Dŵr Cymru
Welsh Water

Trial testing novel technologies in Dŵr Cymru Welsh Water to reduce the challenges for P consents <1mg/l

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Technology & Development Team

Technology & Development - Business Challenges

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- Searching & assessing emerging or improved technology, or new to Dŵr Cymru in accordance with business objectives
- Driving innovative technologies into the business; working with suppliers and alliance partners
- AMP 5 – Saw changes OPA to SIM and consequence of single sample metal failures failing site outright on Iron (Fe) failures
- AMP 6 – Business need to reduce total phosphorus in the final effluent to < 1 mg/l
- PR14 business plan - has prioritised 25 Waste Water Treat Works, approx 50% of the WWTW highlighted under WFD investigations as being responsible or contributing to failure of the river achieving the "Good Status" due to phosphorus

Overview of DCWW Waste Water Assets

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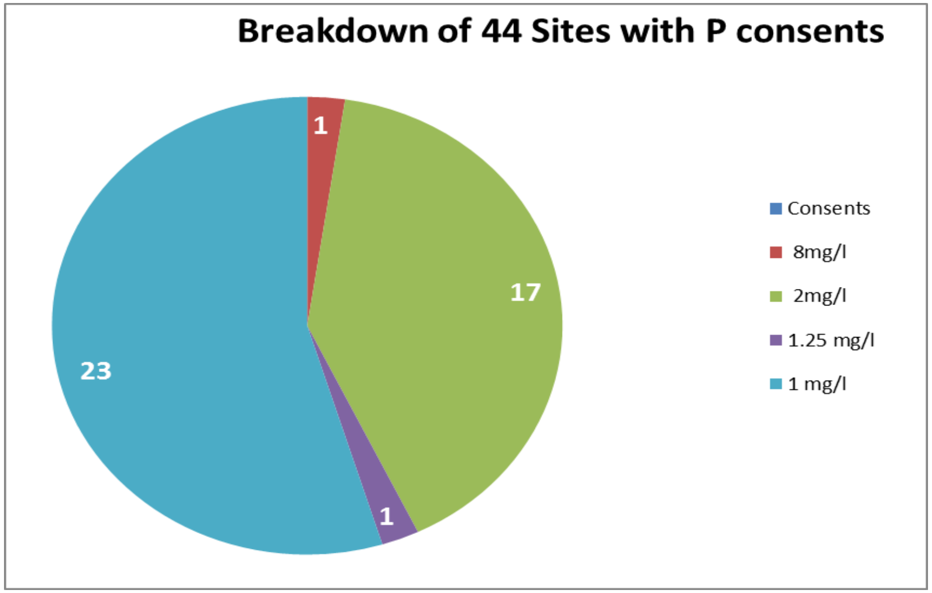
The total number of WWTW assets is 838 WWTW, below showing the geographical challenges:

- Less than or equal to 200 Pe = 380 sites
- Less than or equal to 2,000 Pe = 695 sites
- Less than or equal to 10,000 Pe = 788 sites
- Less than or equal to 100,000 Pe = 830 sites

94% of our sites are below 10000 Pe, with 83% below 2000 Pe, a lot of small sites

The total number of sites with P consents from 1st of April 2015 is 44



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Implications

- Operating cost implications (Increases to chemical consumption, staff etc)
- Energy cost implications
- Increased sludge production due to increased dosing
  = more sludge storage and Increased OPEX costs
- Increased risk of Iron failures due to tighter Phosphorus limits
- Access to sites & available space for chemical storage at sites

Chemical Consumption & Sludge Production Challenge

Electro Coagulation - Background

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- Why
  - DCWW's 25 yr vision is to move towards chemical free treatment, reduce chemical consumption, meet tightening 'p' consents and reduce whole life TOTEX costs
- What is Electrocoagulation (EC) –
  - In its simplest form it's the melting/Dissolving metal electrodes (AL/FE) into the treatment process
- Who
  - Hydro Industries is a local supplier and well established in the EC field
- Trial site
  - Llanelli WWTW, major capital scheme and new 'p' consent
- Findings
  - Did it work, was it cost effective, are there risks?
- Next steps
  - Any potential opportunities in DCWW

Electro Coagulation – Trial

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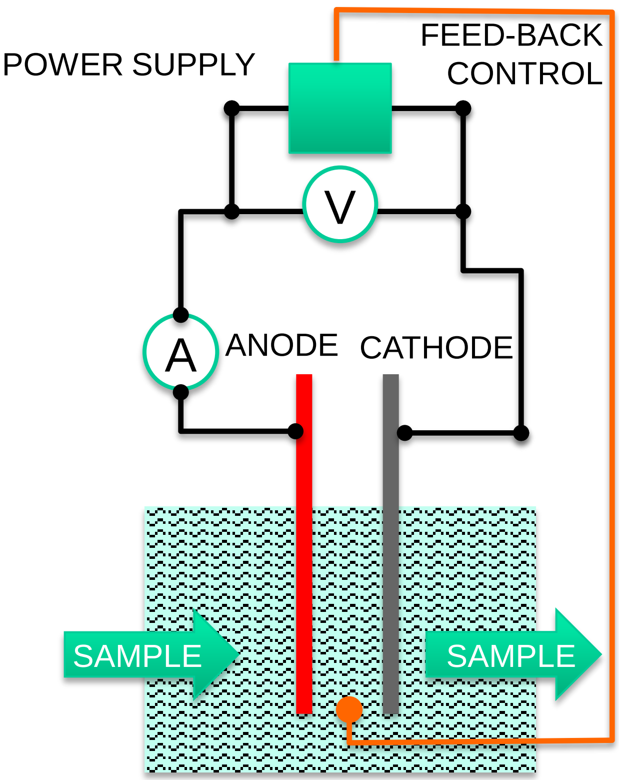
- Phosphorus removal solution is proposed for Llanelli WWTW. Three processes are under consideration and include:
  - Biological P removal
  - Liquid chemical dosing (Iron salts)
  - Electro-coagulation EC (Iron / Aluminium electrodes)

- The brief for the project was based on:- Total Phosphorus in Crude of 5.4 mgl^{-1} and proposed final consent compliance would be set by NRW at 1.0 mgl^{-1} total P, Crude flow rate 600 $lsec^{-1}$.

