SRO - LWR Project

J698-AA-C01X-TEDD-TN-ZD-100000
Pilot Plant Testing Technical Note

Revision: C02
Status: A - Authorised and Accepted

Date: June 2026

Revision Control

Revision	Status Code	Description of Change	Originator	Checked	Reviewed	Approved	Date (DD/MM/YYYY)
C01	A1	Authorised & Accepted	FM	CM	JL	MRR	12/05/2026
C02	A1	Formatting Change Only	FM	CM	JL	MRR	23/06/2026

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1 Introduction

1.1 Purpose of the Technical Note

1.1.1 This technical note summarises the completion of the Teddington DRA pilot plant trials.

1.2 Basis of Design

1.2.1 The basis of design (BoD) for the proposed Tertiary Treatment Plant (TTP) (Table 1.1 Mogden Final Effluent Quality and assumed TTP Effluent Target parameters.) is based on the Mogden Sewage Treatment Works (STW) final effluent quality data collected over the last 20 years.

1.2.2 The scope for the TTP was initially developed using an indicative similar environmental permit in the same freshwater reach of the River Thames, namely Hogsmill STW. This approach was considered conservative as it was a more modern permit (2021) but also had more stringent permit conditions than Mogden STW. Mogden STW also discharges into the estuarine Thames Tideway whereas Teddington DRA will discharge into the lowermost freshwater reach of the River Thames.

Table 1.1 Mogden Final Effluent Quality and assumed TTP Effluent Target parameters.

Parameter	Unit	Mogden STW Final Effluent (95%ile of data 2004 - 2020)	TTP Effluent Target values (Assumed)
BOD	mg/l	12.2	7 (95%ile)
Phosphorus	mg/l	5.4	1 (annual average)
Ammonia. NH_3	mg/l	1.7	1 (95%ile)
Suspended Solids	mg/l	36.0	25 (95%ile)
pH	pH Unit	7.6	6.5-9.5
Iron	Ug/l		3500 (95%ile)
Alkalinity (as $CaCO_3$)	mg/l	230.4	N/A

Discharge Permit

1.2.3 The discharge permit for the Teddington DRA has not yet been granted. Permit pre-application documentation including an initial surface water risk assessment was submitted to the Environment Agency in December 2025 and the project is now awaiting formal Environment Agency feedback to inform the ongoing design. Informal discussions and feedback sessions have been held the Environment Agency as part of developing the pre-application documentation. Our water quality dataset was also shared with the Environment Agency.

Additional Risk Chemicals for Treatment

1.2.4 A list of 19 chemicals was identified from the pre-application screening as potentially require further discussion around environmental risk. This may conclude that they require permit conditions to manage the environmental risk that then need additional treatment. This list has been shown in Table 2.1 Additional Risk chemicals identified from NAU screening at Gate 3 – Chemical permittability risk (all chemicals with EQS – see EA guidance LIT131342), using Thames Water pan-SRO monitoring. This screening was conducted using the Environment Agency's H1 tool which is based on the "Surface Water Risk Assessment for Your Environmental Permit" guidance1. The dataset used spans more than three years and greatly exceeds the Environment Agency's 12 ('minimum') or 36 ('preferred') sample requirements.

1.2.5 The list comprises natural and synthetic hydrocarbons, heavy metals, and some pesticides. Most of the chemicals are either insoluble or have low solubility in water. Based on UK water industry experience and the chemistry of these chemicals, they may undergo some treatment across the TTP following ferric coagulant dosing, though this is not the primary purpose of the baseline treatment process. Understanding the removal efficiency of these chemical substances in the baseline treatment process formed a key part of the pilot testing.

Table 2.1 Additional Risk chemicals identified from NAU screening at Gate 3 – Chemical permittability risk (all chemicals with EQS – see EA guidance LIT131342), using Thames Water pan-SRO monitoring

Determined		Annual Average EQS (µg/l)	Maximum allowable concentration EQS (µg/l)
1	Benzo(b)fluoranthene	0.00017*	0.017
2	Benzo(g,h,i)perylene	0.00017*	0.0082
3	Benzo(k)fluoranthene	0.00017*	0.017
4	Bromine - total residual oxidant	2	5
5	Chloride	250000	n/a
6	Chlorine	2 (total residual oxidant)	5 (95%ile)
7	Cypermethrin	0.00008	0.0006

[1] https://www.gov.uk/guidance/surface-water-pollution-risk-assessment-for-your-environmental-permit

Determined		Annual Average EQS (µg/l)	Maximum allowable concentration EQS (µg/l)
8	(Ethylenediaminetetraacetic acid) EDTA	400	4000
9	Fluoranthene	0.0063	0.12
10	Hexabromocyclododecane (HBCDD)	0.0016	0.5
11	Mancozeb	2	20
12	Mercury and its compounds	n/a	0.07
13	Nonylphenol (4-nonylphenol)	0.3	2
14	Polyfluorooctyl sulfonate (PFOS) and its derivatives	0.00065	36
15	Permethrin	0.001	0.01 (95%ile)
16	Total Anions	250000	n/a
17	Tributyltin compounds (tributyltin-cation)	0.0002	0.0015
18	Hydrogen Sulphide	0.25	1
19	Zinc	10.9 (bioavailable)	n/a
From Polyaromatic Hydrocarbons (PAH) category			

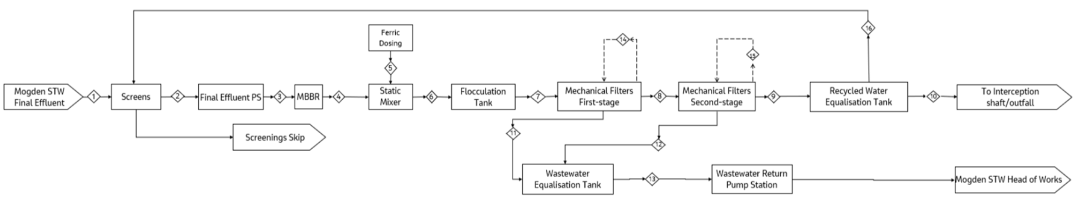
NB: These chemicals were determined from screening conducted using the EA's H1 tool which is based on the "Surface Water Risk Assessment for Your Environmental Permit" guidance

2 TDRA Tertiary Treatment Plant

2.1 Tertiary Treatment Process

2.1.1 The Teddington DRA scheme is intended to treat the final effluent from the Mogden STW (permitted to discharge to the estuarine Thames Tideway) using a TTP before discharging into the freshwater River Thames upstream of Teddington Weir. The baseline tertiary treatment process consists of a combination of ferric dosing, biological process (Moving Bed Biofilm Reactor (MBBR)) and mechanical filtration.

Figure 1 Tertiary Treatment Plant PFD (Baseline Process)



Ferric Dosing

2.1.2 Ferric dosing is widely used in the UK water industry for phosphorus removal. Soluble reactive phosphorus (orthophosphate) reacts with ferric iron to form insoluble ferric phosphate. Other contaminants, such as heavy metals, also react with ferric, forming complex metal hydroxide precipitates that contribute to the overall chemical sludge produced. Some of the insoluble compounds in the feed water are bound within the precipitated solids and are removed along with the sludge.

