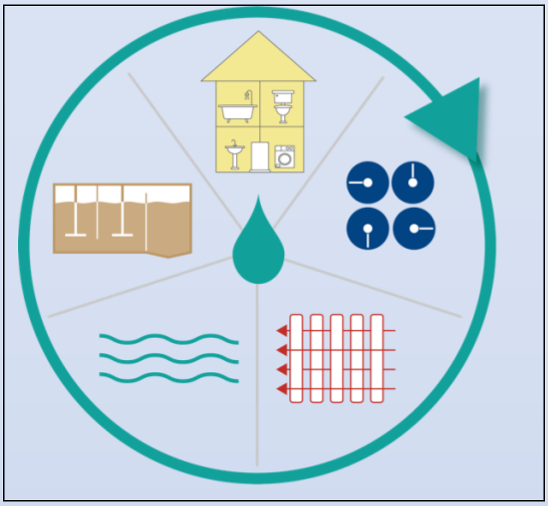

A Full Advanced Treatment (FAT) Pilot Plant was Installed at Budds Farm and Peel Common Wastewater Treatment Works (WwTW) in the South of England between 2020 to 2023. This document provides a summary for the public audience summarising the process, findings and considerations for future full-scale installations.

Reflections on Water Recycling Pilot Plant Performance

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Illustrations by Natalie Huckle

2024

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Glossary

AOP	Advanced Oxidation Process
AWT	Advance Water Treatment
DEFRA	Department for Environment, Food and Rural Affairs
DWR	Direct Water Recycling
EPA	United States Environmental Protection Agency
FAT	Full Advanced Treatment
IDWR	Indirect Water Recycling
MF	Microfiltration
O&M	Operation and Maintenance
PFOS	Perfluorooctane sulfonic acid
PGWS	Proposed Groundwater Source
RO	Reverse Osmosis
RWC	Recycled Water Contribution
SWS	Surface Water Source
UV	Ultraviolet
UVAOP	Ultraviolet Advanced Oxidation Processes
WB	Water Basin
WMP	Water Management Plan
WwTW	Wastewater Treatment Works

Introduction

Living in the 21st century in the UK has many benefits that can be easily taken for granted. The first example being the sewerage infrastructure that enables household wastewater including water from showers, toilets, washing machines and, in fact, anything that goes down the plug hole to be taken away for treatment. The second is the drinking water supply, with more than 15 billion litres supplied to homes across the country every day. This water is treated to very high standards with over 99.95% of samples in England[1] and Wales[2] passing the required standard limits. However, maintaining this supply for the future is challenging due to reductions in the amount of water that can be taken from the environment, an increasing population as well as climate change. To meet future water demand, new sources of water need to be developed to cope with the risk of future droughts. This document aims to review where our water comes from and the role Water Recycling can play as part of the future of the UK's water supply.

What is Water Recycling?

Where does our water come from?

The concept of the 'Water Cycle' is familiar to most people, however, specific details of where drinking water comes from and how these different sources affect its taste are often less well known. There are many factors that affect the taste of drinking water which include, but are not limited to, the type of source it comes from (e.g., river or reservoir) as well as the geography and the geology of the area. This is because water sources are broadly classified as either "groundwater" or "surface water" (see Figure 1 right side).

Groundwater is water that has percolated down into the ground into a body of permeable rock called an aquifer. Groundwater is extracted from boreholes generally drilled deep into the ground. As it passes through the ground, the water can be filtered through the rock, removing larger undesirable particles. This natural filtration process can also lead to the absorption of metals and minerals from the rock itself into the water, which can lead to the water being "hard" with its own distinct taste. Harder water is classically associated with scaling electrical appliances such as kettles. The water can stay underground for a long period of time acting like a natural tank.

Surface water is taken from above ground, generally from rivers, which may be treated directly or stored for a period of time in a reservoir (artificially created storage). Reservoirs can benefit society by providing storage of water supply during periods of low precipitation (summer, periods of drought) as well as providing recreational spaces and a water source for wildlife. There are a number of reservoirs in the South East of England, including Bewl Water, Weir Wood, Darwell and Ardingly.

Although it is easy to think of water being 'clean' when it rains or snows, it doesn't take long to accumulate solids, microbiological or chemical contaminants as it moves over or through the ground. As the population density increases, the likelihood of human inputs to surface water and groundwater also increases. These inputs (see Figure 1 left side) may be from agricultural, industrial or domestic (i.e., wastewater) sources and are therefore legislated, regulated and managed both from the perspective of the environment and drinking water management.

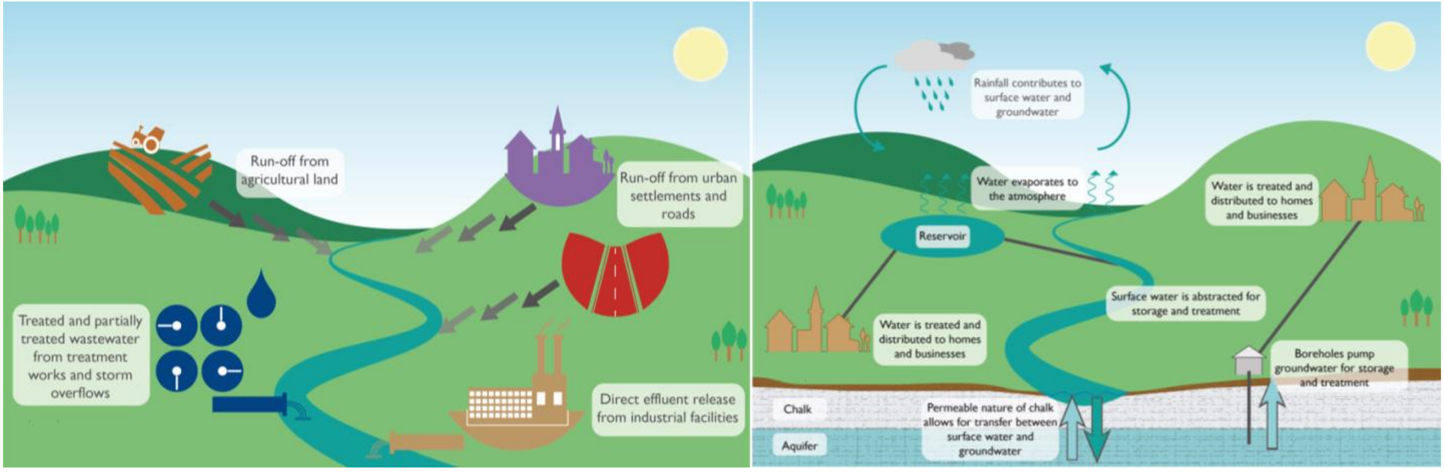

Figure 1 Conceptual illustration of inputs to a water body (left) and abstractions and interfaces with ground and surface water sources (right)

As population increases and the climate changes, water and its many uses need to be carefully managed to ensure there is enough for people and wildlife. This includes reducing the amount of water people use on average, reducing leakage, creating more storage and developing new sources of supply.