- Would EC (i.e. in-situ generation of Iron or Aluminium coagulant) be:
  - As effective as liquid chemicals for P removal;
  - Capex / Opex of EC be lower than chemical transport, handling, storage etc.

WHAT IS MEANT BY ELECTROCHEMICAL WATER TREATMENT



FEATURES

- The ‘reactive’ treatment reagent is an electron which is supplied from an external power source (grid mains, generator, solar PV, turbines etc) to electrodes immersed in the sample
- Treatment reactions can occur DIRECT on electrode surfaces (e.g. oxidation / reduction) and INDIRECTLY (e.g. electro-coagulation) within the bulk of the sample.
- Treatment selectivity is achieved by selecting:
  - Electrode material
  - Amperage and polarity
- Electrochemical plants in general are ‘hybrids’ employing conventional downstream solid-liquid separation processes

TREATMENT UNIT –
'Engine' is the electrochemical reactor

Hydro 200/400 Treatment module

Specification:

Flow up to: 40 m^3hr^{-1} (sample dependent)
Design: Skid
Nos. electrodes: 2 - 4

Dimensions:

Length: 3100mm (10.17 ft)
Height: 1600mm (5.25 ft)
Width: 1500mm (4.92 ft)
Weight: 850 kgs (0.94 ton US)

Llanelli WwTW Trial plant

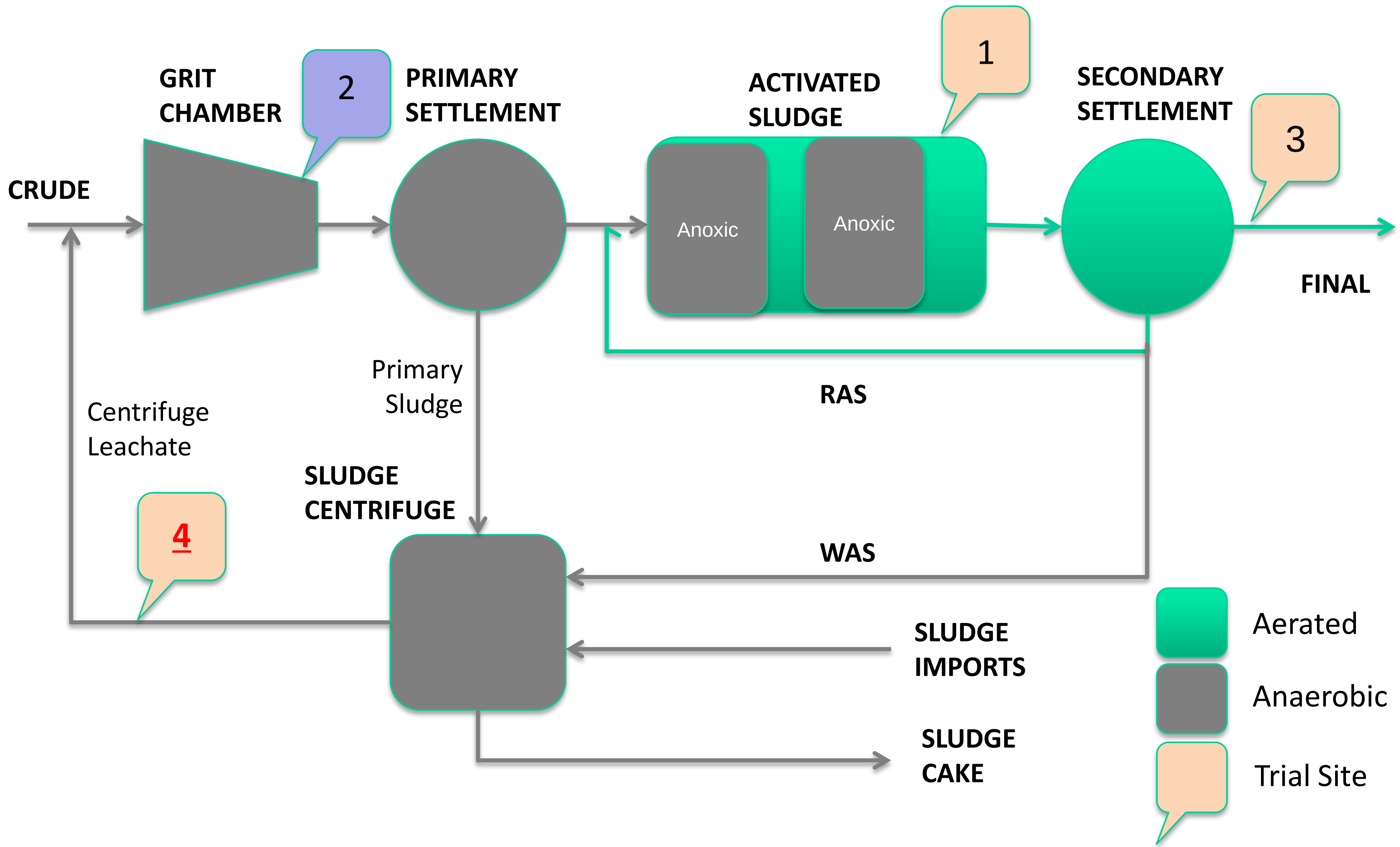
Stage 1 – EC reactor

Stage 2 – Flash mixer & Flocculator

Stage 3a – Lamella plate clarifier

Stage 3b – Radial Clarifier supplied by WRc to overcome excessive sludge build up on Lamella plate clarifier

