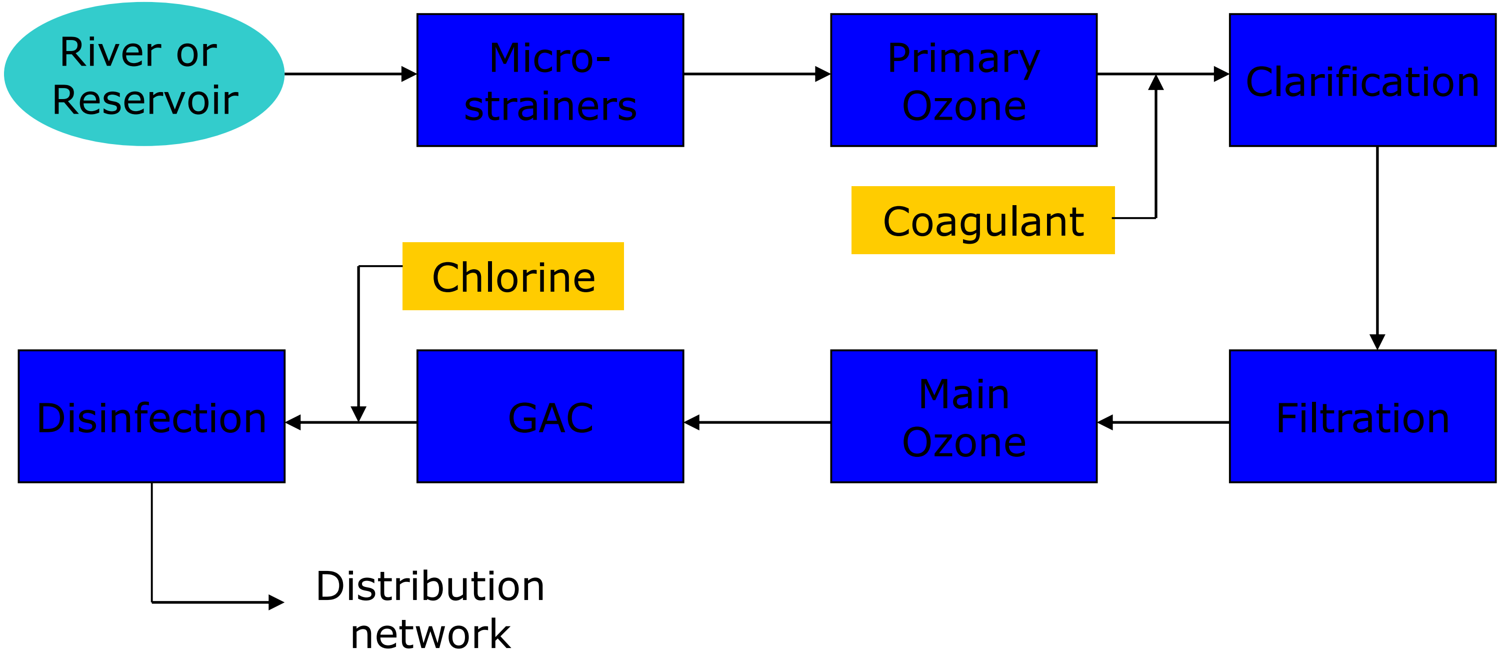
- Rohm and Haas HP555 or Amberlite PWA5
- Purolite A520E
- Macroporous polystyrene crosslinked with divinylbenzene – ethyl group
- Typical size - 0.60-0.85 mm



Surface Water Abstraction

- Direct river abstraction - water taken directly from a river.
- Bankside storage - area of river close to WTW banked off to form a small reservoir.
- Impounding Reservoir - naturally available dammed to retain the water for abstraction and treatment.
- Pumped Storage Reservoir - reservoir located away from the source of water. Raw water pumped from one or more sources through a pipe line to the receiving reservoir.

Surface Water Treatment



Ozone – the first dose

- Ozone is generated from dried air or from oxygen using an electrical discharge.
- Very powerful oxidant – starts to break down pesticides and other pollutants.
- Bleaching effect.
- Aids clarification, reduces coagulant use by increasing –ve charge.
- Too much and has a negative effect.
- No residual ozone.

Clarification

- Particles in water carry a negative charge, and therefore repel each other and stay very small and difficult to remove.

- Ferric sulphate is added as a coagulant – ferric ions have a strong positive charge, and help particles start to stick together.

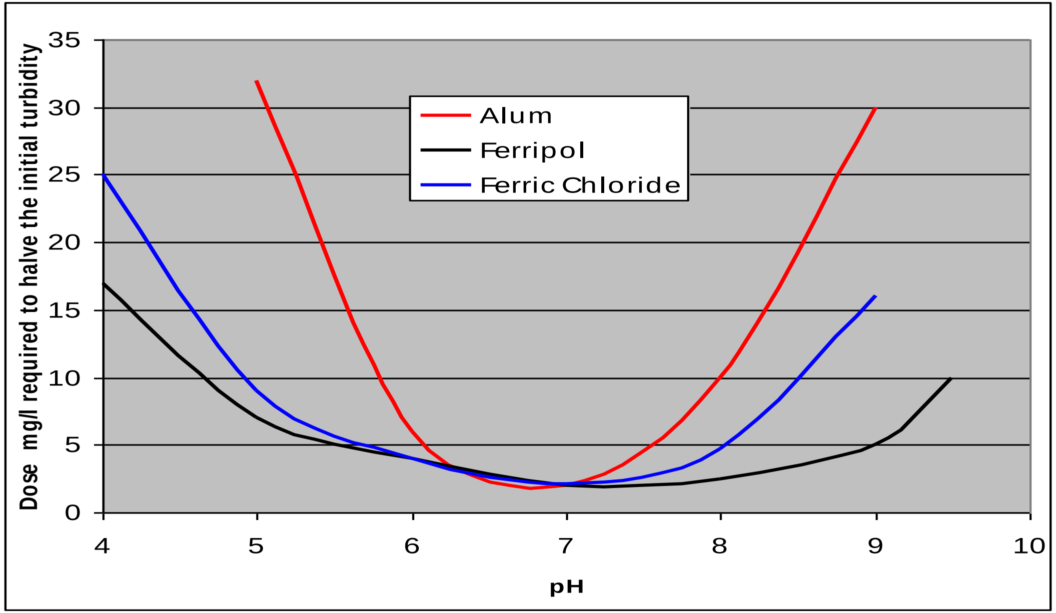
- Ozone actually helps, by making particles more negatively charged, meaning that they stick to the iron even better.