Defining Water Recycling

Water Recycling is the process of turning treated wastewater into purified recycled water that can then be used as a source for drinking water supplies, this can occur in a number of ways as defined below and shown in Figure 2:

Unplanned Recycling – Treated wastewater that is released into a river will form a percentage of the river flow and therefore also a percentage of any water taken downstream for water supplies. As such, many surface water sources globally have a degree of unplanned recycling which varies depending on environmental conditions. Any water taken from the environment, including from rivers, reservoirs, and aquifers needs further treatment to drinking water standards before it is supplied to consumers.

Direct Water Recycling – Treated wastewater is put through a series of advanced treatment technologies to produce drinking water that is generally blended with another water source and supplied to consumers. This has currently not been applied in the UK but has been applied for water drinking water in Namibia, South Africa and the USA[3].

Indirect Water Recycling – Treated wastewater is put through a series of advanced treatment technologies to produce purified recycled water that is then transferred into an “environmental buffer” such as a river, lake or reservoir. This a planned approached with careful consideration as to the additional treatment steps required. Any water taken from the environmental buffer is treated to drinking water standards before it is supplied to consumers.

Water Recycling in the remainder of this document refers to 'Indirect Water Recycling'

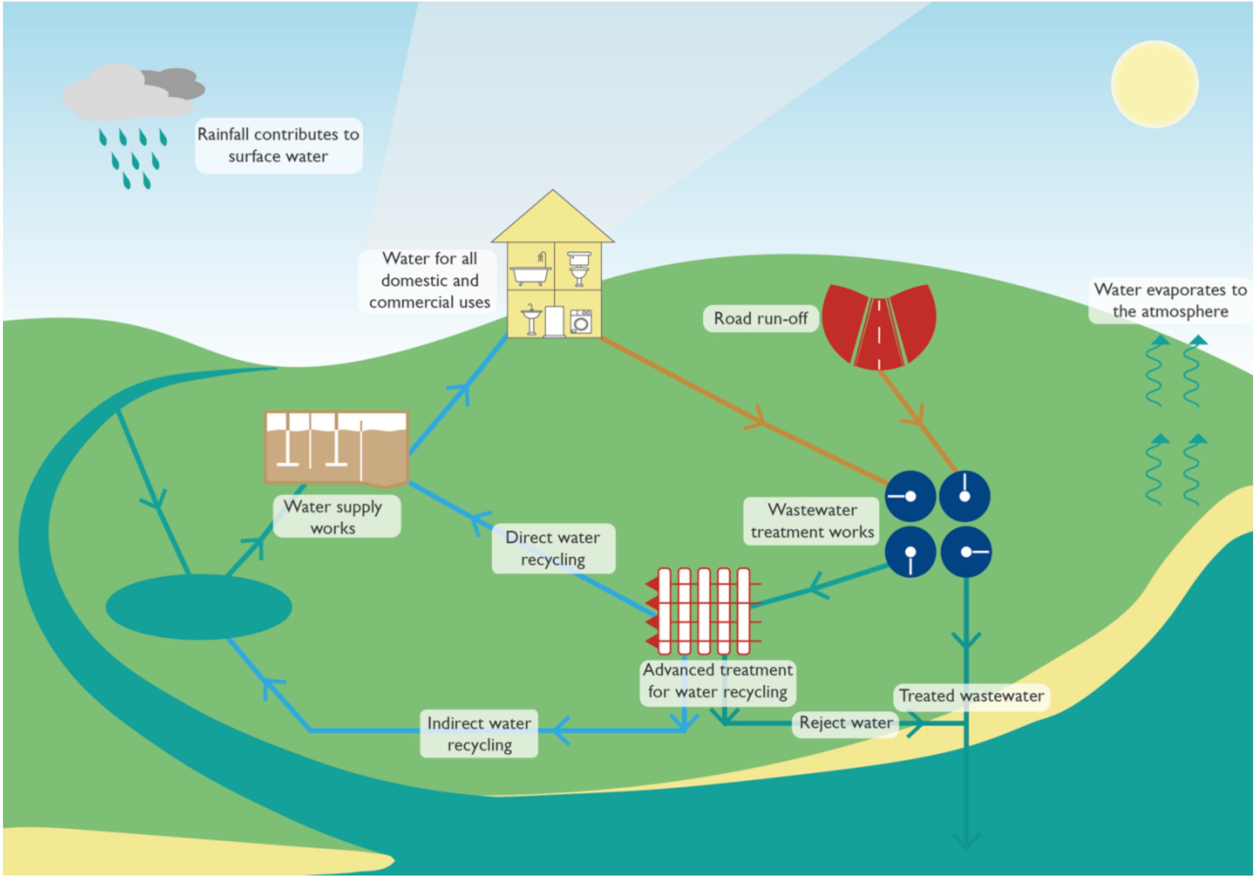

Figure 2 Conceptual illustration of water recycling approaches

A Brief History of Indirect Water Recycling

Water Recycling has been practiced in the USA since the 1930s, initially in simpler forms that didn't use advanced water treatment (AWT) in Los Angeles County, however, California has utilised Water Recycling with AWT for over 50 years[4]. The benefits that Water Recycling can provide are; a relatively consistent source of water all year round even during periods of drought, a blend of water with other available water sources (beneficial in respect to existing water treatment processes and taste consistency for consumers), an additional time buffer/barrier between Advanced Water Treatment and Drinking Water Treatment and the potential to be more desirable to consumers in that the water has returned to the environment for a period of time mimicking traditional water supply. Data from the Southern Water pilot of an AWT system in South East of England is used and the author would like to thank Southern Water to access to the pilot study data.

Why are Water Companies considering using Water Recycling?