2.1.3 Chemical dosing can be applied as pre-precipitation (primary treatment), simultaneous precipitation (secondary treatment), and as part of tertiary treatment (post precipitation). Ferric dosing for the TTP can be carried out upstream of the MBBR or upstream of Mechanical Filter or both. Ferric dosing is considered as ‘business as usual’ within Thames Water and is used to achieve phosphorus consents.

MBBR

2.1.4 Design developments through 2024 resulted in the change of nitrifying technology from Nitrifying Sand Filter (NSF) to a Moving Bed Biofilm Reactor (MBBR). The MBBR is a biological wastewater treatment process that uses suspended biofilm carriers to provide a large, protected surface area for microbial growth. The carriers move freely within an aerated or mixed reactor, allowing biofilm to develop and break down organic pollutants, and nitrogen compounds. The MBBR is used extensively for secondary treatment on wastewater plants and the MBBR process has also shown better performance and resilience compared to the NSF when used for tertiary nitrification.

2.1.5 The biological process poses the biggest risk to the TTP due to the inherent instability of the nitrification process when operating at low ammonia concentrations. The MBBR is a technology that has demonstrated the ability to sustain nitrification under low ammonia conditions but required pilot testing to build confidence in its performance under site specific operating conditions.

Mechanical Filter

2.1.6 Mechanical Filters are widely applied for tertiary solids removal to achieve low suspended solids in the final effluent. Where this is combined with upstream chemical dosing, mechanical filters have been successful in achieving low total suspended solids (TSS), biological oxygen demand (BOD), and low total phosphorus (TP) consents in the final effluent. Mechanical filters offer a compact and efficient tertiary treatment for the removal of TSS, TP, and some micro-pollutant priority hazardous substances (UKWIR,2018). They have low power consumption, and they are one of the preferred options in most tertiary treatment applications. Mechanical filtration technology has been successfully applied for the treatment of effluents from various process streams, including activated sludge and fixed film processes. Thames Water uses mechanical filters on several wastewater treatment works across the region, and the technology is included in the Thames Water Asset Standards.

2.2 Potential Future Mitigation for Additional Chemicals

2.2.1 As described above, the H1 surface water risk assessment work identified 19 different chemicals which require further discussion in terms of environmental risk (Table 2.1 Additional Risk chemicals identified from NAU screening at Gate 3 – Chemical permittability risk (all chemicals with EQS – see EA guidance LIT131342), using Thames Water pan-SRO monitoring). Some may well be included in a future discharge permit and thus an extended treatment process was considered in addition to the baseline process to begin to understand the technology available for additional effluent polishing. The extended process was included in the pilot for testing feasibility of further treatment (for chemicals in Table 2.1 Additional Risk chemicals identified from NAU screening at Gate 3 – Chemical permittability risk (all chemicals with EQS – see EA guidance LIT131342), using Thames Water pan-SRO monitoring) rather than required for baseline design and assumed permit parameters.

2.2.2 The extended process considered was a carbon based treatment comprising Ozone /Hydrogen Peroxide/ Biological Activated Carbon (BAC) and Granular Activated Carbon (GAC). This has demonstrated to be effective globally. The activated carbon-based treatment approach is also well established within the UK drinking water sector, however there is limited references for treating wastewater or final effluent.

3 Pilot Plant

3.1 Objectives

3.1.1 The key objectives of the pilot plant were to:

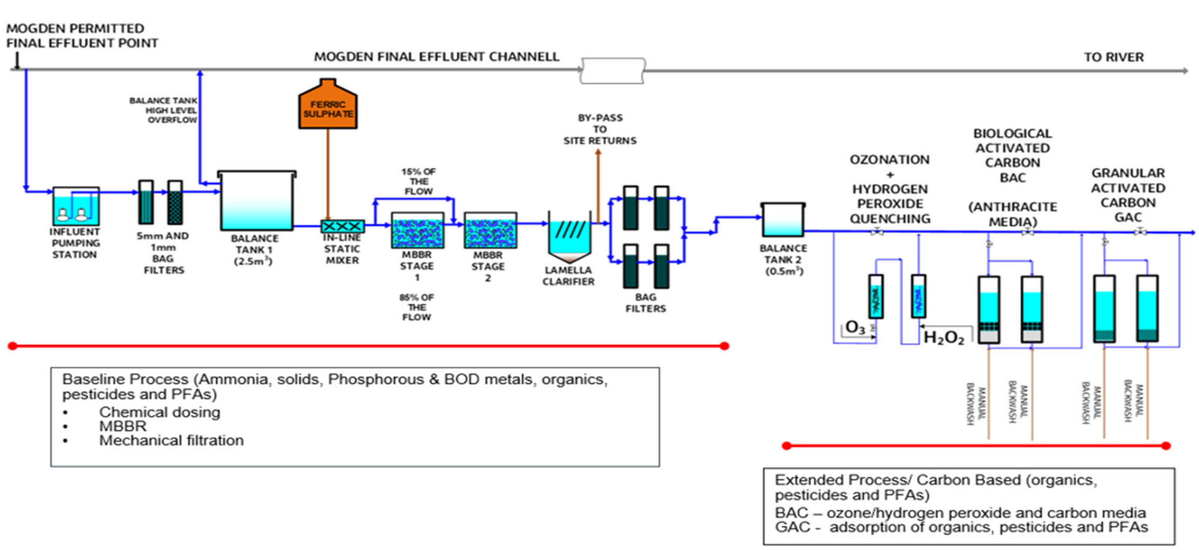
- Test the efficacy of the baseline treatment processes
- Provide performance data to inform the TTP design
- Provide supporting information for permitting and discussions underpinning Best Available Technology (BAT) limits

3.2 Pilot plant set up

3.2.1 The pilot plant configuration was developed around two distinct treatment processes: the baseline process and the extended process (Carbon-Based), as illustrated in Figure 2 Pilot Plant configuration showing Baseline and Extended Processes below. Lamellas and bag filters were used as a suitable scalable process for the pilot plant to achieve a similar representative level of solids removal as the Pile Cloth Filter. A scalable, representative Pile Cloth Filter required a bespoke, purpose-built- unit to match the capacity/flow of the MBBR pilot plant. The suppliers of Pile Cloth Filter did not have units within their standard product ranges that were suitably sized for the MBBR pilot plant flow rates at the time of pilot development. A purpose-built Pile Cloth Filter unit would have required fabrication and long procurement lead times, resulting in significant delays to the pilot plant programme.

3.2.2 The pilot plant was commissioned at the beginning of September 2024 and sampling started two weeks after commissioning. The pilot plant was then run under three sprint events (as set out section below) until decommissioning in December 2025. During the sprint events, intensive sampling was carried daily with a target of at least 36 samples analysed.