Phosphate pathway



Treatment matrix

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Location	Electrode in flow	Electro-gen chemical.	Comments
1- Grit Chamber (Primary)	✗	✓	To avoid ragging / fouling of electrodes with 'plastics'
2- Activated Sludge (Biological)	✗	✓	To avoid potential disruption of biomass (MLSS) and effect on RAS
3- Final Effluent	✓	✓	Flow rate of 11l/sec to remove 2mg/l of 'P'. Option for 'P' polishing plant with reduced sludge loading.
4- Centrifuge Concentrate (Recycle)	✓	✓	Small flow rate of concentrated liquor. Reduced plant size, Capex and Opex. Best WLC solution. Reduced risk to Iron failures

Observations and Findings

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Phosphorus levels

- Total P in Crude plus return liquor ranging 8-19mgl^{-1} due to up to 110mg/l of P from centrate return.
- Total P is being removed by biological treatment through the AS lane, but is being released in the sludge holding tanks due anaerobic conditions.
- Ortho P in centrifuge leachate returned to head of works can be >131 mgl^{-1}

Incoming Sewage Quality

- Over July period low flow, warm conditions Crude became septic and there was a significant odour problem
- Llanelli imports sludges from neighbouring works – these sludges were anaerobic with elevated iron and may have increased septicity of the Crude
- Under high tide conditions there is some Saline intrusion into the incoming crude
- Under anaerobic condition iron dosing (liquid or EC) is **ineffective** and leads to formation of insoluble iron sulphide (FeS) as fine black colloidal suspension. Conventionally this is overcome by dosing x3-6 times stoichiometric equivalent of Fe:P ratio .
- Due to the above septicity problems, EC electrodes were changed to Aluminium. With immediate effect there was a significant improvement in treatment and P removal.

Trial Results: Aluminum Electrodes

Aluminium electrode results:- (average 81% TP & 91 % OP removal)

- Total P in Crude to Hydro unit: average 12.09 mgl^{-1}
- Ortho P in Crude to Hydro unit: average 7.83 mgl^{-1}
- Total P after Hydro unit treatment: average 2.22mg/l
- Ortho P after Hydro treatment: average 0.71 mgl^{-1}
- Aluminium residual in treated water: 0.6 mgl^{-1} (NRW consent 1 mgl^{-1})
  (Further samples to be tested by DCWW)

Centrifuge concentration (Centrate spot sample treated)

- Ortho P in concentrate: 150.4 mgl^{-1}
- Ortho P after EC aluminium electrode treatment: 2.6 mgl^{-1} (Sample)
- 98% removal at 30A

Centrate Trial results

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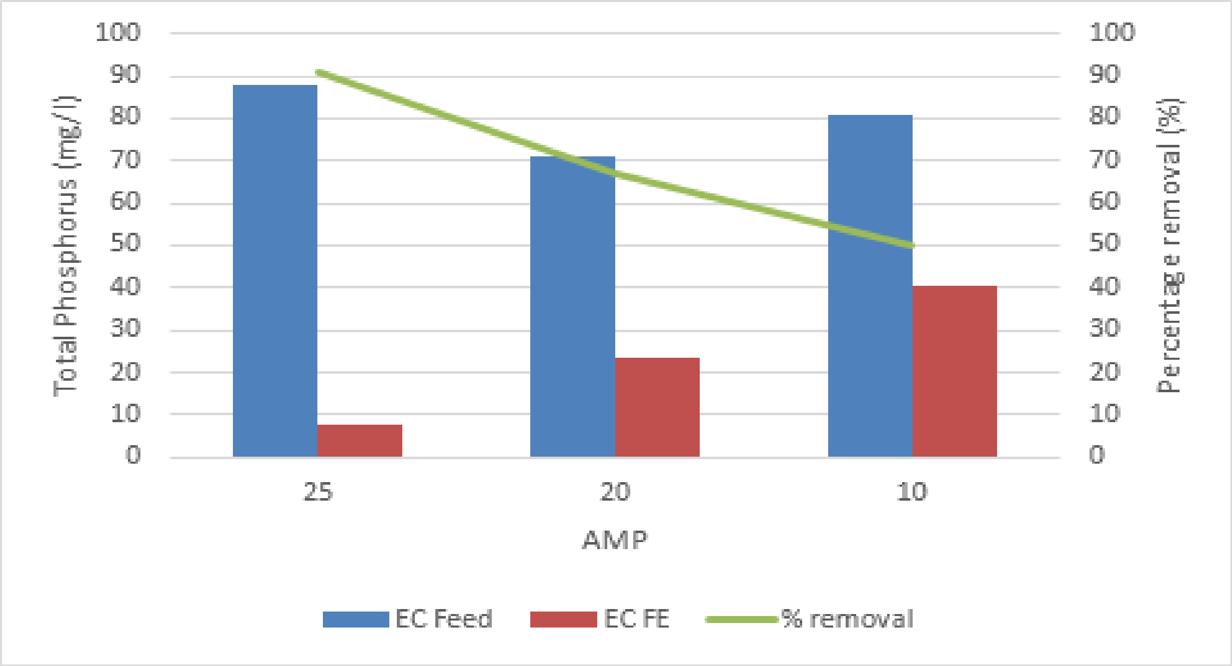