- Slowly a ‘floc’ forms, containing the iron and the particles – the floc is then removed, taking the particles with it.

Coagulants

- What different coagulants are available
  - Iron based salts
    - Ferric Sulphate (trade name Ferripol)
    - Ferric Chloride
  - Aluminium salts
    - Alum (Aluminium Sulphate)
    - PAC (Poly Aluminium Chloride)
  - Organic coagulants

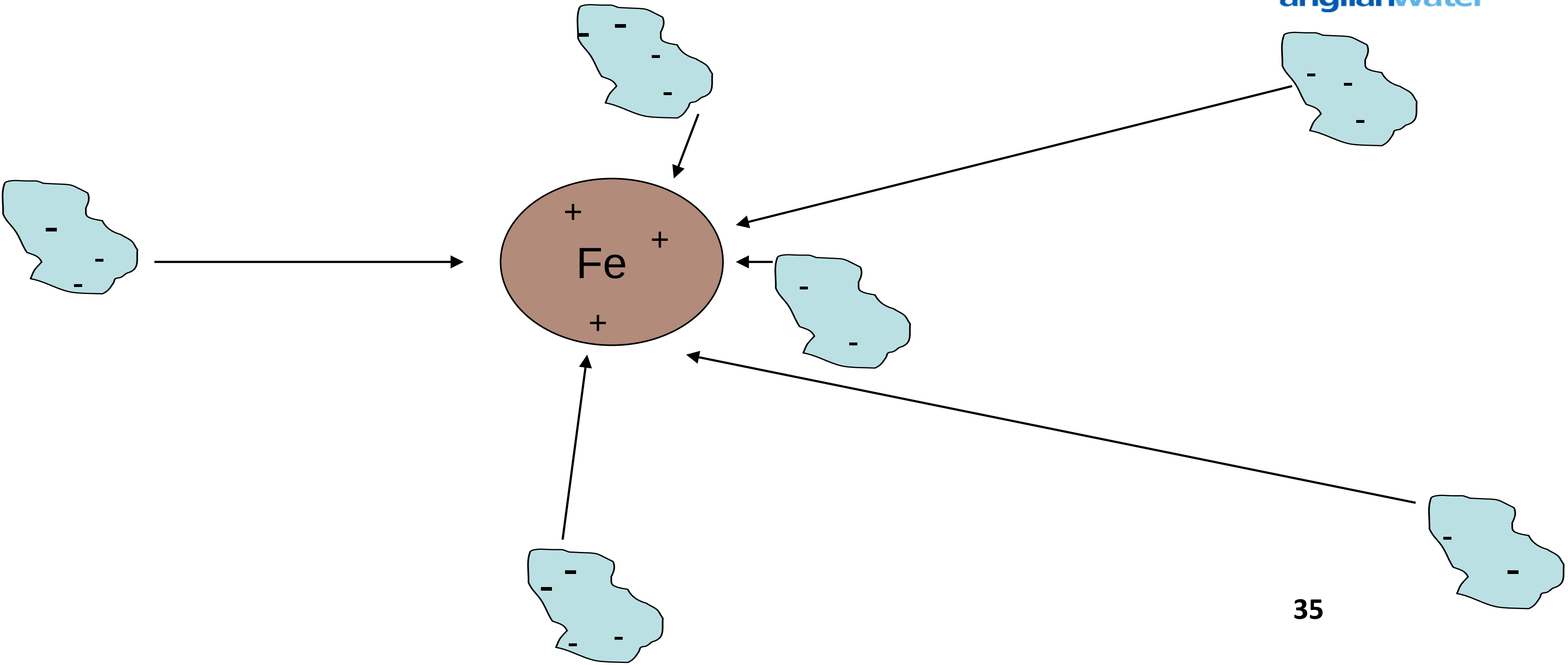
Coagulation efficiency vs. pH



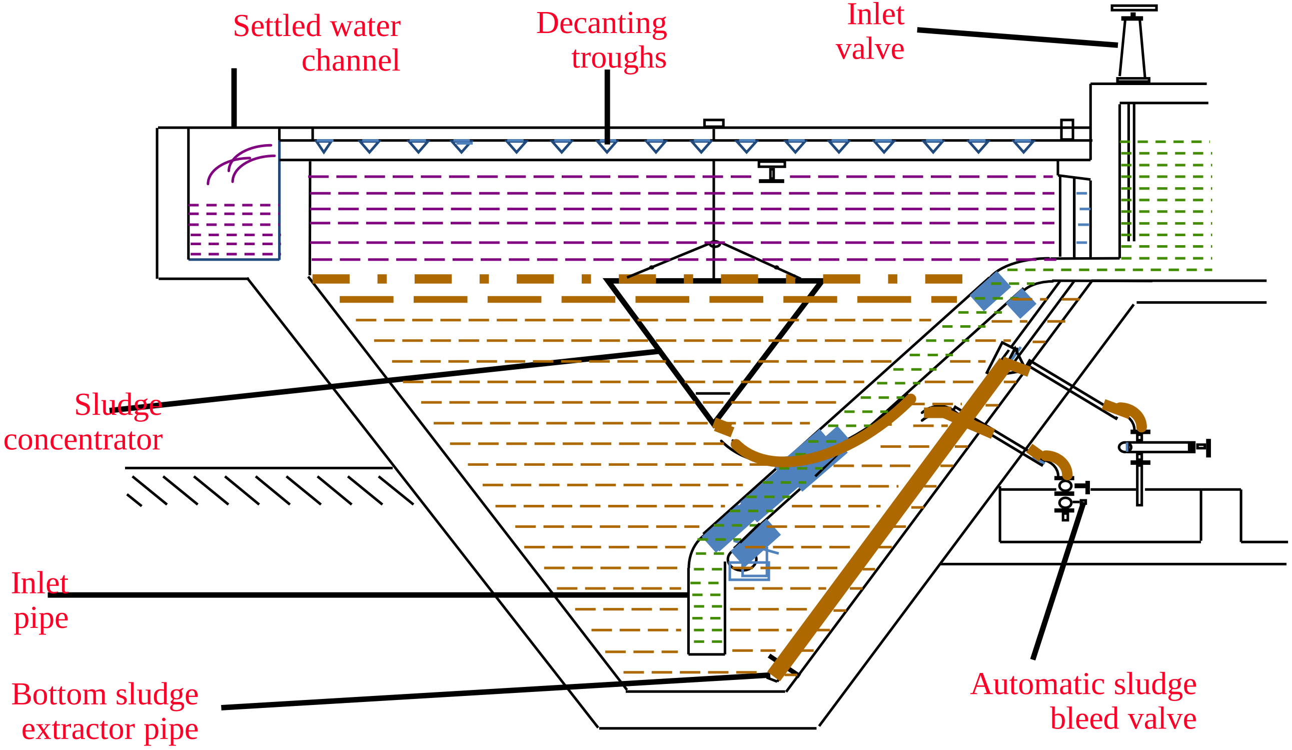
Flocculation

- Floc growth occurs and is promoted by gently agitation.
- Floc growth takes time and several minutes are required for reasonable growth.
- Correct floc size is important for the clarification process.
- Different clarifiers may require different optimal floc size.
- Flocculant aids
    - Polyelectrolytes