Figure 2 Pilot Plant configuration showing Baseline and Extended Processes



3.3 Stage 1: Baseline Process

3.3.1 The baseline process represents the core treatment train within the TTP, designed to achieve the higher water quality standard required to mitigate sanitary and nutrient permittability risk for discharge to the freshwater reach of the River Thames. Pilot testing was undertaken to evaluate the performance and efficacy of the proposed treatment processes.

3.3.2 The baseline process comprises the following stages:

- Chemical dosing for phosphorus removal
- Moving Bed Biofilm Reactor (MBBR) for tertiary nitrification
- Mechanical filtration for solids and residual phosphorus removal.
- In addition to the removal of sanitary nutrients and solids reduction, the baseline process is also designed to facilitate the reduction of certain heavy metals through chemical precipitation followed by solids separation.

3.4 Stage 2: Extended Process

3.4.1 The extended processes (included in Figure 2 Pilot Plant configuration showing Baseline and Extended Processes) above, represent the additional treatment technologies that may be applicable for treating additional future substances e.g. those listed in Table 2.1 Additional Risk chemicals identified from NAU screening at Gate 3 – Chemical permittability risk (all chemicals with EQS – see EA guidance LIT131342), using Thames Water pan-SRO monitoring), identified through environmental screening (following EA guidance LIT1313) as ‘chemicals with a permittability risk’. Although incorporated within the pilot plant, the primary objective of the extended processes was to assess the feasibility of these technologies for treating the identified substances.

3.4.2 The extended process consisted of a BAC stage followed by GAC. The BAC process incorporates pre-oxidation using ozone and hydrogen peroxide to transform recalcitrant or refractory organic compounds into more biodegradable forms, enabling effective removal by the BAC biofilm. The combined BAC/GAC system is designed to target pesticides, micropollutants, and selected pharmaceutical compounds. The activated carbon-based treatment approach is also well established within the UK drinking water sector, however there is limited references for treating wastewater or final effluent.

3.4.3 There remains limited operational experience regarding their deployment in wasterwater or tertiary effluent treatment. The pilot programme therefore provided an evidence base to understand their applicability, and integration potential within the TTP.

3.4.4 Pilot testing of the extended process was undertaken to determine the feasibility and applicability of BAC/GAC technology for final effluent polishing in a wastewater reuse context.

3.5 Testing Regimes

3.5.1 The pilot plant was operated under two intensive testing, sampling, and monitoring campaigns, Sprint 1 and Sprint 2. A shorter, targeted Final Sprint was subsequently undertaken to evaluate the performance of a Pile Cloth Filter.

3.5.2 Samples were collected across the baseline processes (inlet and post-filtration) and the extended process (post-BAC and post-GAC). All samples were analysed for up to 100 parameters previously agreed with the Environment Agency. The analytical suite comprised general water quality and sanitary determinands, heavy metals, hydrocarbons, selected priority substances, and nitrosamines. Samples were analysed by RPS laboratory with a duplicate set of samples (sanitary nutrients) being analysed by Element labs as well for pilot plant monitoring. The Element samples were mainly used for routine plant monitoring and adjustments.

Sprint 1

3.5.3 Sprint 1 was conducted from 23 September 2024 to 28 October 2024 and generated a total of 36 monitoring samples.

Sprint 2

3.5.4 Sprint 2, which was run from 22 July 2025 to 26 September 2025, was commissioned to coincide with the period during which the TDRA project is most likely to be called into use. This sprint was intended to assess process performance under representative seasonal conditions, like water quality and operational temperatures.

Final Sprint: Pile Cloth Filter Trial

3.5.5 The final sprint consisted of a three week trial (14 November 2025 to 8 December 2025) to evaluate the performance of a Pile Cloth filter for tertiary solids removal. The objective was to gain additional insight into solids capture efficiency and operational considerations relevant to full scale application.

3.5.6 In between the different sprints, some process optimisation was undertaken in response to analysis of performance such as changing the dosing location and introducing an organic coagulant to optimise lamella performance.

4 Pilot Plant Results

4.1 Sanitary Parameters

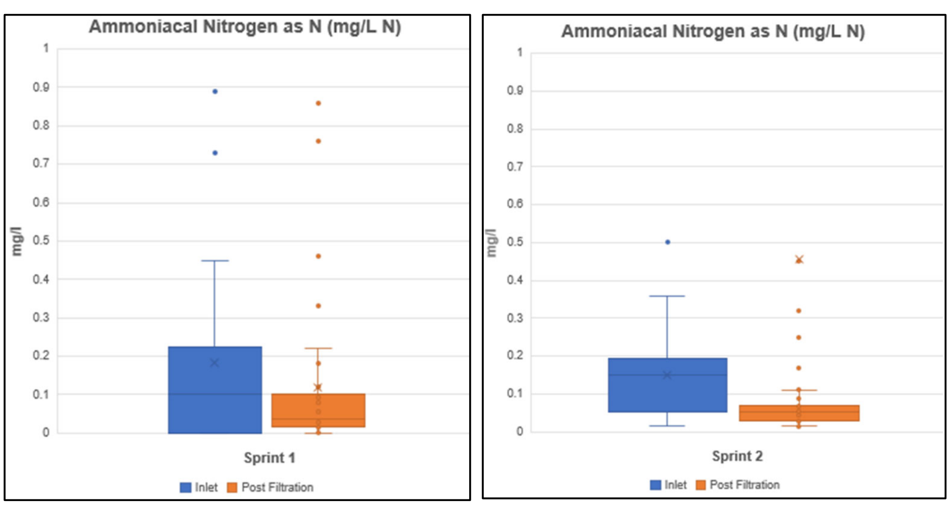
4.1.1 Although total phosphorus was identified as the only sanitary determined with the potential to cause water quality issues in the River Thames, the pilot plant treatment was nevertheless trialed for all the key sanitary nutrients, including ammoniacal nitrogen, Biochemical Oxygen Demand (BOD), suspended solids and total phosphorus. This section provides a summary of the pilot plant performance with regards to these parameters.

4.1.2 The technically achievable limit for ammoniacal nitrogen in wastewater treatment varies by technology and operating conditions but is commonly around 1 mg/l. Nitrification is sensitive to several environmental factors, including temperature, pH, alkalinity, and the influent ammonia concentration. At low ammonia concentrations, nitrification rate declines exponentially and at < 1mg/l tertiary nitrification processes become unstable or fail. When ammonia concentration in the feed increases, the process may take several weeks or months for the nitrifying biomass to recover during which time the process is not achieving the required treatment target. This presents a significant challenge for tertiary systems operating at predominantly low ammonia in the feed water such as Mogden final effluent. Due to the low influent ammonia levels we trialed MBBR as being the most likely process to be stable at lower levels.

Ammoniacal Nitrogen

4.1.3 During both Sprint events the 95th percentile ammonia concentration in the pilot plant feedwater was 0.7 mg/l (NH_3 N). Despite this, the MBBR successfully achieved ammonia removal throughout the sprint, with an 95th percentile reduction of 54%. The results for both Sprints demonstrated a consistent nitrification performance, with ammonia concentrations reduced to <0.5 mg/l (95th percentile) and shown in Figure 3 Ammoniacal Nitrogen results for Sprints 1& 2.

