Appendix 5.1.C – Atkins – Phosphorus removal – technology review

Wessex Water

September 2018

Wessex Water
YTL GROUP

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Phosphorus removal business plan

Technology review

Wessex Water

18 May 2018

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This document has 11 pages including the cover.

Document history

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Client signoff

Client	Wessex Water
Project	Phosphorus Removal Business Plan Technology Review
Job number	
Client signature / date	

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Executive summary

Wessex Water has engaged Atkins Ltd to provide a review of its practices on chemical phosphorous removal schemes contained in the AMP 7 business plan and to compare these to alternative approaches employed by other wastewater practitioners. The specific scope of the report was discussed with Wessex Water and it was agreed its overall aim would be a technical review of the Wessex Water approach against our experience of P removal with other companies. A cost review of solutions and associated equipment have been specifically excluded from this project. The objectives were pursued by reviewing Wessex Water's list of solutions provided and chemical dosing standard against comparable UK water companies processes, standards and known issues surrounding the operation and control of chemical dosing systems.

We have reviewed the approach that Wessex Water have adopted to determining the treatment process and scope of works for the programme of P removal at PR19. We consider that their treatment process selection flowchart is appropriate and that the processes selected for the various phosphorus permit limits are in line with industry standards. Given the large number of schemes to be scoped and costed, the approach that Wessex Water have adopted is an effective way of estimating the scope of a large programme of work.

We consider that the treatment processes selected have a high certainty of achieving the required phosphorus limits, in order to achieve the required environmental improvements in the receiving rivers.

We note that in some cases Wessex Water have the decided to adopt a lower cost approach than that determined solely by following the process selection flow chart. Examples of where costs could have higher include: Cerne Abbas STW, Shepton Mallet STW.

We have also identified areas where there are risks to Wessex Water that costs could increase. These include:-

- A potential need to add alkalinity dosing at STWs with stringent nitrification standards
- A requirement to improve sludge removal processes due to increases in quantity and changes in the characteristics of more chemical sludges.
- A high demand for tertiary treatment plant across the UK water industry affecting lead in times, supply availability and potentially increasing unit costs

Further details of our key observations are listed in section 5.

1. Introduction

There are 64 Wessex Water (WW) sewage treatment works (STWs) that will have tighter P consent imposed in the next AMP. Out of these 64, 14 works will be subject to a reduction of their current P consent.

Wessex Water have requested Atkins to review their current phosphorus removal schemes contained within their AMP7 business plan. This review compares the currently proposed works and solutions with the approach used by the wider water industry, with the review highlighting areas where alternative technologies/approaches may be suitable for implementation along with areas of potential challenge and mitigation of risk.

Where chemical dosing is already in place to achieve the current P consent, the existing dosing control method, chemical storage and dosing system reliability have not been assessed within this review.

2. Option selection

Wessex Water has adopted the following process selection flowchart for implementation within the AMP7 business plan submission for all works subject to new or tighter phosphorous consent under the WINEP (3) scheme.