The Environment Agency has estimated that in England by 2050 there will be a shortfall in 5 billion litres of water between the available sustainable water supply and the expected demand[5]. The Department for

Environment, Food and Rural Affairs (DEFRA) is requiring water companies to enable the following through their Water Management Plans (WMP):

- Improve resilience to extreme droughts
- Ensure preparation for future impacts of climate change
- Serve a growing population and thriving economy
- Mark a transition to longer term planning to protect and improve the environment

Specific current challenges in the South East of England linked to the future proofing of WRMPs include:

- Reductions in the amount of water that can be taken from the environment for drinking water supplies in order to protect sensitive ecosystems, such as the chalk streams in the South East of England.
- Population growth, which is expected to drive an increase in demand in water supply.
- Climate change, that may reduce the amount of water available in the environment that can be taken for water treatment and also drive an increase in demand during prolonged hot weather periods.
- Limitations in the ability to build water storage due to the local environment (e.g., National Parks and Areas of Outstanding Natural Beauty).

A number of measures to address this challenge are underway including reducing leakage in water supply pipes and reducing the per person daily consumption, however, in severe drought periods it is calculated there will still be a significant gap between water demand and water availability. As such, new sources of water need to be identified. The two main technologies being considered across the UK for such water scarcity challenges are desalination (turning sea water into a source for drinking water supplies) or water recycling.

As an island nation, desalination may seem attractive, however there are a number of practical challenges and as a rough comparison it is approximately three times more costly from both a financial and carbon perspective for ocean desalination compared to water recycling[6]. Also, when the considerable invested cost in the wastewater treatment process is considered, the natural question is why wouldn't this treated wastewater be recycled and returned to supply rather than lost to the environment, to provide an efficient source of water for the future?

Why and Where was a Pilot Plant Used?

The Advanced Water Treatment (AWT) Processes described below have been well characterised globally. To assess their application, operation and performance in the local environment, a water recycling pilot plant was established. Smaller units, that still represented industry-standard water quality production, were located on appropriate wastewater treatment sites. These smaller treatment units are referred to as a pilot plant (generally installed in shipping containers for ease of transportation), see Figure 3.

Figure 3 Photograph of the shipping containers the pilot plant arriving for the first time at Peel Common WwTW

Southern Water initially installed it's pilot plant at Peel Common Wastewater Treatment Works (Gosport) and then subsequently at Budds Farm Wastewater Treatment Works (Havant). The pilot plant was installed at these locations as they were potential sources for any future water recycling scheme. The sites can be seen below in Figure 4.

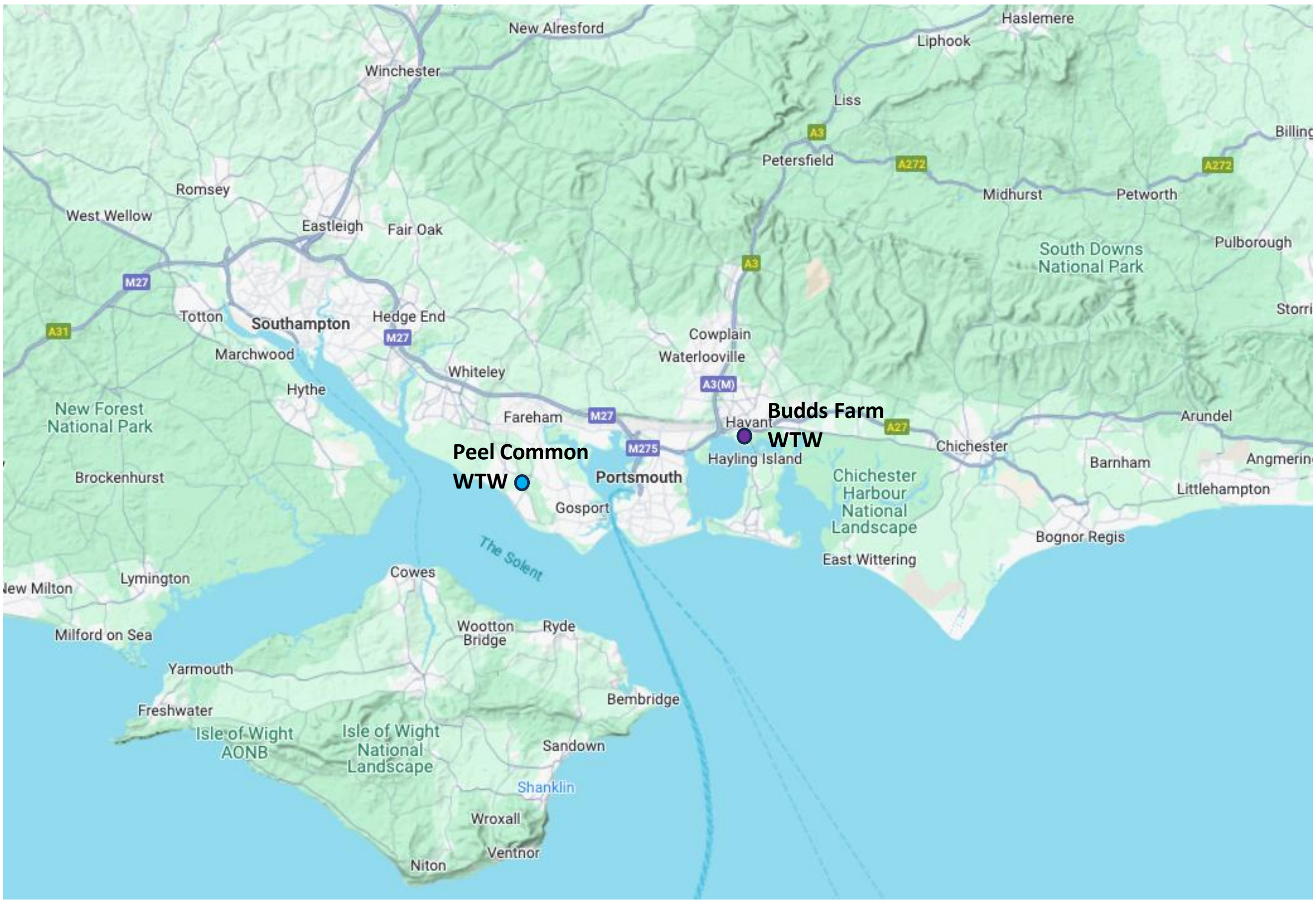

Figure 4 Map showing the location of Peel Common WwTW (left and blue circle) and Budds Farm WwTW (right and purple circle) where the Pilot Plant was located

Full Advanced Treatment (FAT) in the Context of Water Recycling

Water recycling treatment can comprise a variety of different technologies. The most commonly-used series of processes is called Full Advanced Treatment (FAT), the approach applied in California. FAT has two membrane stages (physical treatment barriers) followed by a disinfection and oxidation stage called the Advanced Oxidation Process (AOP). The FAT process is shown in Figure 5 and is used due to its high treatment capability, high level of control at each stage of treatment and demonstrable success through decades of use globally.