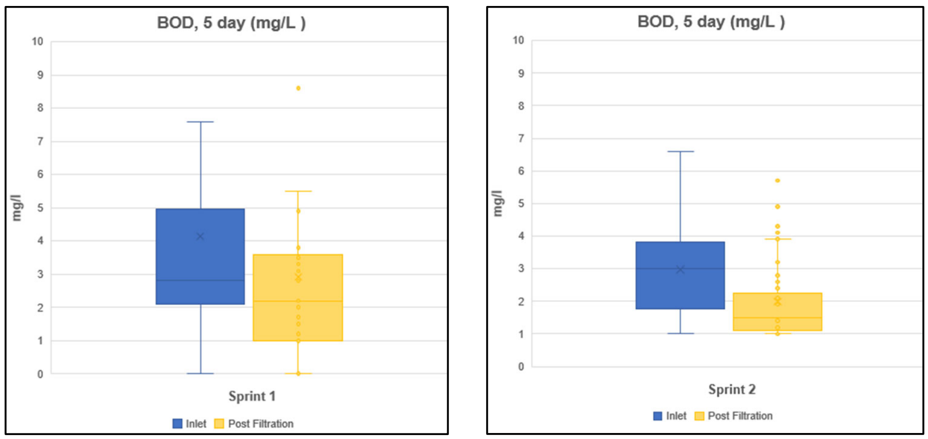
Figure 3 Ammoniacal Nitrogen results for Sprints 1& 2



Biological Oxygen Demand (BoD)

4.1.4 For both Sprint 1 and Sprint 2, the pilot plant achieved robust BOD removal driven by both the MBBR and through tertiary solids removal. An average of < 4mg/l BOD was achieved Figure 4 BOD results for Sprints 1&2.

Figure 4 BOD results for Sprints 1&2



Total Suspended Solids (TSS) and Total Phosphorus

4.1.5 For Sprint 1, the 95th percentile TSS concentration increased to 91.2 mg/l due to the formation of chemically precipitated solids. After tertiary removal of solids concentrations reduced to 56 mg/l, representing a 61% removal. Although this level of solids removal is significant, the treated water did not meet the expected suspended solids standards. Most of the solids present were inorganic colloidal precipitates produced from ferric dosing.

4.1.6 The average total phosphorus concentration in the pilot plant feed water was 3.5 mg/l, which reduced to 1.9 mg/l after tertiary solids removal (TSR), corresponding to a 45% removal. Total phosphorus removal performance was strongly correlated with suspended solids removal, and therefore suboptimal solids capture adversely affected total phosphorus reduction.

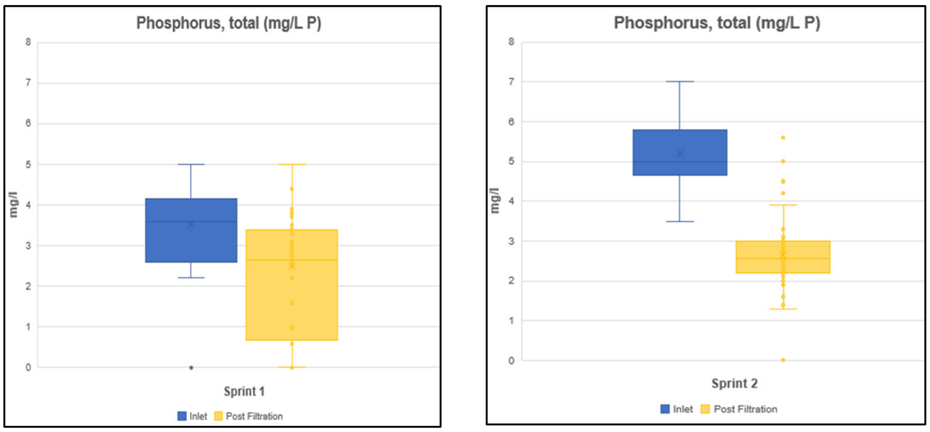
4.1.7 The lower than expected removal for both suspended solids and total phosphorus was attributed to inadequate optimisation of the coagulation and flocculation stages. Specifically, the static mixer and pipe flocculator were not optimally designed to deliver the required mixing energy and flocculation conditions. This resulted in poor floc formation and poor solids capture through tertiary solids removal.

4.1.8 For Sprint 2, the 95th percentile suspended solids concentration increased to 88.2 mg/l as a result of the effects of chemical dosing. After removal the solids concentration reduced to 37.6 mg/l, representing a 57% removal. Just like in Sprint 1, solids removal was significant; however, it was insufficient to meet the suspended solids concentration target.

4.1.9 The average total phosphorus concentration in the feed water was 4.6 mg/l, which reduced to 2.6 mg/l after TSR, representing a 44% removal efficiency. Total phosphorus removal performance was strongly linked to suspended solids capture, and therefore the suboptimal solids removal negatively affected total phosphorus removal Figure 5 Total phosphorus results for Sprints 1& 2.

4.1.10 Despite challenges in achieving the target reductions for TSS, phosphorus, and iron at the pilot plant, the UK water industry has extensive empirical full scale performance data demonstrating that mechanical filtration with upstream ferric dosing and flocculation can reliably achieve the levels we sought to attain.

Figure 5 Total phosphorus results for Sprints 1& 2



4.2 Results from Element Labs

4.2.1 A duplicate set of samples, mainly sanitary parameters, were analysed by Element Lab Solutions ('Element'). This analysis was used for close monitoring of the operation of the pilot plant as it had a quick turnaround period. The overall summary of these results has been included in this report for completeness.

4.2.2 The Element Results confirmed the excellent performance of the MBBR achieving ammonia levels of <0.5mg/l in the treated water with the chemical dosing located either upstream or downstream of the MBBR. The results also confirm the good BOD removal as reported above.

4.2.3 The removal of total suspended solids, total phosphorus, and total iron was low, consistent with the other results, confirming that the issues observed are related to the lack of optimisation of the chemical dosing and flocculation.

4.3 Metals

4.3.1 Chemical dosing using ferric sulphate followed by tertiary solids removal is the Best Available Technique for phosphorus removal. Ferric ions react with dissolved phosphate to form insoluble iron–phosphate complexes, which are subsequently removed through TSR process. The optimum pH range for direct iron phosphate precipitation is typically pH 4 and pH6. At slightly higher pH values, phosphorus removal can still occur via adsorption onto ferric hydroxide flocs, although efficiency may decrease due to competing iron hydroxide formation.

4.3.2 Chemical dosing can also facilitate heavy metal removal. While certain metals such as Mercury and cadmium can be removed at or near circumneutral pH, effective precipitation of metals such as Zinc and nickel generally requires significantly higher pH values (typically > 9). At elevated pH, these metals form insoluble metal hydroxides, enabling their removal through solids separation. Achieving this requires dosing an alkaline reagent, such as lime or sodium hydroxide, to increase the pH to the optimal range for metal precipitation.