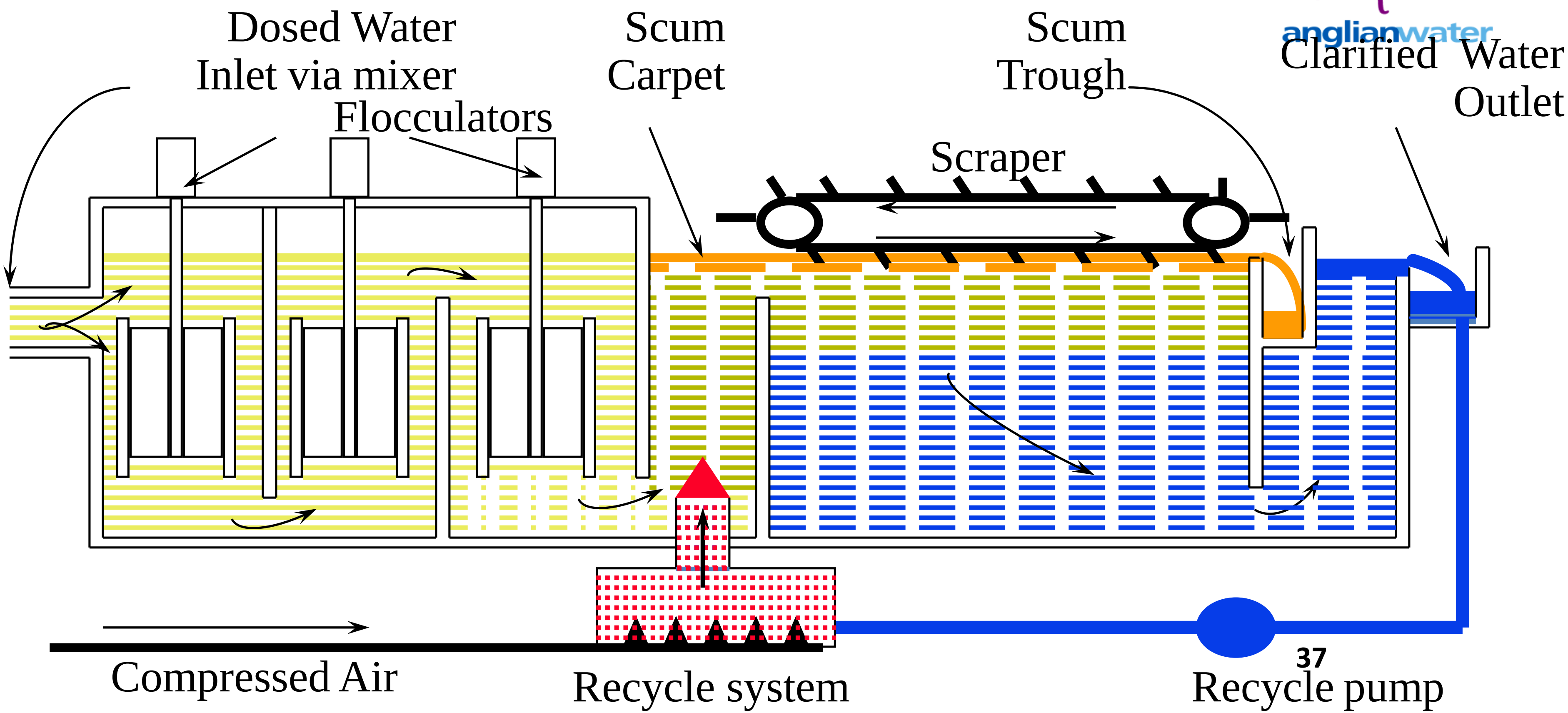
Highly Charge Fe ion Attracts Particles



“Hopper” bottomed clarifier



Dissolved Air Flotation



Flocculator and Flotation cell

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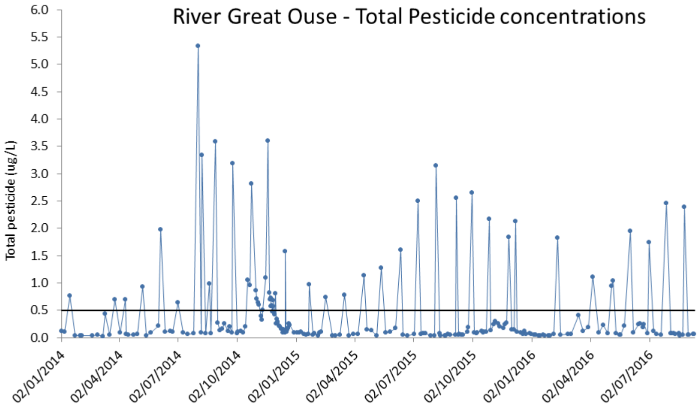
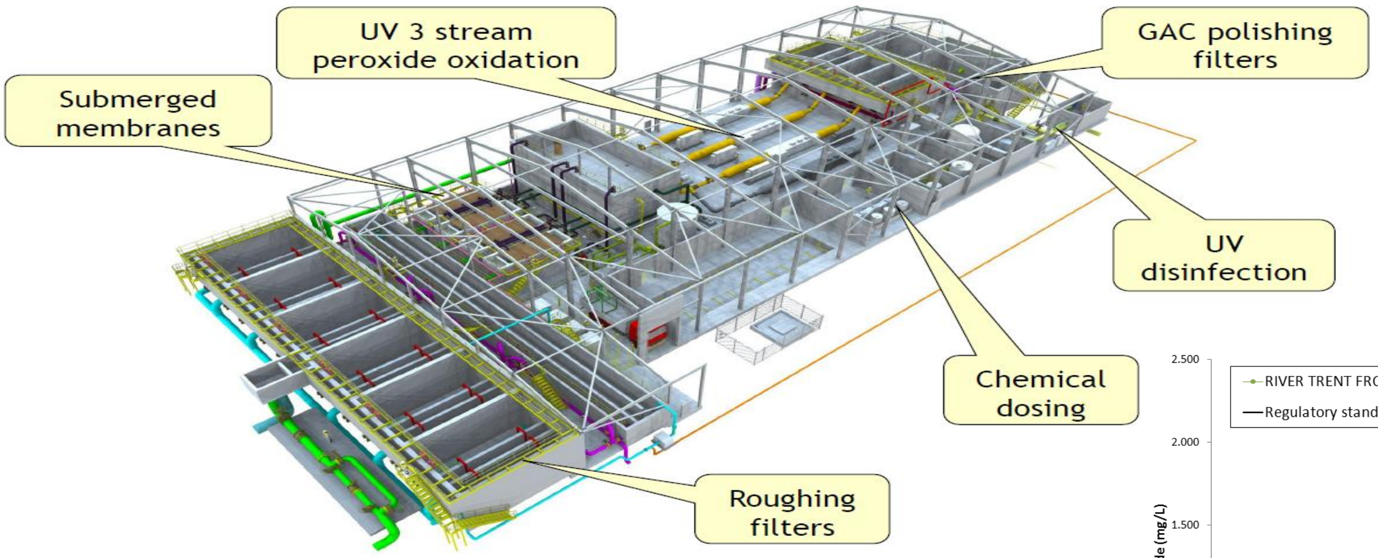