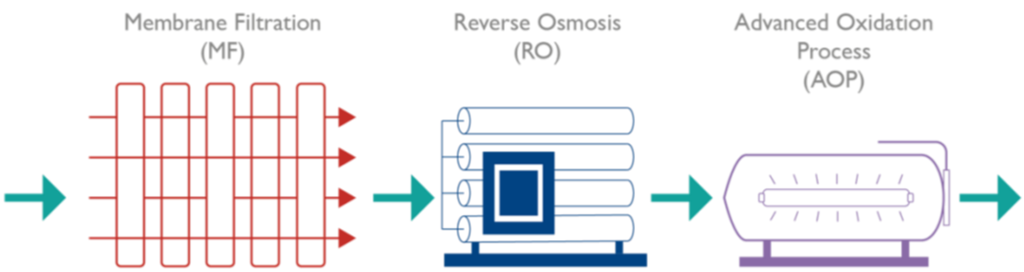

Figure 5 Representation of Full Advanced Treatment (FAT)

Water recycling treatment processes can, in theory, provide almost any level of water quality. However, there are practical restrictions in respect to space, financial costs, carbon costs and desired final water quality. If water quality is broadly defined, the different water sources or stages of treatment can be considered on a spectrum (see Figure 6) where treated drinking water has a very high quality but water treatment processes have the potential to produce water that is of higher quality than tap water if required (e.g., manufacturing processes).

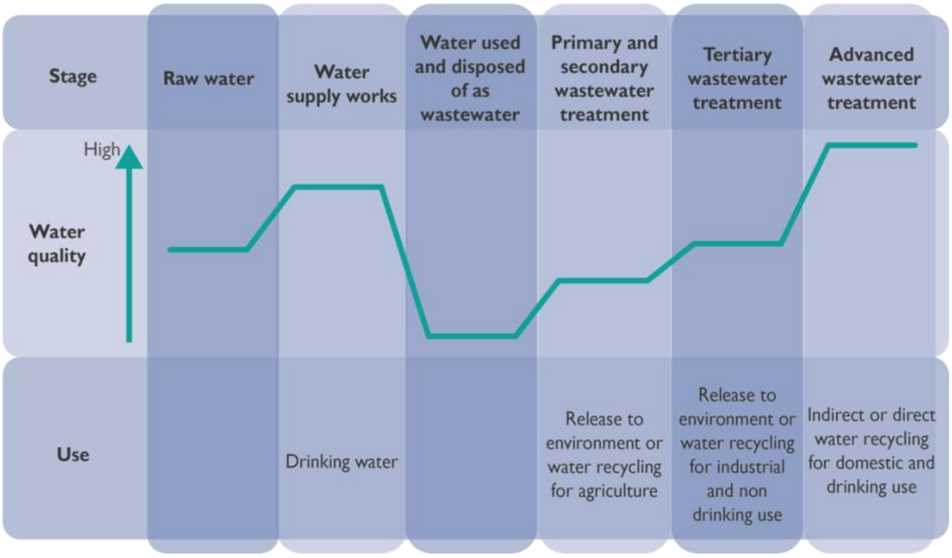

Figure 6 Representation of Relative Water Quality (adapted from EPA 2012[7])

Details of Southern Water's Water Recycling Pilot Plant

Source Water – Treated Wastewater

The source water for the pilot plant was fully treated wastewater from a high-quality wastewater treatment process (at Peel Common WwTW and at Budds Farm WwTW) the treatment stages of which are represented in Figure 7.

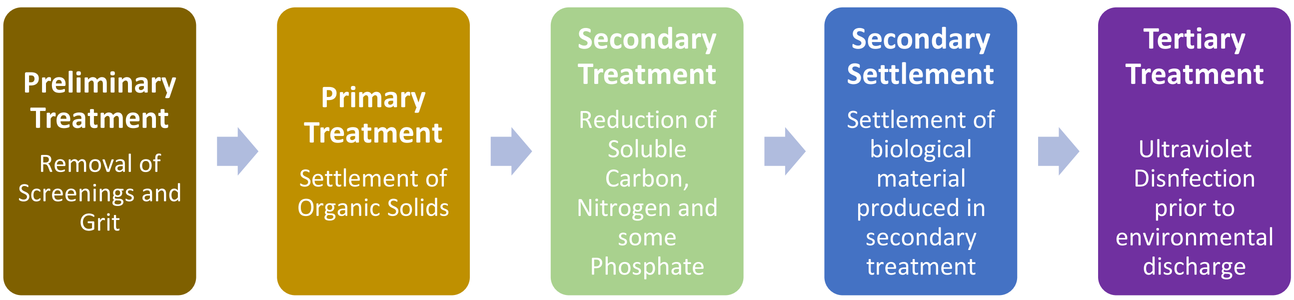

Figure 7 Representation of the standard treatment processes at Peel Common and Budds Farm Wastewater Treatment Works

In the majority of wastewater treatment processes in the UK, preliminary and primary treatment (initial stages removing coarse solids) are generally similar in respect to performance and often design. Secondary treatment processes do vary but are generally biologically based, as is the case at Peel Common WwTW and Budds Farm WwTW, and produce a very high quality of treated wastewater with low levels of nitrogen. The source water for the AWT process, that was used for the pilot plant is shown below in Figure 8.

Figure 8 Image of secondary settlement tank at Peel Common and source for the water recycling pilot plant

Pilot Plant Design

The processes in the pilot plant followed the same as the FAT process above. An image of the initial pilot plant installation at Peel Common is below:

Figure 9 An image of the pilot plant (membrane container right)

The pilot plant was specified and installed prior to any firm decision on final details of water recycling projects, source water selection and discharge permit conditions which would have to be agreed with regulators. As such, generally representative technologies from reputable suppliers that could be delivered within the project timescales were used. As with most technologies, variations are available and can be optimised for differing parameters but this would be completed with a full-scale installation when design parameters are finalised (see Section Considerations for Water Recycling at Full Scale for more details). A comparative example would be purchasing a car where although most cars will get you from A to B, a number of factors will determine which one you finally buy/lease e.g., number of seats, efficiency, range, acceleration etc. In the same way FAT technologies can be optimised, such as membranes in respect to rejection rates of compounds, or configuration of membranes to alter percentage of recovery rates e.g., 75% recovery means 1/4 of water gets rejected through a membrane and 3/4 passes through, in this case to the next stage of treatment.