Zinc and Mercury

4.3.3 The Environmental Quality Standard (EQS) for Zinc is based on bioavailable dissolved Zinc, with a threshold of 10.9 µg/l. A significant increase in dissolved Zinc concentrations was observed following chemical dosing (Figure). This increase is suspected to be due to ferric contamination or potential leaching from the lamella plates made of galvanised steel. The increase in Zinc was much higher in Sprint 2 when dosing was located just upstream of the lamella (downstream of MBBR) which suggests that that ferric was attacking the lamella plates at first contact.

4.3.4 Effective Zinc removal via hydroxide precipitation requires above neutral pH (typically > 9.0). If pH is not appropriately adjusted after ferric sulphate addition, Zinc remains in soluble form and will not be removed.

4.3.5 The EQS for dissolved Mercury is 0.07 µg/L. For both Sprint 1 and Sprint 2, most influent data for dissolved Mercury concentrations were reported below the analytical detection limit (0.01 µg/l). Following chemical dosing and treatment through the TSR, dissolved Mercury concentrations in the treated water remained well below both the Annual Average EQS (AA EQS) and Maximum Allowable Concentration (MAC) thresholds Figure 7 Mercury results for Sprints 1& 2.

Figure 6 Zinc results for Sprints 1& 2

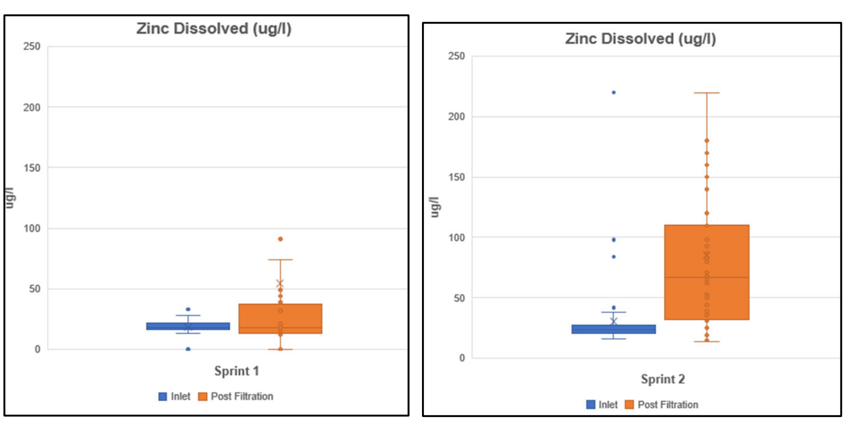
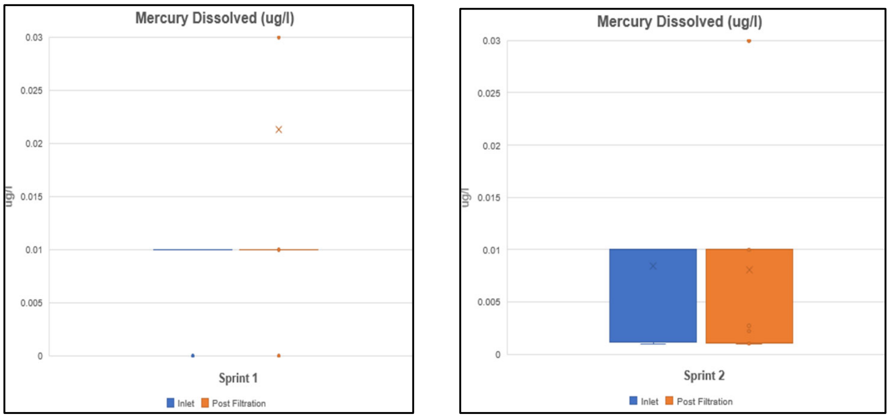


Figure 7: Mercury results for Sprints 1& 2



Residual Iron Removal

4.3.6 The iron concentration in the feedwater to the TTP is generally below the EQS for iron. However, iron is introduced into the treatment stream through the application of ferric sulphate used for chemical phosphorus removal. Although ferric dosing is considered Best Available Technique (BAT) for achieving low phosphorus concentrations, there is a regulatory and environmental need to ensure that residual iron in the treated effluent does not adversely affect the receiving environment.

4.3.7 During both Sprint 1 and Sprint 2, the average total iron concentration in the treated water exceeded 8,000 µg/L. Iron concentrations of this magnitude are expected to have a significant detrimental impact on the receiving water body. As with total phosphorus, iron removal performance reduced by the limited effectiveness of suspended solids removal. Suboptimal coagulation and flocculation resulting from inadequate optimisation of the chemical dosing regime was a major contributor to poor iron reduction. Despite challenges in achieving the target reductions for iron at the pilot plant, several full scale performance data from the UK water industry demonstrates that mechanical filtration can reliably achieve low iron levels after ferric dosing.

4.3.8 The TSR technology tested during Sprint 1 and Sprint 2 in the pilot plant was considered to not be suitable for full scale implementation at the TTP, as its solids capture performance was insufficient to reliably meet the required treated water quality standards for iron.

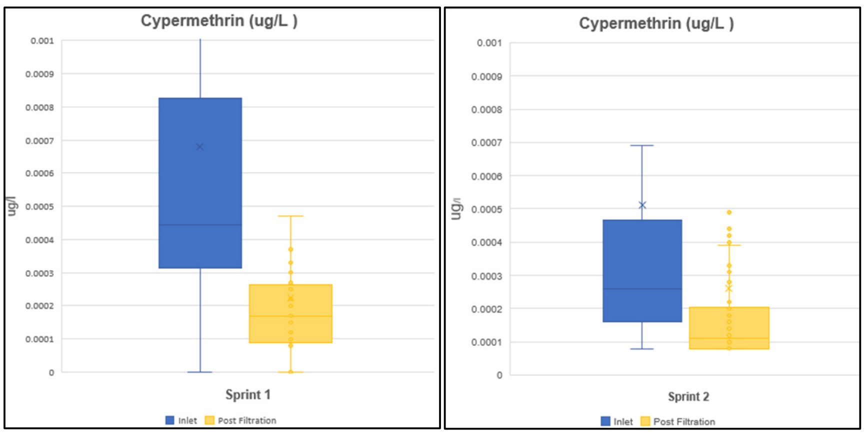
4.4 Pesticides

4.4.1 Preliminary screening assessments identified that Cypermethrin and Permethrin required further consideration in terms of environmental risks. The treatment performance of the baseline process configuration (MBBR, chemical dosing, and TSR) was therefore evaluated for both substances.

4.4.2 For Cypermethrin, a 27% reduction was observed following the TSR stage, based on the 95th percentile concentrations from both Sprint events. This level of performance is considered conservative, as several analytical results were reported as “less than” the detection limit, distorting the true removal efficiency. Despite the observed significant reductions, treated water concentrations for Cypermethrin remained above both the Annual AA EQS and MAC thresholds after the filtration stage Figure 8 Cypermethrin results for Sprints 1& 2

4.4.3 For Permethrin, the removal efficiency could not be reliably determined because most influent concentrations during Sprint 1 and Sprint 2 were reported at, or marginally above, the analytical detection limit. Nevertheless, treated water concentrations for Permethrin were consistently at or below both the AA EQS and MAC limits after the filtration stage.