This afternoon.....



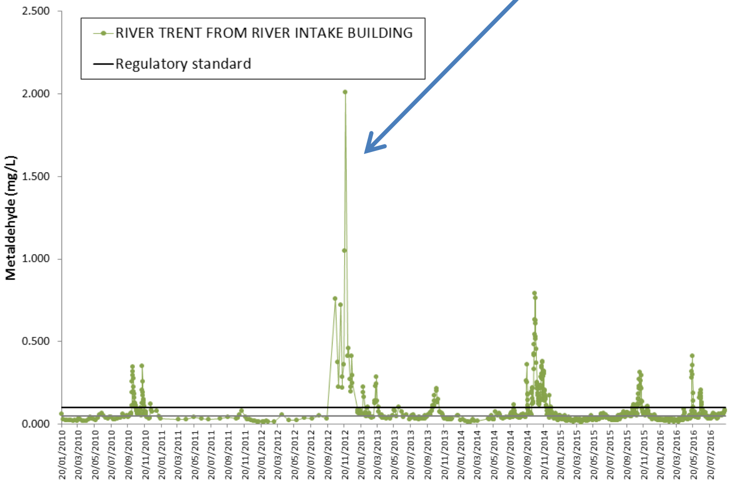
Future Surface Water Treatment Strategy?

Creating the first purpose-built metaldehyde removal works

3D process overview



2012 peak
>2 µg/l



GTM

2 year construction period
£44m capital cost
15,247 tonnes CO_2 equivalent embodied carbon