The Pilot Plant was configured with PALL Corporation Microfiltration (MF) and Reverse Osmosis (RO) systems with the RO configured in a closed-circuit operation (CCRO). CCRO enables a circulating loop of flow prior to the RO membrane, this can increase the percentage of water recovery but also means the water in the loop concentrates and so is periodically rejected/replaced. The AOP is an Ultraviolet Advanced Oxygen Process (UVAOP) low pressure system and was supplied by Trojan Technologies using a small concentration of hydrogen peroxide as the oxidant.

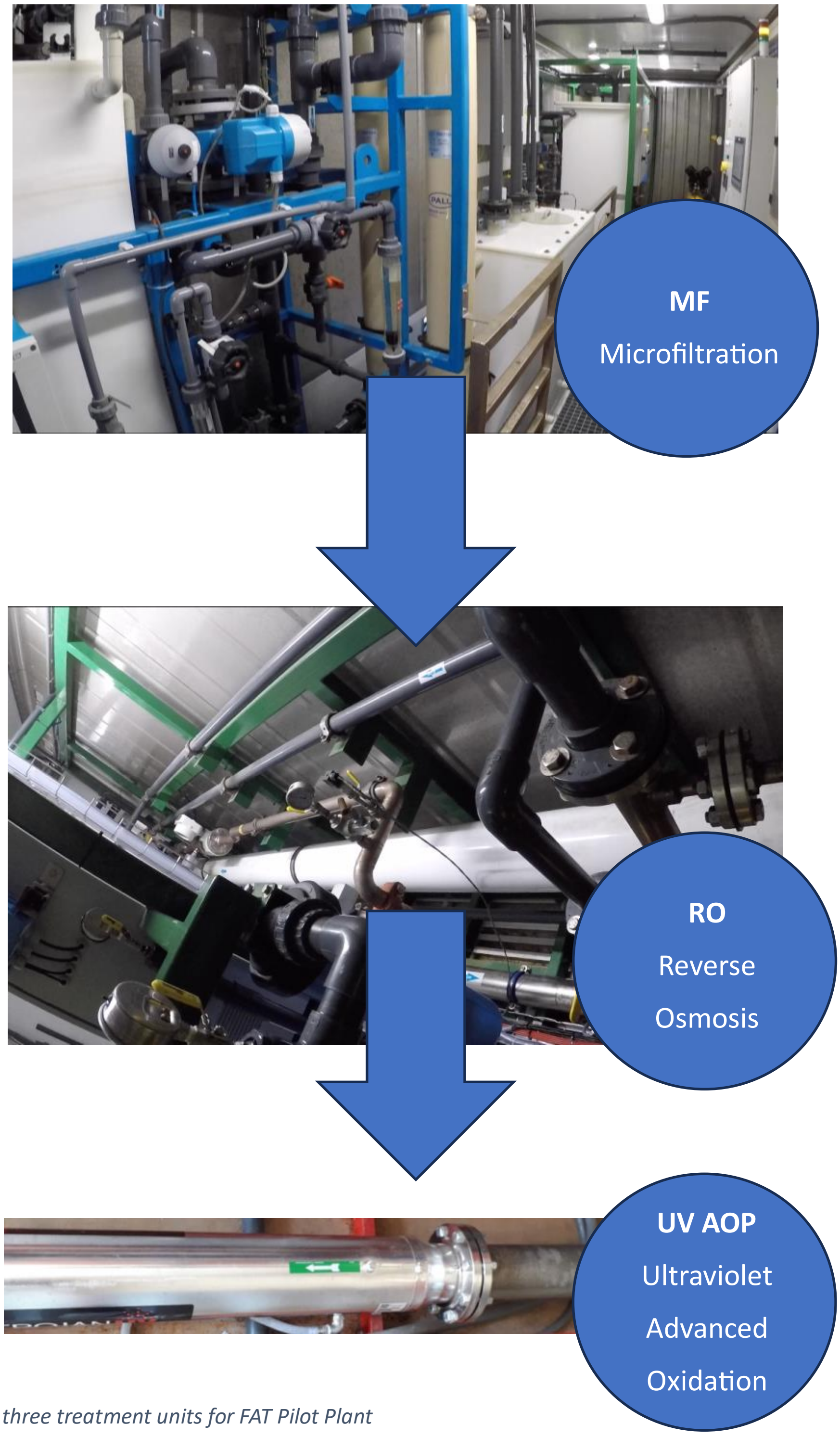

Figure 10 An image of all three treatment units for FAT Pilot Plant

Pilot Plant Findings

The Pilot Plant was sampled throughout its installation at Peel Common WwTW for approximately 1.5 years and Budds Farm WwTW for 8 months. The treatment processes at Peel Common and Budds Farm WwTWs are nearly identical and both were initially considered as potential sources for Water Recycling. Sampling frequency and parameters depended on the needs and requirements of the sample and location; however, this could be up to 557 parameters per sample taken. The parameters can be categorised into groups as follows with numbers in brackets noting the number of parameters; General Water Quality (24), Biological Indicators (19), Inorganic (23), Metals (27), Per- and polyfluoroalkyl substances-PFAS (51), Iodo_Phenol compounds (32), Pharmaceutical and Personal Care Products-PPCP (81), Pesticides (155), Trace Organics (37), Volatile Organic Compounds-VOCs (89) and Disinfection Byproducts (19). These cannot all be reviewed in this report for practical reasons; however, a focussed number of compounds will be below.

Although at beginning of the Pilot Plant installation the details of a full-scale Water Recycling project were not known, at the time of writing this document the proposed plan is to utilise the Havant Thicket Reservoir[8] as an environmental buffer. The reservoir would be fed with groundwater, taking excess water during the winter[9] as well as purified recycled water from a water recycling facility using the Full Advanced Treatment process (as described in the previous Section), using treated wastewater from Budds Farm WwTW. This therefore provides a context for the environmental buffer – a reservoir with environmental and recreational value. It also provides the two proposed water sources for the reservoir to enable comparison.

To provide a review of the Pilot Plant findings, parameters have been selected from some of the parameter groups above where possible linking them to parameters defined in the Water Supply Regulations 2016[10] (WSReg). Although raw water sources for water supply treatment would not need to meet the requirements in the regulation (as treatment has not taken place), it does provide a point of comparison. Further details of Parameters in the regulations can be found in the Appendix. In addition to this, comparing the pilot data to other proposed sources helps to provide a relative water quality and comparison of their characteristics.