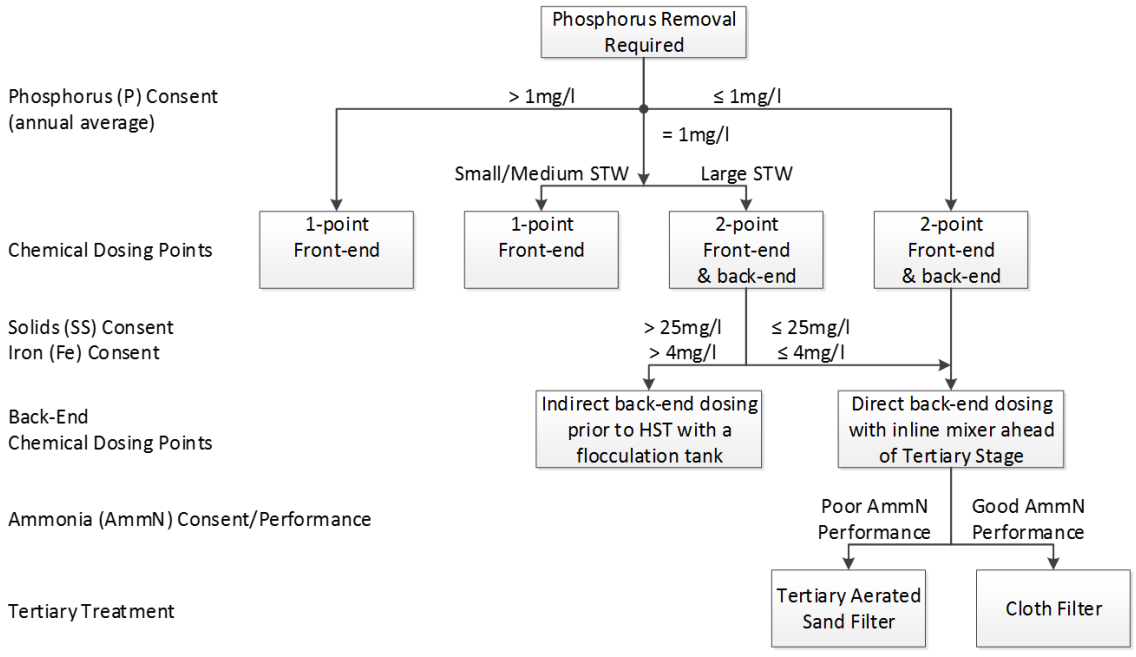

Table 2.1 Wessex Water PR19 Phosphorus Removal Process Selection Flowchart

2.1. Sites with Phosphorous upper permitted limit >1 mg/l

Under WINEP (3) scheme, twenty No. Wessex Water STWs will receive a new phosphorous (P) upper permitted limit above 1 mg/l. The individual site limits vary between 1.1 mg/l and 4mg/l. For these higher P consents, single point front-end dosing is the widely used P removal method in the waste water industry.

2.2. Sites with Phosphorous upper permitted limit = 1 mg/l

According to the Wessex Water design standard for P removal, where the site serves a population equivalent (PE) greater than 40,000 the recommended method of P removal is dual-point dosing. However, in the proposed solution for Holdenhurst (PE - 184,264) and Shepton Mallet (PE- 50,362) STWs the proposed method of P removal is single-point dosing.

Holdenhurst STW : Single point dosing has been selected here for the potential 1.0 mg/L UWWTD standard. WW stated that this is due to the fact that the STW is an activated sludge treatment process with high MLSS loadings on the FSTs. The alternative option of installing secondary dosing would require the provision of additional final settlement tank capacity to accommodate the associated increase in solids loading.

Shepton Mallet STW : At this STW WW already have single point dosing installed to meet the existing 2.0mg/L standard. WW. The STW has a high trade load and the resident population is only 11,020 pe, with associated relatively low average flows. WW stated that their experience of operating the existing dosing plant has demonstrated that a 1.0mg/L P standard can be reliably and efficiently achieved using the existing plant.

Although P upper permitted limit of 1 mg/l can be achieved with single point dosing, there is risk of overdosing chemicals if adequate mixing and flocculation is not provided. Mixing is extremely important in the application of chemicals to crude sewage. If rapid mixing is not achieved then up to three times more chemical may be required to achieve optimal cost-effective phosphorus removal. Ferric salts hydrolyse to insoluble ferric hydroxide precipitants within 1-2 seconds. Ferric hydroxide will still react with the phosphate but over the course of hours rather than seconds. The use of multi-point dosing improves the efficiency of the mixing. Some water companies adopt dual point dosing, taking the view that achieving >90% P-removal in a single stage is uneconomic. It is also found that some water companies standards specify dual-point dosing for filter works to achieve <=1.5 mg/l P upper permitted limit.

2.3. Sites with Phosphorous upper permitted limit between 1 mg/l and 0.5 mg/l

To achieve low P upper permitted limits (between 1 and 0.5 mg/l), dual-point dosing is widely used within the wastewater industry. There are 22 No. Wessex Water sites that will receive low P (0.5 – 1 mg/l) upper permitted limit in AMP7. The industry norm is to provide inline mixing with flocculation and tertiary treatment for achieving low P upper permitted limits. The proposed solution for Cerne Abbas STW is 2-point dosing only, with no tertiary treatment, even though its P upper permitted limit is 0.8 mg/l. According to the Wessex Water option selection flow chart, recommended solution would be dual– point dosing with cloth filters as tertiary treatment.

2.4. Sites with Phosphorous upper permitted limit <= 0.5 mg/l

There are 7 No. of Wessex Water sites that will receive an ultra-low P upper permitted limit (<=0.5mg/l). The industry norm to achieve P removal to this level is via 2-point dosing, inline mixing, flocculation at the secondary dosing point and tertiary treatment. To achieve this tighter P upper permitted limit without overdosing or breaching residual iron or aluminium upper permitted limit other water companies have successfully trialled feed forward real-time dosing control systems. Applying the dose immediately prior to tertiary treatment, this has the effect of mitigating against upstream alkalinity deficiency which is an unavoidable side-effect caused by increased dosing ahead of the main biological processes, potentially inhibiting nitrification.