Figure 21. Graph showing total phosphorus high (70-90mg/l) levels in the EC Feed and FE, with percentage removal at different amperages

Figure 21 shows that as the AMP's are increased there is a higher percentage removal of total phosphorus, when incoming levels are higher than 70mg/l. At 25AMP's total phosphorus levels were decreased from 87mg/l down to <10mg/l (90% removal); at 10AMP's a feed of 80mg/l of total phosphorus was reduced to 40mg/l in the final effluent (50% removal).

Centrate Trial results

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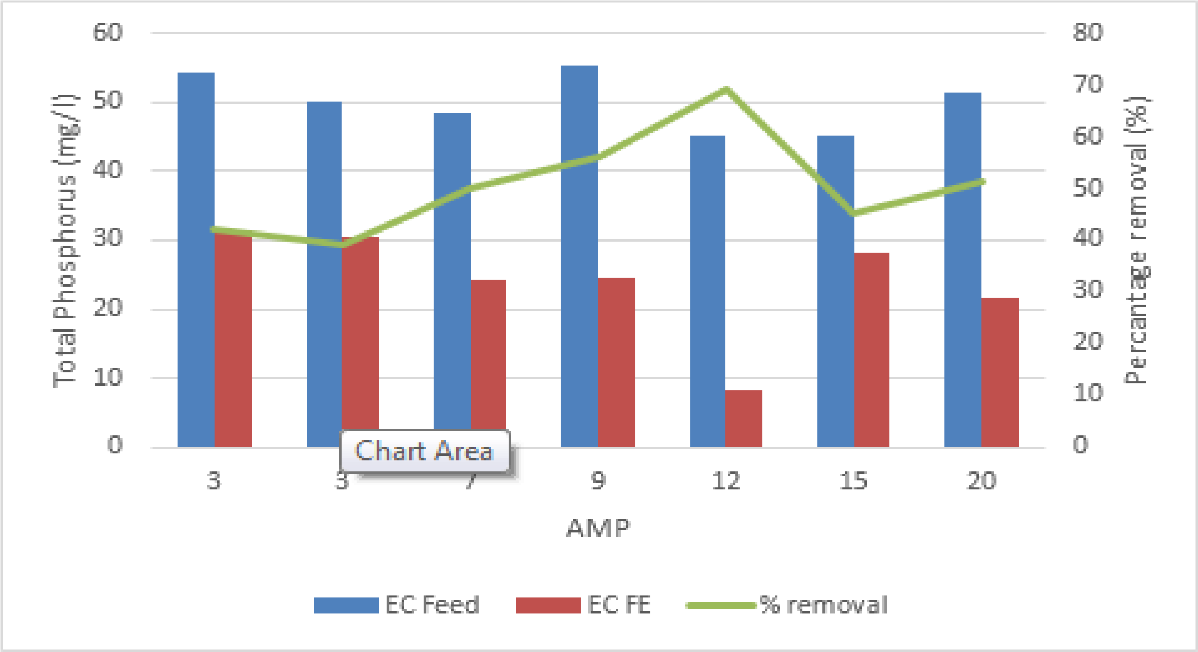

Figure 23. Graph showing total phosphorus (45-55mg/l) levels in the EC Feed and FE, with percentage removal at different amperages

As with lower levels of total phosphorus in the incoming load, levels between 45-55mg/l display a simila removal rate across all amperages (Figure 23). The removal rate ranges from ~40% to ~70% across the amperages, with 12AMP's showing to be the optimum level; with incoming levels of 45mg/l being reduced to 8mg/l in the final effluent (71% removal). 3AMP's does display the lowest rate of removal overall ~40%.

Trial Conclusions & Recommendations

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- Phosphorus is being recirculated around the facility and level is increasing overall crude to max 23mg/l.
- Biological P removal currently occurs in the AS zone but is recycled around due to centrate
- There is a requirement to chemically bind the phosphorus to make it insoluble and to remove it from the wastewater circuit. This will require the addition of a coagulant.
- An Iron based coagulant may not be appropriate for P removal for this particular facility given its susceptibility to septicity and formation of Insoluble, colloidal FeS.

- **Treat centrate return to remove high ‘P’ concentrations**
  - This option represents the best ROI to reduce the ‘P’ loading at the inlet works.
  - Treating the centrate together with any Bio P option could provide a lower cost ‘P’ removal solution.

- **There is also the option of EC polishing plant for ‘P’ removal on final effluent**.