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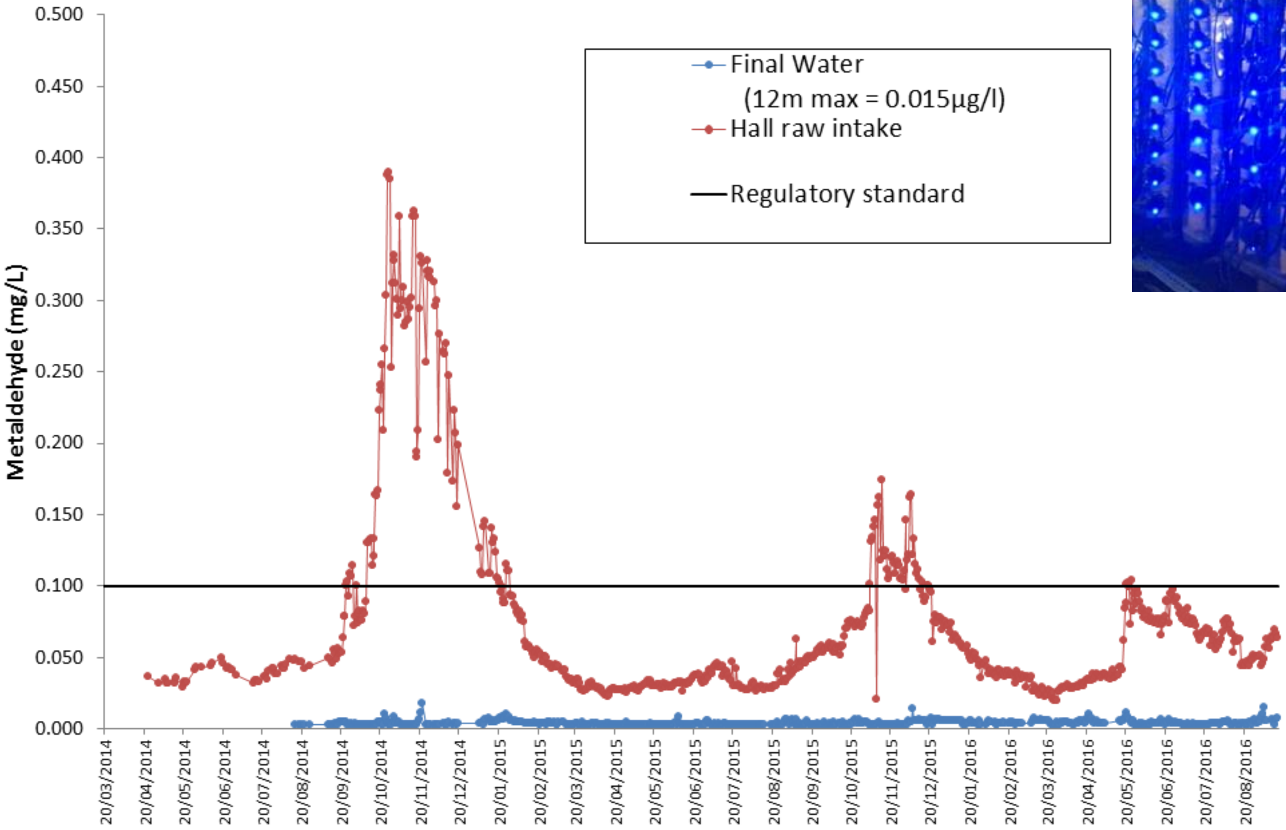
Does it work?



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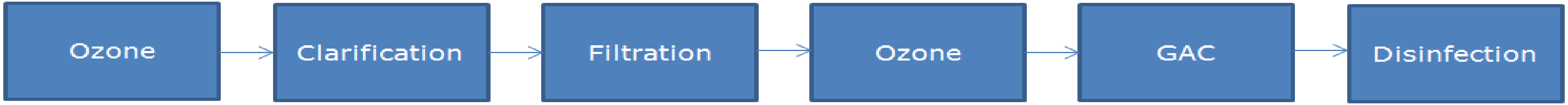
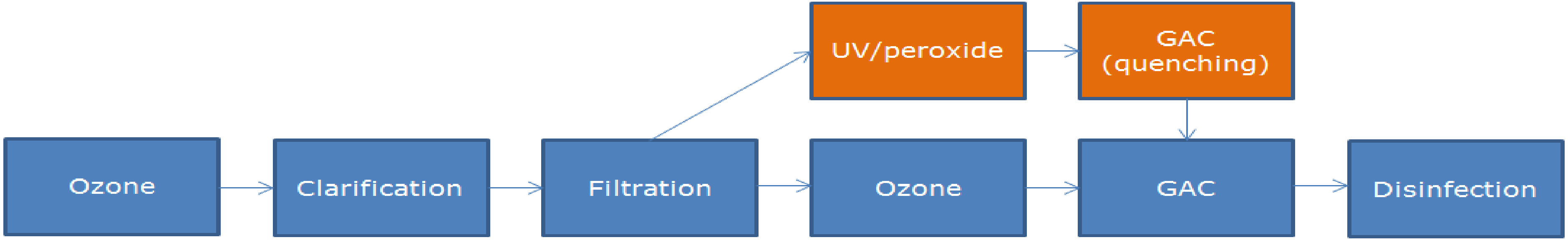
Doing this everywhere in AW

Current surface water process stream:

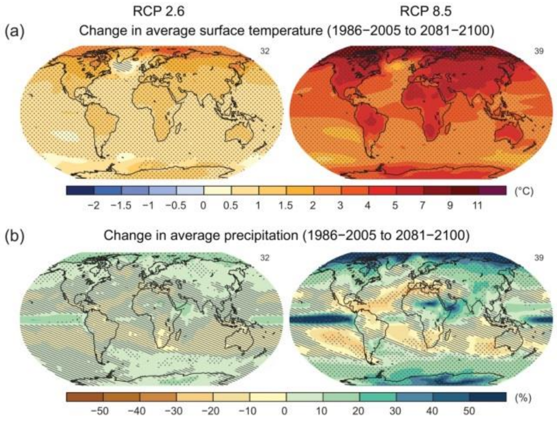


Future surface water process stream?



Treatment is not the answer for metaldehyde ?.....

Future pesticide scenarios?