3. Chemical Dosing

The review of other UK water companies' practices on chemical precipitation of phosphorous found that:

- Ferric sulphate is the most commonly used coagulant. Other chemicals that are widely used are ferric chloride and aluminium sulphate
- Different companies adopt different equations/design, metal: P molar ratio figures for establishing design doses.
- Pre-precipitation (to PST influent) is the most common dosing configuration with mixing being achieved by dosing into the top of standing wave downstream of a flow measurement flume. If such conditions are not available, providing additional mixing facilities to achieve mixing within 1-2 seconds should be considered in the design to achieve efficient mixing.
- For RBC sites chemical is dosed directly into the first biozone of the RBC, as the disc rotation provides adequate mixing.
- Where 2-point dosing is required on trickling filter works, most common configuration is dosing upstream of primary settlement and into the influent to the distribution system of the humus settlement tanks. Mixing and flocculation prior to humus tanks are provided to achieve sufficient mixing and dispersion. For works with ultra-low P upper permitted limits, mixing and tertiary treatment requirement are considered to achieve enhanced solids removal, as filter works can release metal ions during variable flow/weather conditions and seasonal periods such as sloughing.
- Where 2-point dosing is required on ASP works, the most common configurations are dosing upstream of primary settlement and to the head of the ASP or alternatively dosing prior to primary settlement and immediately upstream of the final settlement tanks. Where dosing into final settlement tanks is carried out, mixing, flocculation and tertiary treatment are generally provided.
- The requirement for tertiary treatment by most water companies is established based on the P upper permitted limit in force and effluent metal upper permitted limit. Wessex Water's standard approach is to trigger the introduction of tertiary filtration in cases where secondary precipitation is employed and/or where Total Iron upper permitted limits are ≤4mg/l and suspended solid content is <=25 mg/l.

3.1. Dosing Control

The success of the phosphorous removal process through chemical precipitation is heavily reliant on the use of appropriate instrumentation and control. An automatically controlled chemical dosing system is usually provided to meter the output of the dosing pumps. The dosing systems are usually capable of operating under a selection of different automatic dosing methods. Water companies operate their chemical dosing systems under different control regimes. Preferences vary and are commonly site specific. These include:

- Flow proportional
- Pre-programmed diurnal profile
- Fixed rate (mostly used for very small wastewater sites)
- In response to a 4-20mA analogue signal from an external phosphorus monitor, either feedback or feed forward control.

Wessex Water standards state that site with a PE up to 2000, preferred dosing control method is to provide a fixed dose and to provide sites with a PE of over 2000 to have flow proportional dose control applied. For smaller sites a fixed dose control philosophy is often used, as the residual iron or aluminium upper permitted limits at these sites are less stringent. However, for larger sites fitted with flow proportional dosing there is significant risk of overdosing of coagulation chemical, during periods of high flow with a low biological contaminant concentration in the inlet. It may be necessary

to cap the overall dose rate to prevent this occurring when the site is subject at storm flow conditions. Reviewing other water companies' practices on dosing control found that:

- For larger sites with variable inlet P loads, other water companies use measured P load proportional dosing, using automatic online P monitors and feed forward dose control systems, instead of flow proportional dosing.
- For smaller to medium size sites with variable inlet P loads, an alternative approach is to dose based on a predictive diurnal P load profile to avoid overdosing. This approach requires a period of continuous online crude sewage sampling during dry weather condition (period of sampling can vary) to derive a reliable P load profile. This profile should also be checked/revisited periodically to ensure conditions have not changed significantly. The costs of this regular validation and adjustment sampling should be included within the business plan submission.

3.2. Chemical Storage

A comparison of various water company standards shows that the minimum chemical storage volume requirement varies considerably;

- For smaller sites storage ranges from of 45 - 60 days minimum storage assessed at the average dose rate
- For larger sites this is reduced to a minimum of 10 – 14 days, again calculated at the average dose rate

When deciding the storage volume, factors such as access to the site, delivery cost bands, capacity and frequency of tanker delivery should be taken into consideration. Particularly at small sites the philosophy of a tank sized based on the minimum tanker capacity or the ability to perform a 'milk round' approach to delivery with a larger vehicle will form part of this assessment.

3.3. Additional Sludge Volume

Sludge production can increase significantly due to precipitation of ferric phosphate, ferric hydroxide and increased solid and BOD settlement due to the effect of adding multivalent metal ions to the main process flow. A comparison of other water company standards shows that the "factor" use to calculate amount of chemical sludge production varies. As the type of chemical that Wessex Water selected for each site is not known, the potential additional sludge volumes or implication on storage and handling is not assessed at this stage.

4. Risks

4.1. Chemical Selection and Dose Control

Wessex Water hasn't provided detail information on the type of chemical proposed for each site for P removal. Both ferric chloride and ferric sulphate are options for the precipitation of phosphate in activated sludge and trickling filter applications. In the water industry ferric sulphate is the preferred chemical option because it has a slightly higher pH, thereby reducing material corrosion and H&S risk.

Aluminium chloride or aluminium sulphate is used if there are problems associated with iron salts such as the potential formation of colloidal iron or the possibility of iron affecting downstream processes such as dosing for filamentous control or staining UV system components. If aluminium

based chemical is selected for P removal, there is risk of breaching tighter aluminium upper permitted limits imposed due to overdosing.