Centrate Budget Costs (22l/sec@10mg/l)

Costs	CAPEX	OPEX	15yr Totex	Cost per M3	Comments
Bulk Ferric sulphate	£240k	£40k	£840k	£0.08	H&S risks with corrosive chemical. Increased sludge production, risk of Iron failure if overdosed. Will need access for bulk deliveries. Septicity issues.
Bulk Sodium Hydroxide	£198K	£65K	£1173K	£0.11	H&S risks with corrosive liquid. Will be needed to raise pH if low alkalinity and ferric doing. Will need access for bulk deliveries.
Electro-coagulation	£264k	£31k	£729k	£0.07	No corrosive liquids, does not depress ph, reduced sludge production compared to bulk chemical dosing. Instant treatment and can be turned on/off dependent of 'P' load. Reduced risk to Iron failure and good removal rates for sites with tighter 'P' consents – 0.6mg/l. Costs based on 22l/sec for 10mg/l P removal @3amps
Note:- Budget Construction Costs only					

Benefits of Electro-coagulation:-

- Similar costs per m3 to bulk Ferric chemical dosing (no pH adjustment)
- Lower sludge volume, higher %DSS
- Reduced alkalinity-pH issues
- Lower risk of Iron failures
- Capable of high removal rates on sites with tight ‘P’ consents
- Well suited for smaller sites with limited access
- Reduced H&S risks
- Additional benefits of COD, BOD, Ammonia load reduction
- Instant treatment and flexible operation for ‘P’ polishing removal
- Mobile mitigation units

Next steps and future developments:-

- Consider EC treatment as an option for other small WWTW's and compare WLC's.
- Trial as DAF on potable water treatment works (side stream)
- Assess potential for mobile mitigation units for solids and 'P' removal
- Tertiary treatment for WWTW's prior to UV

Low Level P Targets Challenge

Background

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- Why
  - meet tightening ‘P’ consents and reducing risk on metal compliance
- What is Blue Pro Process
  - In its simplest form it is creating a regenerated active media increasing the surface area for removing Phosphate out of solution.
- Who
  - Evergreen Engineering is the UK distributor for Blue Water Technologies in the USA.
- Trial site
  - Llanberis WWTW, major capital scheme and new ‘P’ consent March 2016
- Findings
  - Did it work, was it cost effective, are there risks?
- Next steps
  - Any potential opportunities in DCWW

Llanberis WWTW Trial site

- Population equivalent of 2107
- Current consent Total P 1 mg/l (rolling average) & 5 mg/l (UT) Total Fe
- Discharges into Llyn Padarn (inland bathing water) & High Tourist site
- DCWW 2009 incident blamed for damaging water quality of Llyn Padarn, and causing a toxic algal bloom closing the lake for weeks.
- Arctic charr future and key to improving water quality

AMP 6 Investment for Total P removal includes Llanberis WWTW, as new consent been agreed by the Conservation agencies and Natural Resources Wales under the Country side and rights of way (CROW) driver a sub act under the Wildlife and Country Act.

New consent is a **Total P consent of 0.5 mg/l** (rolling average) & **Total Fe of 4 mg/l** (95% tile) and 8 mg/l (UT), which comes into **effect in March 2016.**

Why Trial the Blue Pro Process?

The reasons for looking at the Blue Pro process were the following:

✓90% Phosphorous removal guarantee

✓Achieved lower than 0.1 mg/l Total Phosphorus final effluent quality.

✓Reduced Iron Failure risk with Total Fe < 1 mg/l achieving low level Phosphorus consents

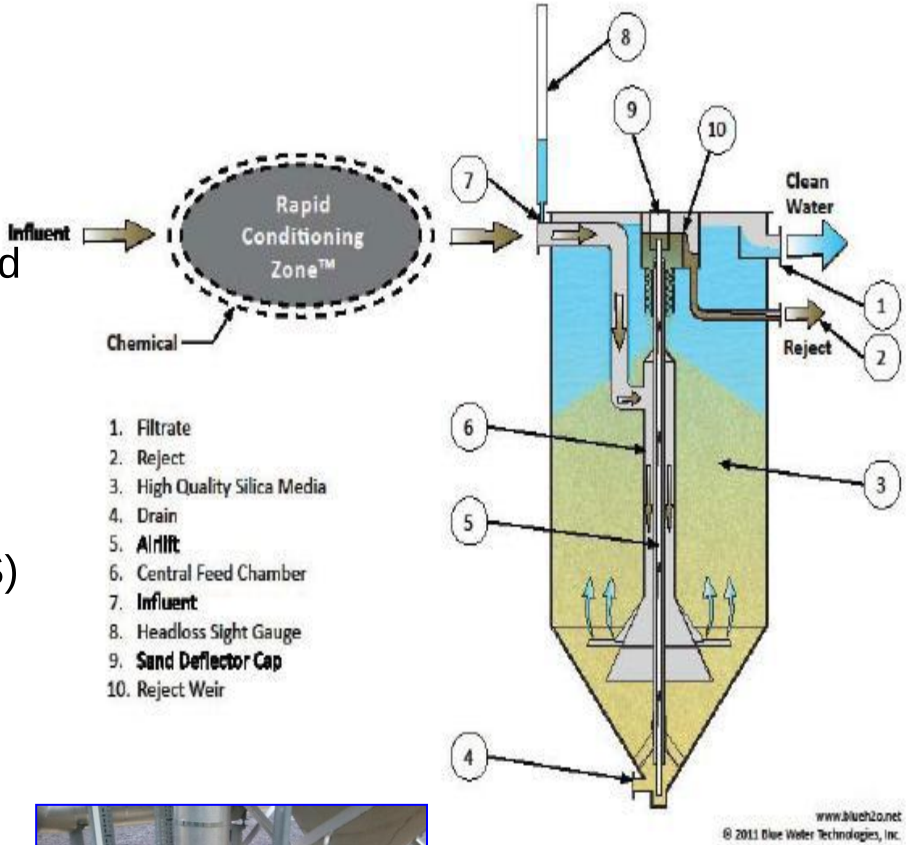
✓Potential solution for complicated control philosophies at pumped sites

✓Ability to remove Phosphorus straight away (75% removal of Total Phosphorus (Total P) within an hour of start up or load spike) unlike standard chemical dosing taking days and longer time to respond.