Interpreting the Pilot Data

Water quality data for selected parameters, from the source water (treated effluent) to the purified water from the UVAOP process were assessed, including water quality testing after every stage of treatment. This approach enabled an evalution of the performance of every stage of treatment, i.e., efficacy of the treatment applied. In addition, data from the actual proposed groundwater source for the Havant Thicket Reservoir and a randomly selected local surface water source have been included for comparison. These three sources will be referred to as raw water sources yet to pass through drinking water treatment processes. Laboratories generally provide results from analytical testing as a number including concentration in specified units. Analytical instruments and testing methods may sometimes result in data being provided as “less than” or “greater than” a reference point such as the limit of detection for the method. Practically, for the data presented below any values in the dataset noted as “less than” or “greater than” were plotted at the minimum or maximum values stated to enable plotting. This generally produces a higher/conservative value for plotted parameter data.

Some of the data in this section is represented in box and whisker plots which can be helpful when reviewing data as they display a number of characteristics of the data relating to a sample point over time including the mean, median and overall spread of the data the concept shown below in Figure 11.

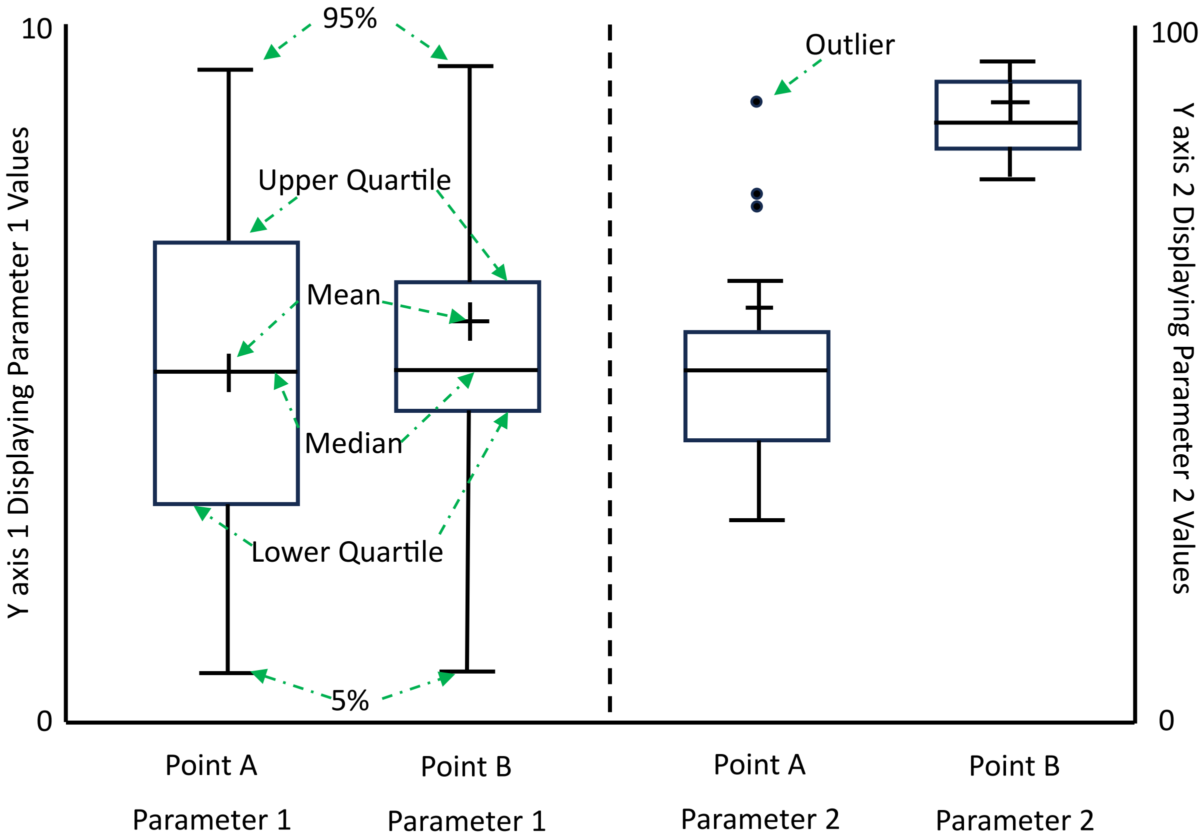

Figure 11 Example of a Box and Whisker Plot

Figure 11 hows the concept of the Box and Whisker plot in which an example of two sample points and two parameters are shown. Values for parameter 1 are shown on the left y axis and parameter 2 on the right axis, the right axis being ten times the scale of the left axis. The mean value is indicated with a cross and the median as a horizontal line in the box which shows where 50% of the data points sit. The whiskers show where 95% or more of the data sit with any outliers shown individual data points as dots. The central dotted line shows the separation of the plots each axis with Parameter 1 being read on the left and parameter 2 on the right.

In this example some key aspects of each plot are:

Point A Parameter 1 – shows a wide spread of data with a 'normal distribution' that would have a bell shape curve with the mean and median having the same values. In this case the mean and median are helpful values to reflect the data in the category.

Point B Parameter 1 – shows the same spread of data as per point A and parameter 1 with more of the data points sitting closer to the mean and median shown by a smaller box and reflect the the data in this category well.

Point A Parameter 2 – shows a narrower overall spread of data as per point B and parameter 1 with more of the data points sitting closer to the mean and median shown by a smaller box. There are three points that sit above of the other 90% of data which are helpful to identify outliers from majority of the data

Point B Parameter 2 – shows a very consistent dataset with a much reduced spread to Point A Parameter 2, however as the scale of axes are so different the spread is relatively similar to the Point A and B of Parameter 1 (assuming the units on the axes are the same)

Microbiological Parameters

Microbiological parameters described below *Escherichia coli* (*E.coli*) and F+ coliphage are indicators for potential pathogens (microorganisms that causes disease) and therefore associated risk of pathogens to consumers. As would be expected very high levels can be seen (Figure 13) in the treated wastewater (note break in left y axis in), compared to say, the UVAOP effluent or even the surface water source. It is worth noting that the 'take off point' for recycling of treated wastewater is prior to disinfection stage at both Peel Common and Budds Farm WwTW which is shown schematically in Figure 12.