Due to the application of a nationwide low P upper permitted limit strategy in the AMP7 funding period and the industry preference for ferric sulphate, there may be high demand, which could lead to higher unit supply costs as a result. Therefore, there may be benefits from designing the chemical storage and dosing system to allow use of the alternative chemicals to maintain operational flexibility. In addition to the cost and availability of chemicals, the impact on alkalinity and need for alkalinity correction should also be taken into consideration.

For ultra-low P upper permitted limits, jar tests would establish the metal: P molar ratio to fine-tune chemical dosing. As a basis for sizing flocculation tanks, Wessex Water uses a 15min retention time calculated at flow to full treatment (FTFT) including return liquors. Alternative approaches have taken by other water companies sizing flocculation volumes with the addition of upstream inline mixers, flocculation tank retention time can vary within the range of 5 - 15 mins at FTFT.

4.2. Sludge Handling

As discussed, above dosing metal salts for the removal of phosphorous from wastewater results in a significant increase in the quantities of sludge produced. It is important to take into account of the impact of this on the design of new biosolids processing facilities or on the retrofitting of existing ones, as not only the quantity but also the characteristics of the solids removed are substantially modified.

Pre- precipitation dosing can increase total primary sludge production by 25-50%, therefore, there may be benefits in fitting auto desludging systems to any downstream settlement tanks. If the existing de-sludge pumps are assessed as suitable it may still be necessary to adjust the de-sludge timer settings to regularly remove additional sludge from the process stream.

To summarise, with addition of chemical coagulants for P removal, the suitability of existing de-sludge pumps to handle chemical dosed sludge, onsite sludge storage and sludge handling capacity typically need to be assessed. Further to this, because of alterations to sludge composition and quantity additional sludge transfer, the capacity to handle additional sludge at sludge receiving sites may also need to be considered along with the sludge handling strategy.

4.3. Selection of Tertiary Filtration

For sites with ultra-low P upper permitted limits, Wessex Water's preferred tertiary treatment technologies are automatic cloth filter units or nitrifying sand filters, depending on each respective site's AmmN upper permitted limit. As cloth filters are becoming the most popular tertiary treatment option for P removal schemes within the UK water industry it is anticipated that there will be high demand for these systems affecting supply availability and lead times.

4.4. Alkalinity

With chemical addition to primary settlement, residual influent alkalinity can be reduced significantly which can result in nitrification impairment due to low pH. If total nitrogen removal is required, it can reduce BOD load from primary settlement to levels which could compromise denitrification, requiring larger quantities of an exogenous carbon source. Therefore crude sewage sampling may be needed, particularly for sites where liquors from digested sludge processing are returned to head of the works for treatment.

If pH or alkalinity is found be a problem for any of the sites, corrective measures such as addition of alkalinity (lime /sodium hydroxide) downstream of point of metal ion dosing will be required. It is suggest that a cost is included within the AMP7 business plan to cover for additional sampling to determine the presence of this potential issue. It is also suggested that alkalinity dosing is included as a cost, as a risk based methodology, and applied within the AMP 7 business plan.

5. Summary observations

- For works with ultra-low P upper permitted limits (<=0.5 mg/l), other water companies adopt online P monitoring and feed forward dosing control as flow proportional dosing can result in chemical overdosing and resultant metal upper permitted limit failures.
- For smaller to medium size sites with variable inlet P loads, an alternative approach is to dose based on the site specific predictive diurnal P load profile to avoid chemical overdosing
- If flow proportional dosing is selected, consider limiting dose to mitigate against overdosing during storm conditions.
- Consider the risk of additional validation and optimisation sampling and whether appropriate costs have been allowed for this within the AMP7 business plan,
- Alkalinity dosing needs to be considered on a site-by-site and programme level, if it hasn't been already, and incorporated into the AMP7 business plan.
- Wessex Water standards for chemical storage requires a minimum of 14 days storage, however, other water companies consider larger volumes for smaller sites to avoid multiple smaller deliveries, e.g. minimum storage tank size is limited to the smallest bulk chemical delivery. There may be longer lead time for smaller deliveries and the potential to put a 'milk round' delivery approach should be investigated.
- Consider the potential lead time for new tertiary treatment process units and its effect on the delivery programme
- Consider the benefits of providing chemical storage and dosing system that to allow use of the alternative chemicals to maintain operational flexibility as this is the industry practice.
- Additional sludge production, auto desludging, sludge storage, handling and removal should be assessed. It is unknow whether Wessex Water has already derived its regional sludge strategy approach with this additional sludge production due to chemical dosing.
- For works with UV treatment, Iron can interfere with the UV treatment which may affect the chemicals selected for dosing.
- Carry out jar tests to fine tune chemical dosing particularly for ultra-low P upper permitted limit works.

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