Figure 8: Cypermethrin results for Sprints 1& 2

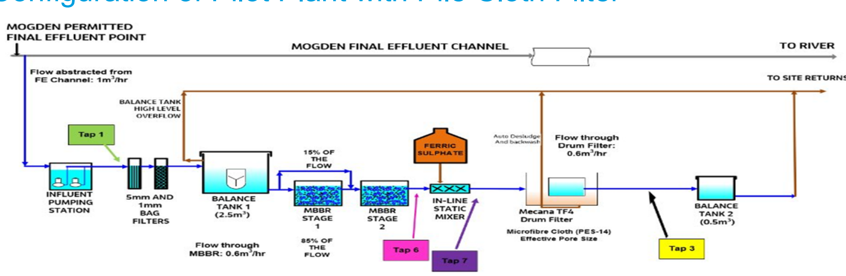


4.5 Pile Cloth Filter Trial

Pilot Plant set up with Pile Cloth Filter

4.5.1 Following the challenges experienced with the bag filters for tertiary solids removal in Sprints 1 and 2, an alternative tertiary solids removal process was trialed for a limited period in the final sprint study. A Pile Cloth Filter was hired from Mecana and installed and run for a three-week period as shown in Figure 9 Configuration of Pilot Plant with Pile Cloth Filter below. Pile Cloth filters are widely used in the UK for tertiary effluent polishing and for achieving low total phosphorus concentrations.

Figure 9: Configuration of Pilot Plant with Pile Cloth Filter



4.5.2 The Pile Cloth trial was commissioned to evaluate the technology that is proposed for the full scale TTP. However, the Pile Cloth filter unit used for the pilot plant testing was not sized to optimise the performance of the pilot plant for the flows from the MBBR, which meant that the operation could not be optimised. The Pile Cloth Filer TF4 unit is designed for a flow of > 10m^3/hr (240m^3/day). The actual flow treated was up to 14.4 m^3/day (6% of the minimum design flow). The low flow resulted in excessive hydraulic retention time, insufficient solids loading and unstable filter cake which compromised the treatment process.

4.5.3 The performance data obtained was used to infer indicative performance on suspended solids, total phosphorus and total iron removal.

Ammonia and BOD

4.5.4 The MBBR continued to show a good performance, with both ammoniacal nitrogen and BOD in the treated water reaching 0.48 mg/l and 3.8 mg/l respectively Figure 10 Ammoniacal N, BOD and Total Phosphorus

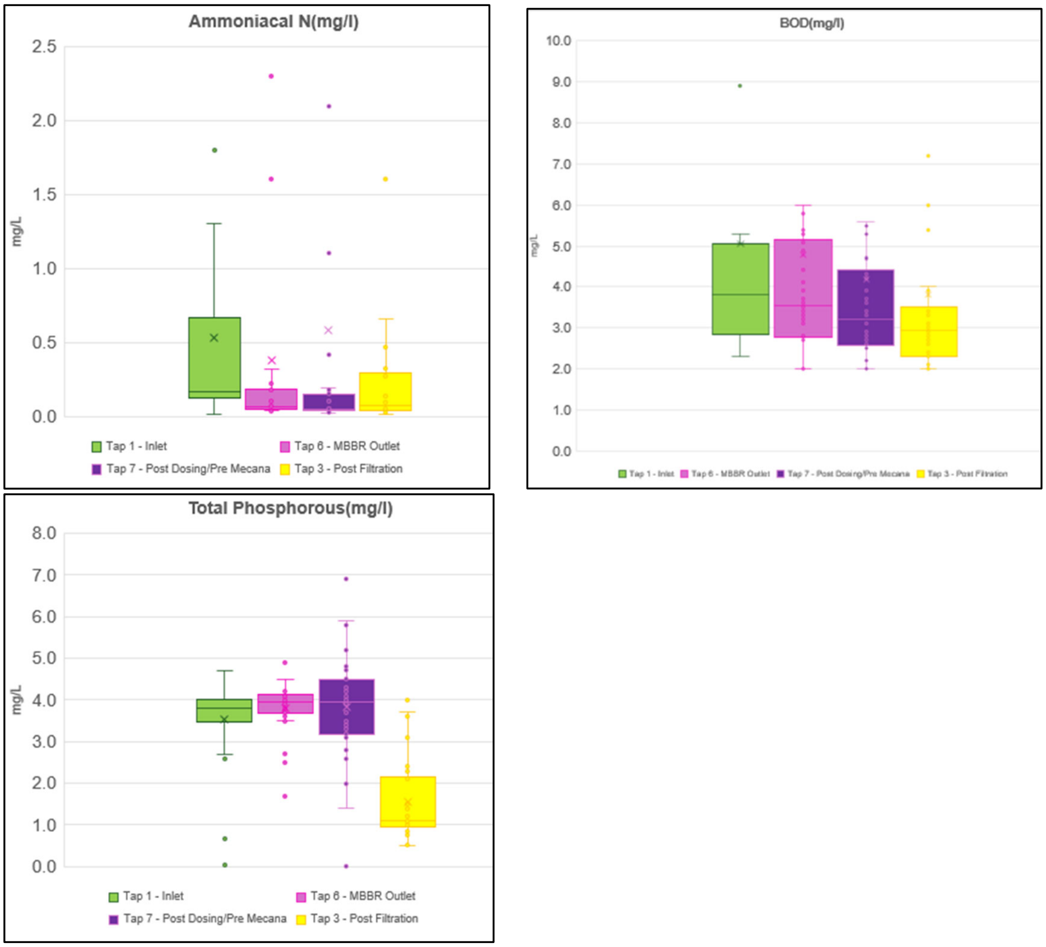
Total Suspended solids removal

4.5.5 The average TSS in the feed water to the pilot plant remained low, with a 95th percentile value of 16 mg/l. The TSS increased to 110 mg/l following chemical dosing. After filtration through the Pile Cloth Filter, the 95th percentile TSS was reduced to 21 mg/l (representing an 80% removal efficiency). Although this level of removal demonstrated effective solids removal, the expected performance for the media that was used on the Pile Cloth Filter (PES 14 Optifibre media) is a final effluent TSS of <5 mg/l. The limited running of the trial and the lack of optimisation of the chemical dosing contributed to the Pile Cloth Filter achieving performance outcomes below the anticipated design capability.

Total phosphorus removal

4.5.6 Phosphorus removal improved significantly compared to Sprints 1 and 2. Total Phosphorus in the treated water averaged 1.5 mg/l Figure 10 Ammoniacal N, BOD and Total Phosphorus. Most of the residual phosphorus was present in particulate form, therefore further reductions to below 1 mg/l are considered achievable when the chemical dosing and Pile Cloth Filter operation are fully optimised. A second stage filtration is even possible to further reduce concentrations.