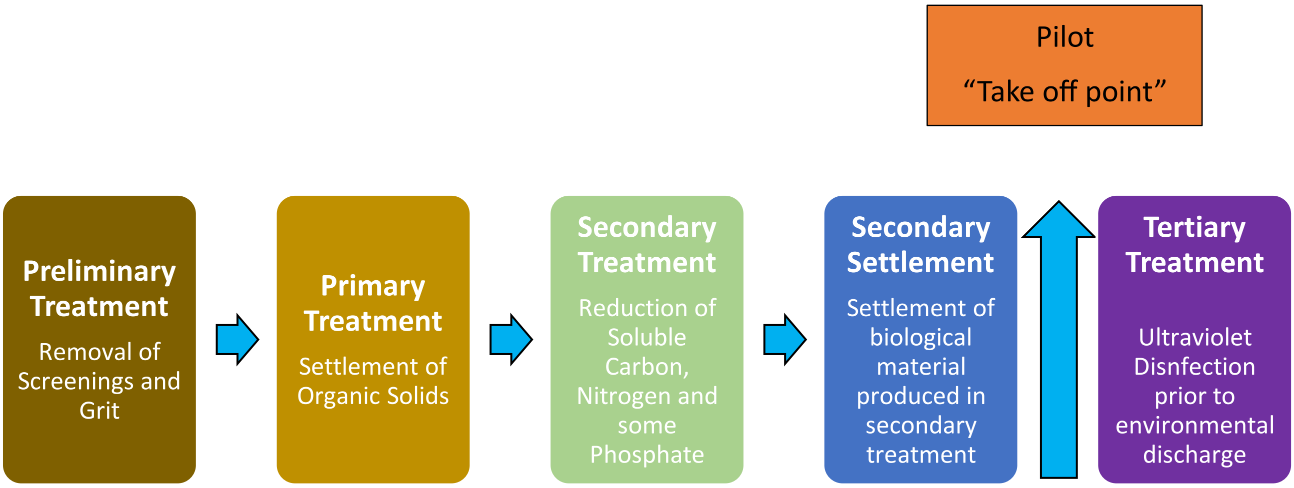

Figure 12 Figure identifying the "take off point" for the pilot study

Substantial removal can be noted through MF and complete removal post RO meeting the requirement in the WSReg, the only one of the three Raw Water Sources to do so. There are regular bacterial values (see right y axis) noted in both the groundwater and surface water sources which would be treated in subsequent drinking water treatment processes to meet the WSReg.

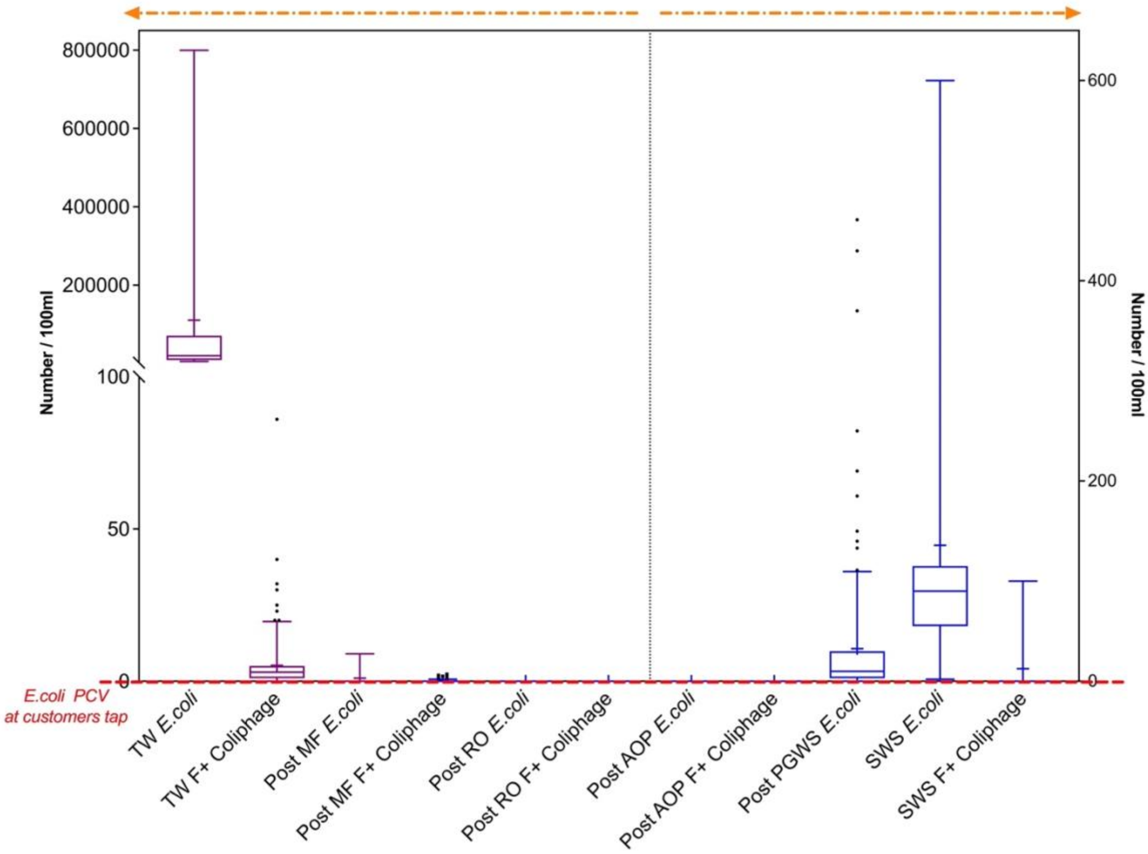

Figure 13 A graph displaying microbiological data from the pilot and potential raw water for drinking water treatment

Inorganic Parameters

Inorganic parameters are critical parameters with respect to both health and taste and as a consequence acceptability. Ammonium levels vary to some degree in the treated wastewater (Figure 14) but there is a consistent drop in levels across the RO, which is as would be expected for the technology and provides confidence in the functionality of the process. However, although relatively low values (all data points except for 2 are less than 1 mg/l) the Pilot Plant has higher values than the groundwater and surface water sources. However, improvements in the treated wastewater which is relatively easily achieved (see Considerations for Water Recycling at Full Scale) will directly translate into improved post RO values and therefore FAT values.