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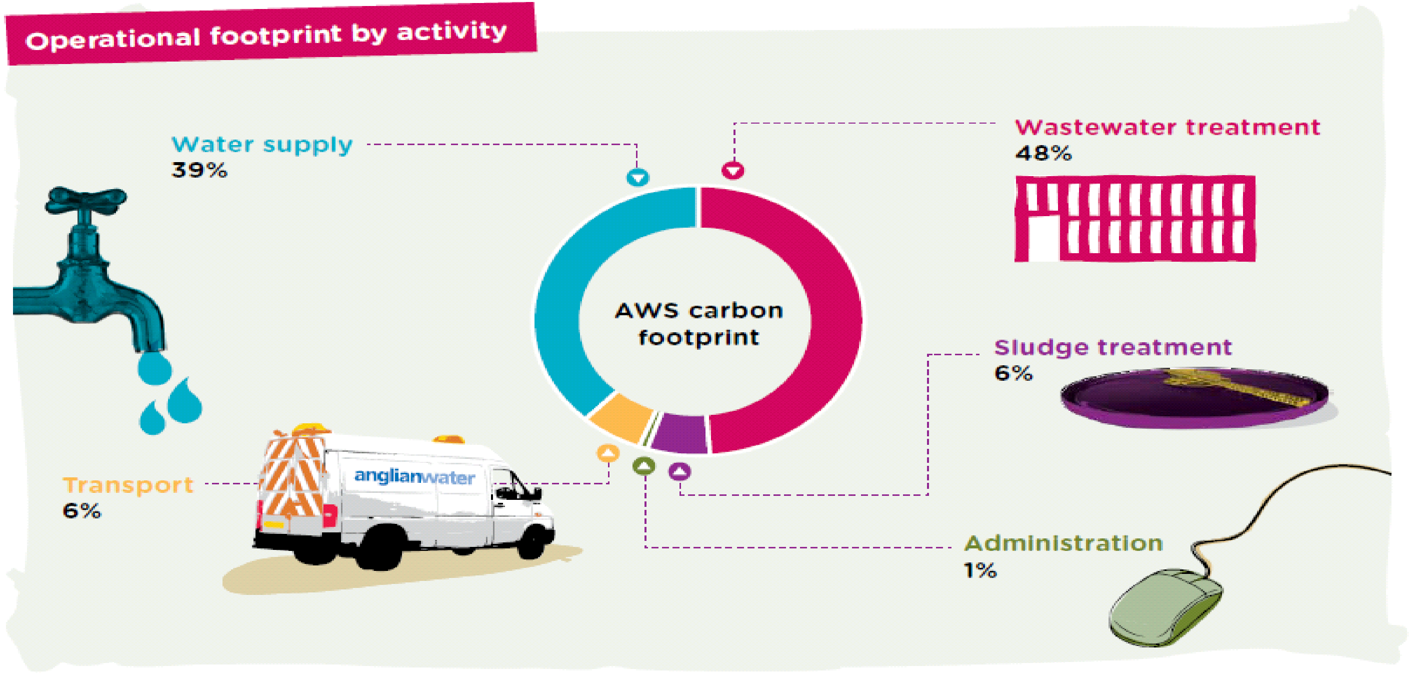
Wastewater Treatment