Figure 10: Ammoniacal N, BOD and Total Phosphorus



Iron removal

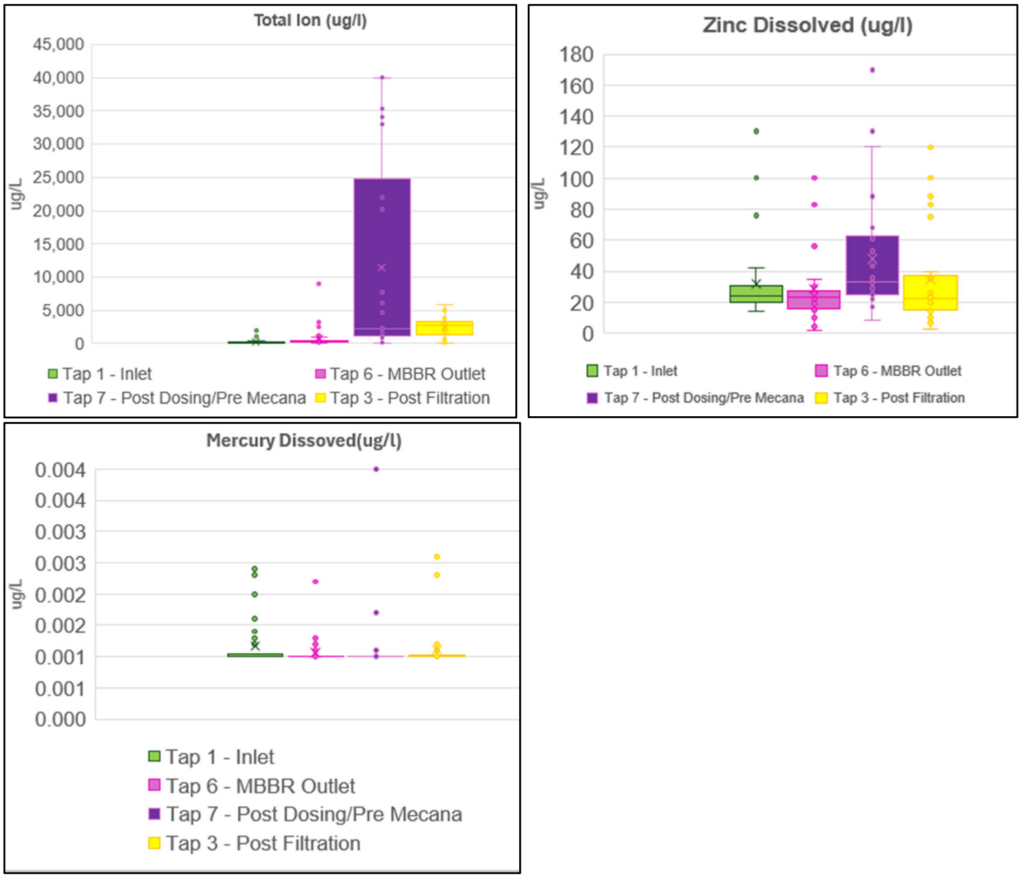
4.5.7 Following a significant improvement in TSS removal by the Pile Cloth Filter, total iron removal was significantly enhanced, achieving a concentration of 4,550 µg/l (95th percentile) in the treated water Figure 10 Ammoniacal N, BOD and Total Phosphorus. This performance is much closer to the assumed target for the scheme shown in Table 1. With optimisation of the Pile Cloth Filter, it is possible to achieve much higher performance.

Other Metals Removal

4.5.8 Several heavy metals were analysed during the Pile Cloth Filter trial. Zinc and Mercury Figure 11: Metals are highlighted here as these have been flagged up in the H1 screening. The results show that there was no increase in total Zinc and dissolved Zinc concentrations as observed in Sprints 1 and 2. This suggested that, as suspected, the increase in Zinc observed earlier was due to possible ferric contamination like the lamella plates. There was effectively no removal of Zinc across the Pile Cloth Filter. Zinc removal typically requires pH adjustment to values above pH 9.

4.5.9 All samples for dissolved Mercury were below limit of detection and EQS for both the feed water and treated water.

Figure 11: Metals



Conclusion of the Pile Cloth Filter Trial

4.5.10 The Pile Cloth Filter Trial provided valuable information regarding the performance of mechanical filtration. Although not fully optimised, the results inferred that sufficient treatment is achievable for the removal of total suspended solids, total Phosphorus and total Iron. In addition, the performance of the filter also confirmed enhanced performance in removal of metals that precipitate at circumneutral pH. However, as highlighted in section 4.2 above, other heavy metals like Zinc and Nickel require pH adjustment (to pH>9) for efficient removal.

4.6 Extended Process Results

The carbon-based process trialled as part of the pilot plant consisted of a Biological Activated Carbon (BAC) stage followed by Granular Activated Carbon (GAC), as outlined in Section 3.3 above. The extended process was designed to target pesticides and organic micropollutants, including PFOS and related compounds. TOC was monitored throughout the trial as a surrogate indicator for the broader organics load in the final effluent. The extended process was included in pilot for testing feasibility of further treatment rather than required for baseline design of the TTP.

4.7 Performance assessment of the Extended Process

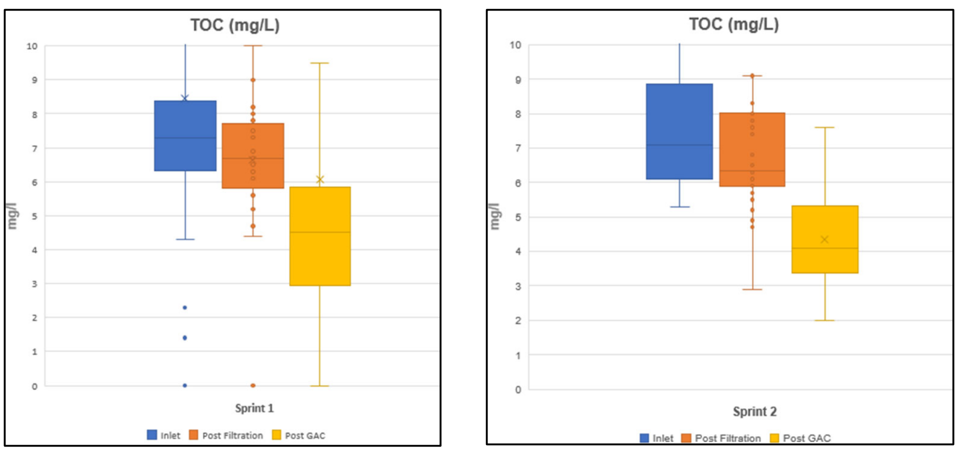
4.7.1 The key assessment criteria for evaluating BAC/GAC performance were:

- TOC breakthrough curve
- Micropollutant removal (e.g., PFOS and related per- and poly fluoroalkyl (PFAS) compounds)
- GAC bed life / exhaustion rate

Total Organic Carbon (TOC)

4.7.2 TOC was monitored as a surrogate indicator for the removal of all organic contaminants. For both sprints, the 95th-percentile TOC concentration in the feed water ranged between 9 and 12 mg/L, which is typical of final effluent Figure 12: TOC profile for Sprint 1 and Sprint 2. After the filtration stage, TOC was reduced by approximately 30%. Following BAC/GAC treatment, the 95th-percentile TOC concentration was between 6 and 7 mg/L for both sprints.