✓Reduced chemical consumption for Total P consent – claim 30% reduction

Blue Pro Process

- Centra-flo Upflow moving bed (continuous) reactive sand filter
- Ferric Sulphate dosed in patented rapid conditioning zone
- Optimised to improve surface reactivity, and sand cleaning
- Dynamic combination co-precipitation & adsorption
- Hydrous ferric oxide coated sand (HFOCS) is formed
- HFOCS is now an adsorbent media.
- Adsorptive surface is continuously regenerated HFO
- Sand continuously washed and Fe & P removed in reject water



Blue Pro Full Scale Plant – Llaberis WWTW

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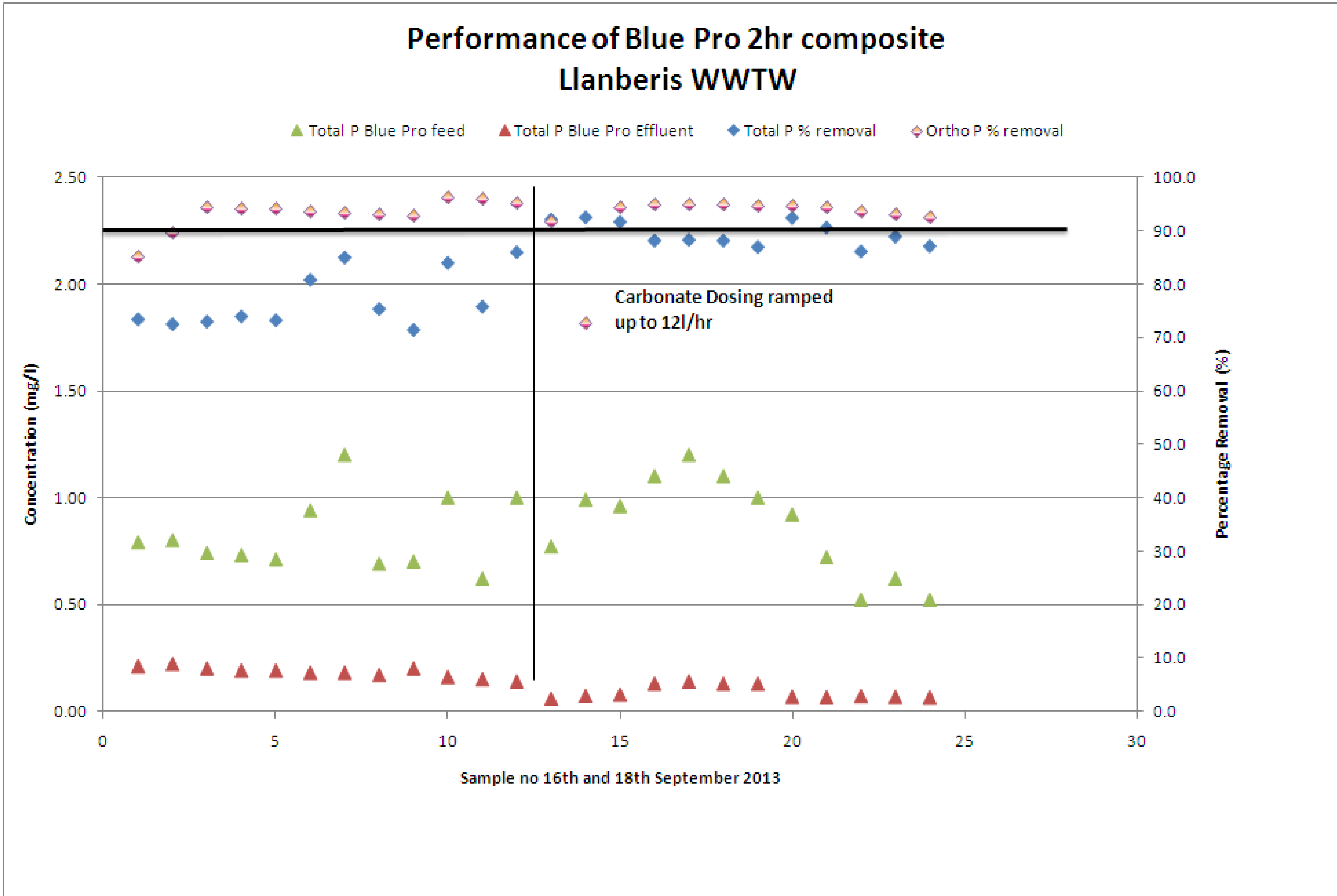
Blue Pro CF64 unit installed at site – biggest above ground unit available
First UK installation

Parameters	Value
Diameter	2.7m
Surface Area	5.9m2
Sand depth	1.5m
Air Lift	180 SCFH (21Psi to 24Psi)
Feed Flow	10 l/s (peak 18.9l/s)
Backwash	0.55 l/s (6%)
Hydraulic Load	5.85 m/h to 6.15 m/h
Feed TSS	≤32mg/l
pH	6.2 to 7.5
Ferric Sulphate dose	13.3 mg/l (2.5l/hr)