Energy and Carbon

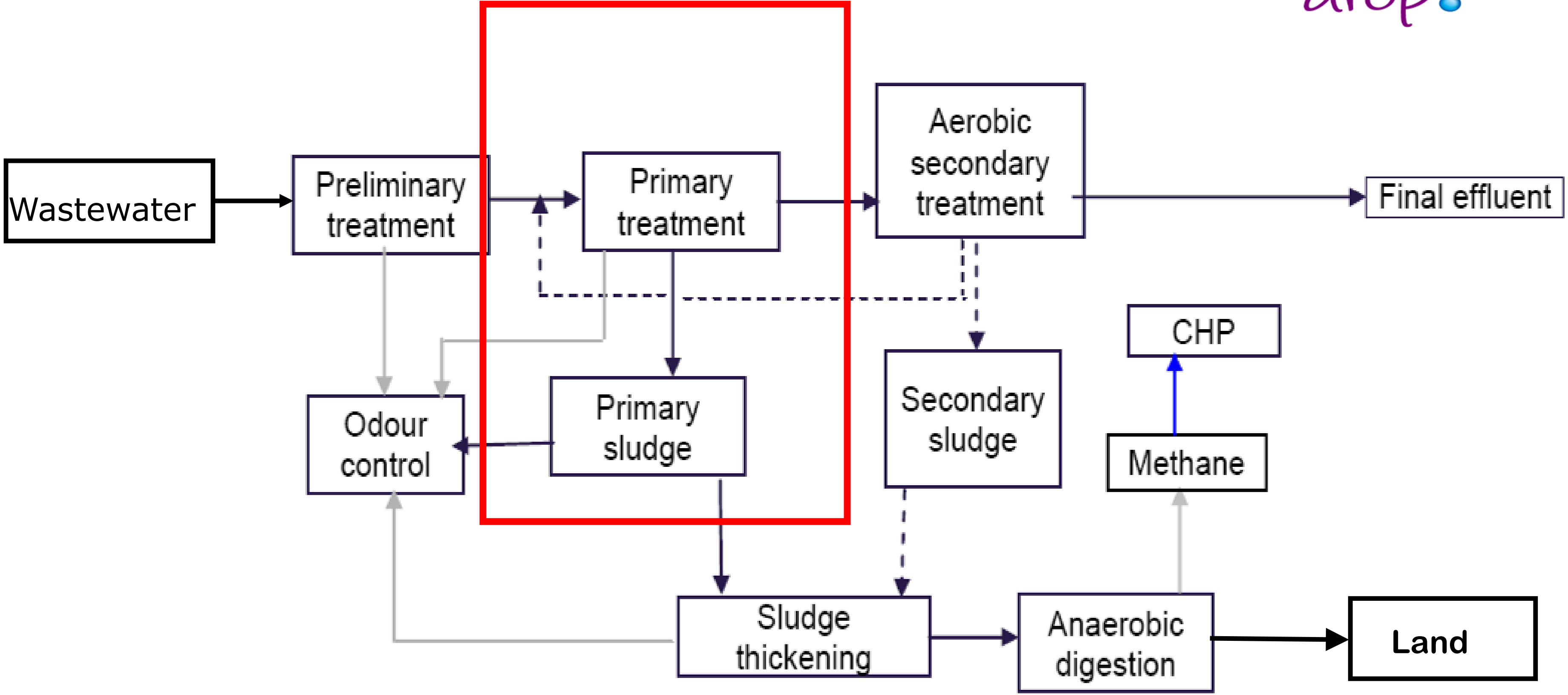


Electricity consumption around 670 GWh/annum

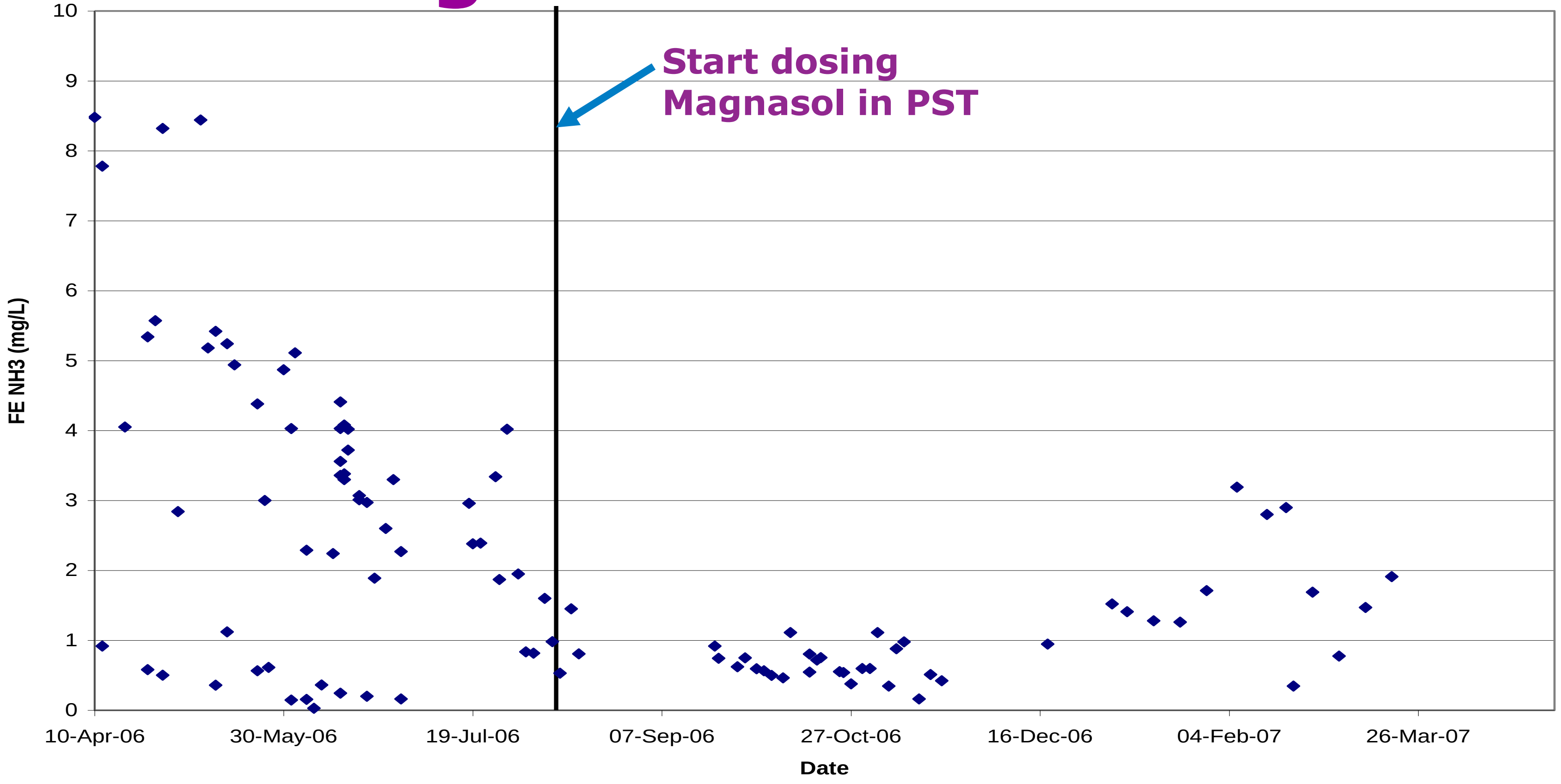
Methodologies to improve performance

- Primary de-sludge control
- Chemical dosing
- Flooding/flushing
- Wet augering
- Recirculation
- Adding plastic media filters

Sewage Treatment Flowchart



PST Dosing



Start dosing
Magnasol in PST
FE NH3 (mg/L)
0
1
2
3
4
5
6
7
8
9
10
10-Apr-06
30-May-06
19-Jul-06
07-Sep-06
27-Oct-06
16-Dec-06
04-Feb-07
26-Mar-07
Date

Sewage Treatment - Over 100 Year Old Technology

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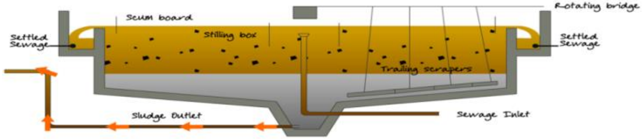
Activated Sludge