Figure 12: TOC profile for Sprint 1 and Sprint 2



PFOS Removal

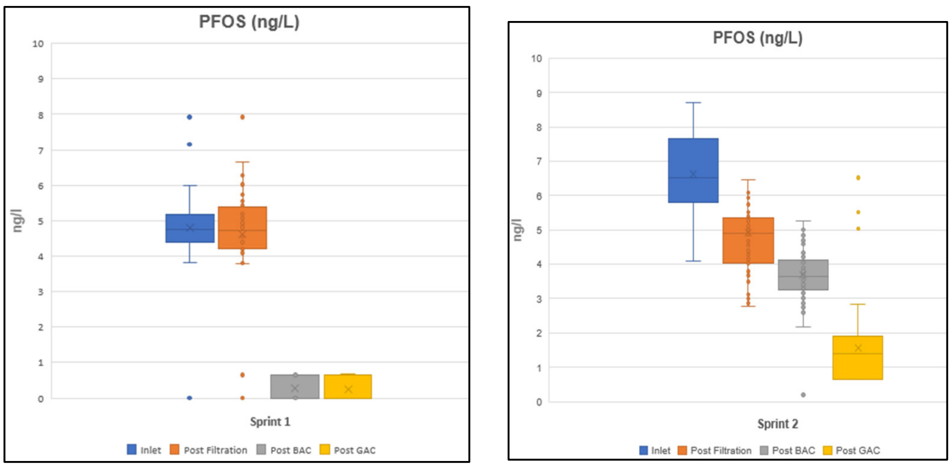
4.7.3 Perfluorooctane sulfonic acid (PFOS) is classified as a priority hazardous substance under WFD. The AA-EQS for PFOS in surface waters is 0.65 nanograms per litre (ng/l) or 0.00065 µg/l. The MAC is significantly higher at 32 µg/l. During Sprint 1 the 95th percentile PFOs concentration of PFOs in the feed water was 6.3 ng/l and this increased to 8.7 ng/l during Sprint 2.

4.7.4 A significant removal happens in the BAC/GAC with removals of up to 81% for both Sprint events Figure 13 PFOs results for Sprints 1 and 2. Although the overall removal performance was substantial, PFOS breakthrough above the

AA-EQS threshold occurred rapidly during both Sprint events, typically after 7200 bed volumes (less than one month of operation).

4.7.5 This rapid breakthrough of PFOS is an indication of the challenges of the technology for achieving tighter treated water PFOS targets, which requires a specialist approach. A conventional BAC/GAC configuration would require frequent media regeneration, reactivation or replacement, which is operationally challenging and result in significant additional operational expense for full-scale application.

Figure 13 PFOs results for Sprints 1 and 2



5 Benefits derived from Pilot Plant Trial

5.1.1 The Pilot Plant Trial primarily served as a learning platform for treatment process selection, identification of operational risks and optimisation requirements, derisking of full scale capital investment, and the generation of representative design inputs to inform and refine the concept design.

5.2 The Requirement for Screening

5.2.1 At Gate 3, TTP baseline design assumed direct abstraction of final effluent from the Mogden FE culvert to feed the TTP. The long-term final effluent quality was not anticipated to present any issues for pumps or downstream treatment processes. This finding aligns with experiences from other processes that use final effluent for cleaning as they too have had to include screening and in some cases filtration. However, during pilot plant trials, the feed pumps experienced frequent failures during the spring period (beginning February 2025). The failures were attributed to clogging.

5.2.2 This observation represents a key learning from the pilot plant, directly informing required modifications to the TTP design. Specifically, the abstraction system will need to incorporate:

- appropriate FE screening to prevent ingress of vegetation and debris, and
- robust pump selection, such as the use of Vaughan chopper pumps or equivalent, to manage residual solids and prevent pump blockage.

5.3 Suitability of the MBBR process technology

5.3.1 A key process risk identified was the low ammonia concentration in the TTP feedwater (1.7 mg/l at the 95th percentile). Achieving an effluent ammonia concentration of <1 mg/L requires a resilient nitrification process. Tertiary nitrification at low influent ammonia concentrations is inherently challenging, and many technologies exhibit instability or frequently fail due to insufficient ammonia loading to sustain a healthy nitrifying biomass. Consequently, verifying the suitability of the selected nitrifying technology for the baseline design was a critical objective of the pilot plant testing.

5.3.2 Ammonia removal performance was not affected by the location of chemical dosing, with similar outcomes observed under both pre- and post-MBBR dosing configurations.

5.3.3 The pilot plant results confirmed that the MBBR technology is a robust and reliable nitrification process, even under low and variable influent ammonia conditions. Throughout the trial, ammonia concentration in the treated effluent was consistently reduced by approximately an order of magnitude relative to the feed water quality, and the treated water concentration was maintained at <0.5 mg/l for most of the testing period. This level of performance confirmed the suitability of the MBBR technology and provided strong confidence in the applicability of the MBBR for the full scale TTP.

6 Conclusions

6.1.1 The pilot plant testing and performance is providing valuable information and critical insights for the development of the TDRA TTP. The trial improved understanding of the source water characteristics and screening requirements, leading to an update of the concept design to incorporate appropriate screening.

6.1.2 The performance of the MBBR has provided strong confidence in the biological treatment stage, which represents the highest process risk element of the TTP. The ability of the MBBR to operate effectively under low ammonia conditions is considered a key requirement for the TTP reliability. Under both ‘normal’ and ‘hot standby’ modes, the MBBR offers significant operational resilience. The responses and behaviour of the MBBR during ramp up and ramp down conditions will be governed by a tailored control philosophy, which will be further refined during commissioning.

6.1.3 Despite a sub optimal pilot scale chemical dosing system, ferric sulphate coagulation phosphorus and improved removal capture was significant. Chemical dosing and tertiary solids removal can be optimised for the full scale plant through detailed design and commissioning to meet required targets for suspended solids, total phosphorus, and total iron. Chemical dosing processes for solids, phosphorus and iron removal are well established and considered business as usual (BAU) within the UK water industry.

6.1.4 The pilot plant also demonstrated substantial removal of several other compounds such as metals at ambient pH conditions (e.g., Mercury, Iron, and Cadmium), although concentrations did not necessarily reduce to EQS levels. Certain metals, such as Zinc and Nickel, require elevated pH (typically >9) to achieve effective precipitation. While pH elevation is technically feasible, it imposes a significant chemical burden because the pH must subsequently be reduced prior to environmental discharge. This would require further chemical dosing. A change of coagulant and a review of materials of construction could reduce Zinc and Nickel to an acceptable level.

6.1.5 The combined findings indicate that the future full scale TTP when optimised for proper flow distribution, chemical dosing and filtration can meet the required effluent standards.

Thames Water