Blue Pro performance - Two hourly external survey



Blue Pro performance - Two hourly external survey

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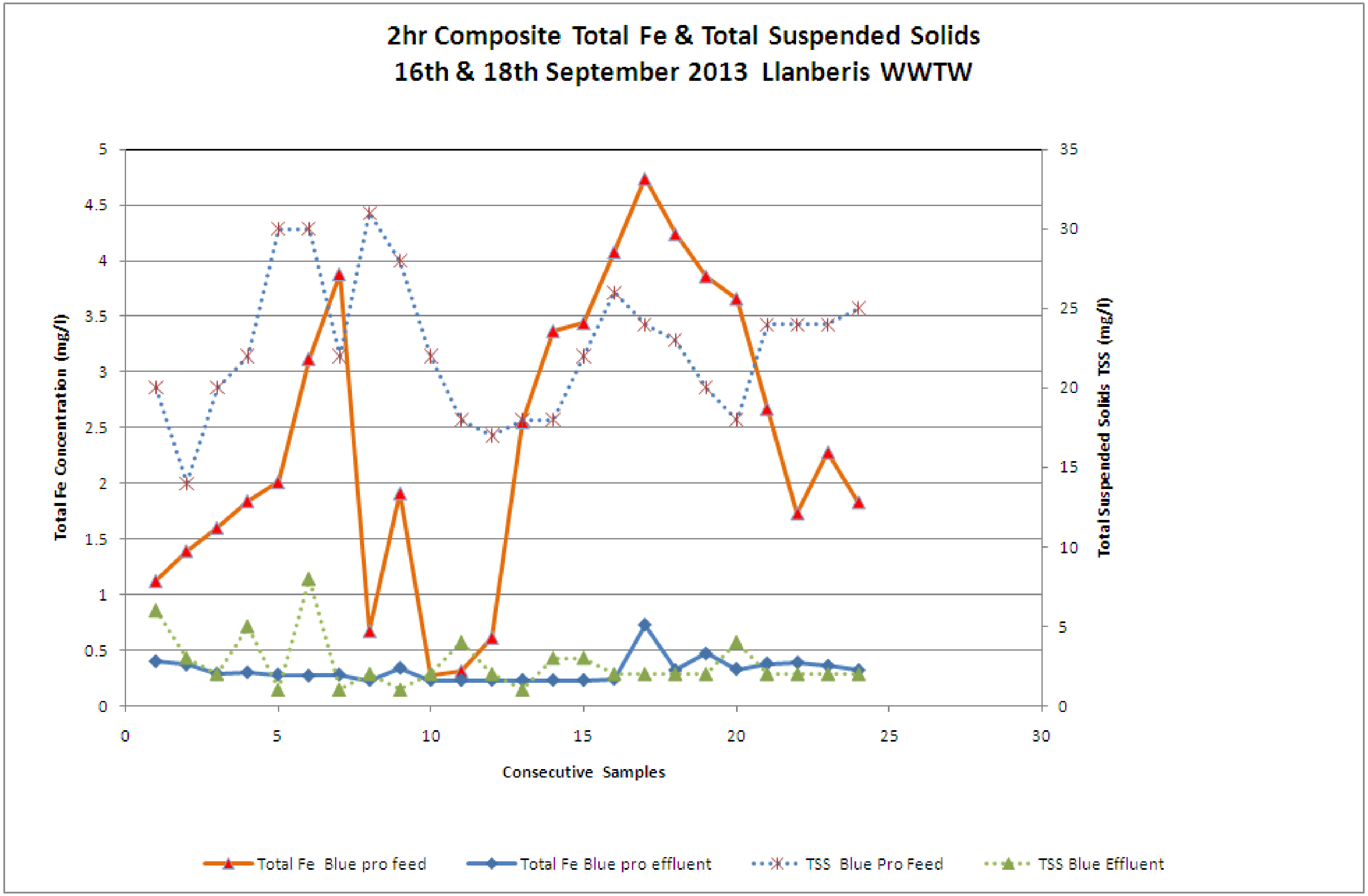

CAPEX Comparison

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Cost comparison for 1 ML/day versus current available options for treatment made with the following assumptions used: (prices UCD October 2013)

Detail	Blue Pro (£)	Dynsand Filter (£)	Disc Filter (£)
Unit cost	54K	140K	137
Flocculation & Mix	0K	14K	14K
Chemical Dosing Equipment & tanks	100K	100K	100K
Pumping station	80K	80K	80K (0K)
Total (£)	**234K**	**314K**	**311K (231K)**

•Cost do not include electrical, mechanical or civil costs, but does include installation & unit price

•Pumping stations cost would be the same across all three for most plants, the Disc filter may, dependant on site survey not require a pumping station, a 12 kwHr pump been used for cost

•All options would be duty and standby

•Chemical dosing equipment requirement for both primary and secondary dosing would be same

•Flocculation and mixing tank assumed £7K each, Blue Pro does not require these elements

Conclusions & Recommendations

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✓Blue Pro process achieves low TP effluent and 90 % removal with lower Fe risk, and it is a lower CAPEX cost option compared to Dynasand and Disk filter.

✓90 % Process guarantee was given for 70 mg/l alkalinity, the plant obtained near to it around a lower alkalinity level so there is room for optimisation for future installations.

✓Ferric Hydroxides excess in reject line has got additional benefit of use as long as it doesn't precipitate it out in the sludge, which may confirm the 30% reduced chemical cost requirements.