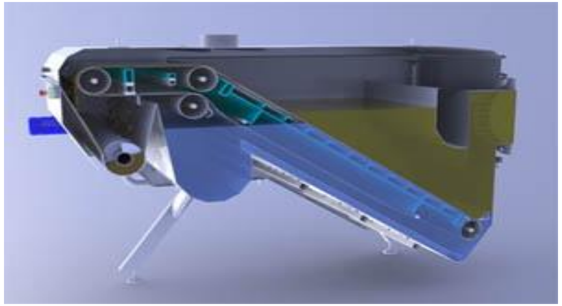
Trickling Filters

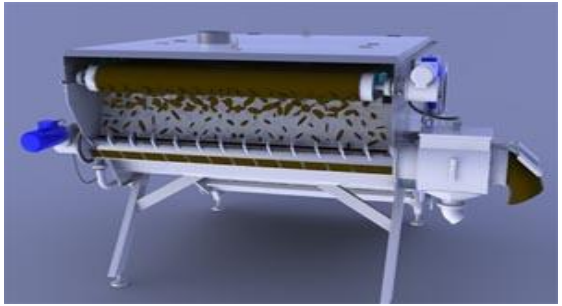
Technologies To Increase Capacity

Salsnes



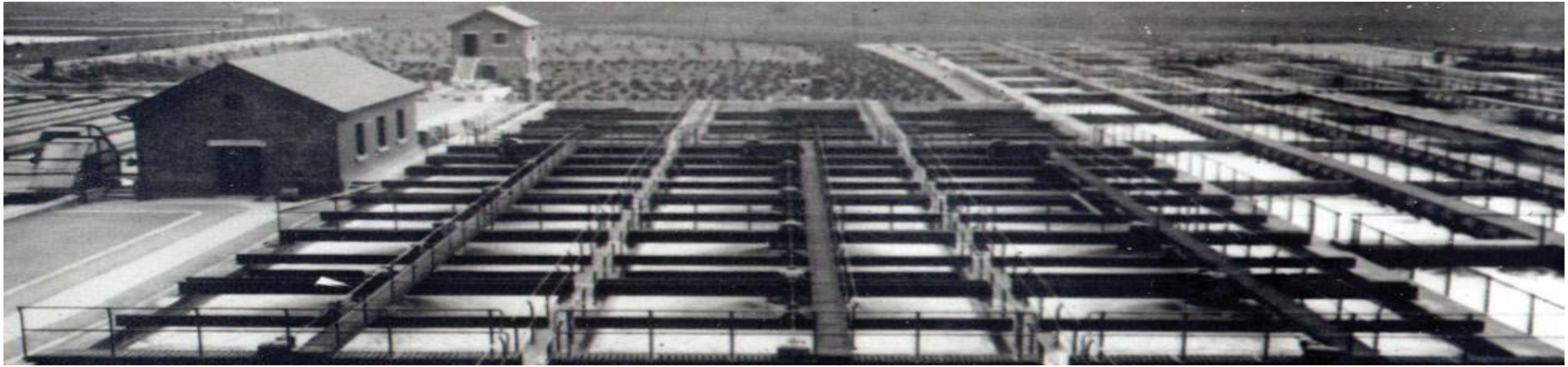
- Alternative method to primary treatment
- Solids removal between 40 and 70%





Activated sludge – a model of radical and incremental innovation

Arden and Lockett, Clark and Gage, Jones and Attwood



FBDA

BNR

IFAS

Advanced control

Energy efficient blowers

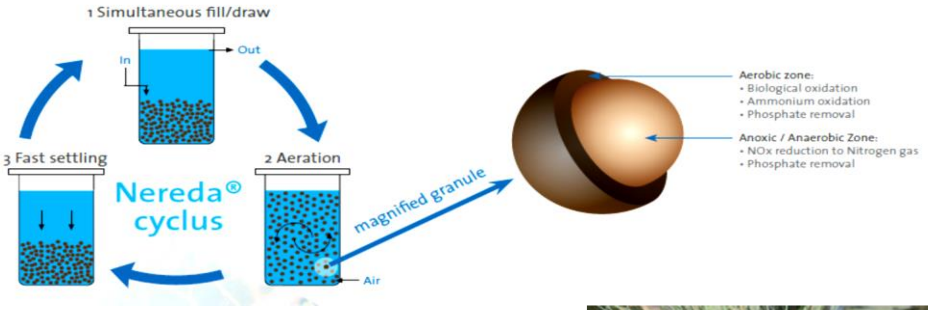
Granular biomass

HYBACS

Photo source: CIWEM/Aqua Enviro/United Utilities

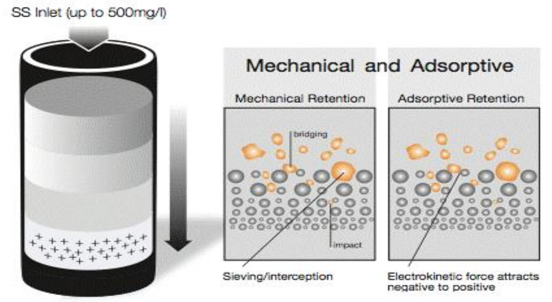
Nereda

- Granular biomass SBR
- Biological nutrient removal to low N and P concentrations

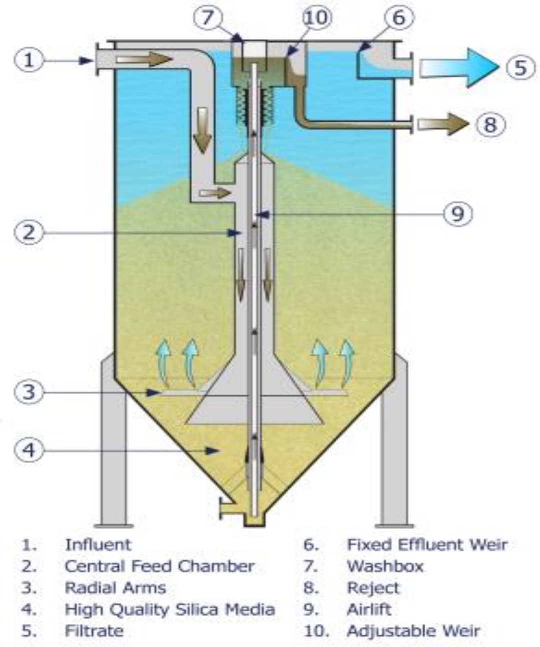


Tertiary solids removal

- Alternative methods to traditional sand filters for suspended solids/BOD removal – Bluewater Bio FilterClear and Bosman Fuzzy Filter



Blue Pro – P removal



Anaerobic digestion and renewable energy

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- Increase in Advanced Anaerobic Digestion Biological and Thermal Hydrolysis pre-treatment
- Delivered ‘energy positive’ treatment work
- Maximise recovery of nutrients and energy – 86.8 GWh target

Anaerobic treatment

- Anaerobic processes have inherent advantages over current systems including low sludge yield and associated costs; and net energy yields due to methane production.

- Main driver for the water industry is lower running costs, in particular for energy (45% reduction in energy possible)

- Moreover, membranes make conventional sedimentation tanks and clarifiers superfluous, thereby reducing the overall plant footprint, and enable better BOD and TSS removal, and allow a pathogen free effluent.

- Zero TSS effluent allows use of ion exchange resin for removal of N and P; producing a concentrated liquor, potentially suitable for recovery

Anaerobic treatment

Pilot plant
41.5m^3 reactor volume
Design MLSS 6000mg/l
12 hrs HRT

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