❑Alkalinity dependency needs to be fully and better understood for all technologies utilising Ferric dosing as advanced TP removal as well as for conventional chemical dosing

❑We should investigate further the additional benefits to achieve the 30% reduction in Ferric Sulphate consumption, which was not part of the trial but is claimed by Blue Water& Evergreen Engineering, and supported by Surface complexation modelling WERF.

❑OPEX costs need to be compared between the various technologies and dosage requirements, early indications suggest 30% reduction when we go to 0.5mg/l

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Benefits of Blue Pro Process:-

- Lower risk of Iron failures
- Capable of consistent 90- 95% removal on sites with tight P consents
- Capable of targeting low level P (<1 mg/l) to even lower
- Rapid Conditioning Zone – good mixing & intergral part
- Well suited for Medium (40000pe) to Small sites
- Well suited for difficult pump controlled sites e.g. Llanberis
- Protects overdosing on biological filter sites and ponding
- Instant treatment and flexible operation for P polishing removal
- Modular and scalable for further tightening consents (two stage pass)

Next steps and future developments:-

- Keep Blue Pro at Llanberis and make permanent
- Review other sites for suitability
- Compare WLC's to other rising novel technologies that claim to achieve 0.1 mg/l
- Utilise as polishing of final effluent levels
- Retrofit where possible

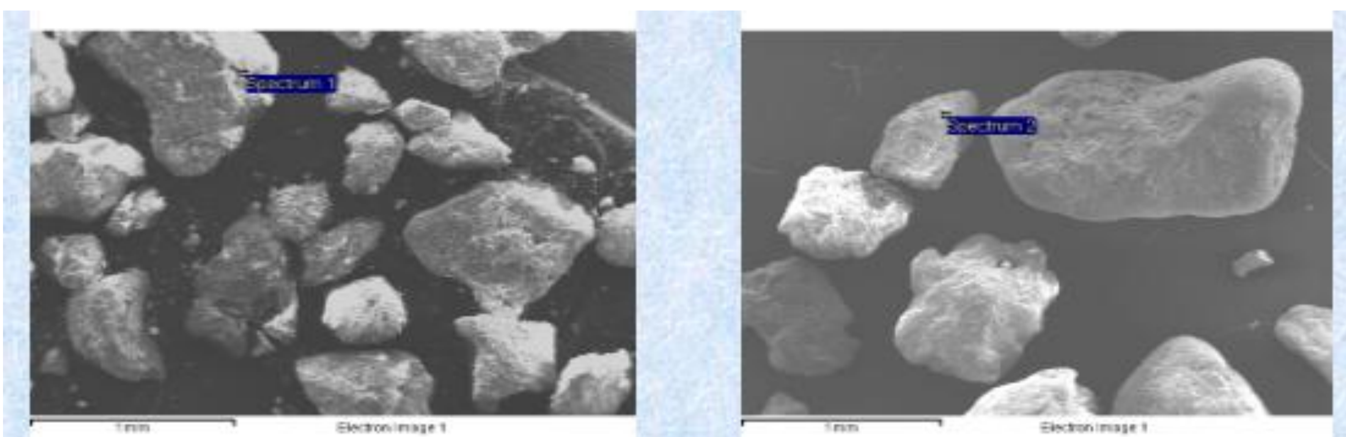
PASSIVE/POSITIVE P REMOVAL
CHEMICAL FREE CHALLENGE

Cardiff University – Engineered Wetlands for P Removal

- Concept is based on the use of dewatered water treatment works sludge to enhance P removal via ligand exchange in an engineered wetland system
- Determined the P adsorption capacity of selected DCWW drinking water treatment works sludges; to serve as a primer for the development of the system which will reduce/eliminate the need for chemical dosing and minimize sludge production.
- P adsorption capacities of the sludges ranged from 0.7 to 5.8 mg-P/L
- Next step pilot scale to determine performance & engineering data

Benefits:

- being able to achieve low effluent P concentrations without the use of chemicals
- creating a product of value and enabling P recovery
- considerably smaller footprint
- cost-effective and environmentally friendly



Cardiff University – Passive P removal

- A novel P precipitation process is being piloted by Dr. Devin Sapsford
- The technology is based on a precipitation technique using limestone, field trial completed January 2014
- Under a non disclosure agreement and subject to IP

Benefits

- Initial results have been promising on a number of accounts compared to chemical dosing, to achieve 1mg/l.
- High level OPEX costs shows potentially 50% reduction to OFWAT values for P removal
- No risk with Ferric dosing and Fe failures
- Some of the potential advantages this technology could provide include:
  - Precipitate can be used on agricultural land
  - Removal of other metals
  - 10^{th} of the area required for constructed wetland design

Next steps for both projects:

Taking both work by Dr Babintunde and Dr Sapsford to pilot scale, and have a joint agreement with Cardiff University & ARM to develop this technology.

Comparison of nutrient recovery struvite & microalgae

Comparison	Struvite	Microalgae
Technology Readiness	Advanced	Developing
Chemical Dependence	Mg & pH	CO_2
Scalable	✓	✗ (Challenge)
Value product	$765/ton	$10884/ton
N&P capture (% removal)	70-90% (ratios & pH dependant)	80% (include NH4) over 4 days
Running Costs*	Higher	Lower

**Swansea university accomplish report section 5.4 although lighting required this is still cheaper than running struvite recovery*

Routes for disposal of Algae:

- ✓ Fertiliser or shrimp feed
- ✓ Feedstock for AD or AAD were similar to Rye grass (paper being written)

Acknowledgements:

“Doing more with less”
“Spend to Save”

Thank you & Questions