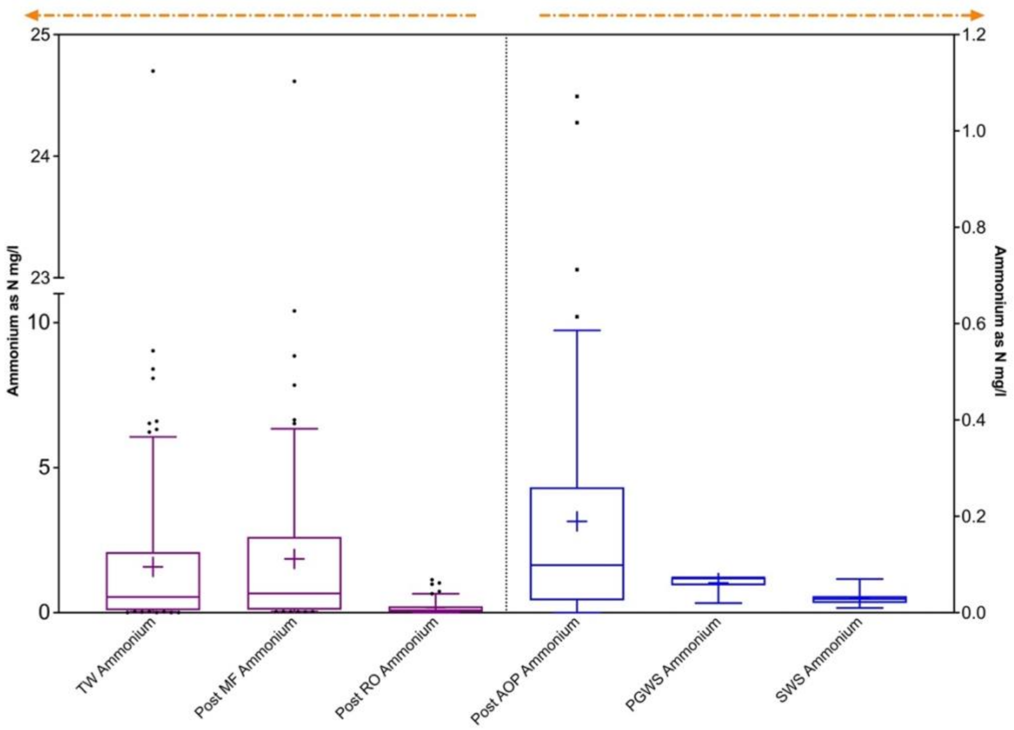

Figure 14 A graph displaying ammonium data from the pilot and potential raw water for drinking water treatment

Nitrate has a maximum concentration in the WSReg of 50 mg/l and all raw water sources are well below this limit, although the pilot plant is substantially and constantly lower than the other sources due to the RO process. This is still the case with a wide variability of concentration in the Treated Wastewater which feeds the membrane processes. The groundwater source has relatively higher Nitrate levels to Post UVAOP, in fact these are even similar to that of the surface water sources (often higher due to surface runoff), which coupled with the microbiological data may indicate impact from an anthropogenic source (see Figure 1) such as agriculture in the groundwater. The phosphate levels in the treated wastewater are relatively stable and the reduction through RO is consistent, albeit not reaching the levels of the other two Raw Water Sources. Understanding the overall quantities of Nitrate and Phosphate from a blended water source is key for the reservoir. In respect to blending, the purified recycled water would reduce the overall concentration of Nitrate compared to the PGWS and the reverse for Phosphate. However, the RO process can be seen to consistently reduce both the levels of Nitrate and Phosphate.

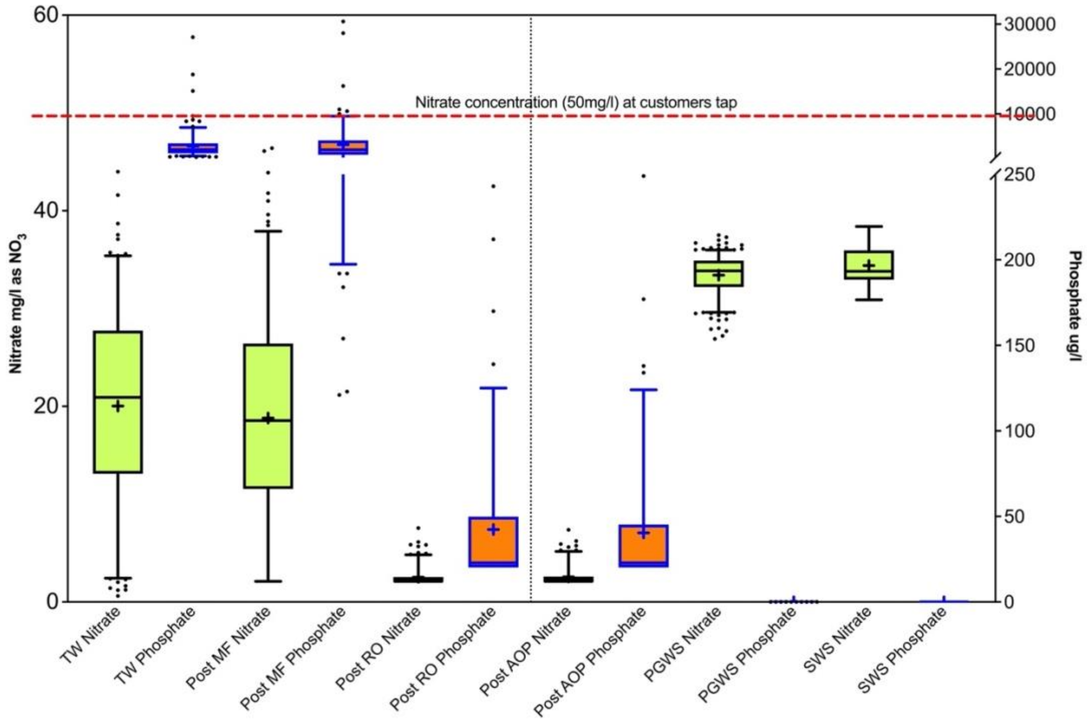

Figure 15 A graph displaying phosphate and nitrate data from the pilot and potential raw water for drinking water treatment

Chloride also has a maximum defined limit in the WSReg of 250mg/l and as can be seen in Figure 16 all three Raw Water Sources are well below this limit. However, as forms of chloride e.g., sodium chloride, can have impact on taste it is an important consideration. As such RO membrane selection and configuration will be critical at full scale (see Considerations for Water Recycling at Full Scale) where this can be further enhanced. Similarly, as the purified recycled water will be blended this will enable a further balancing and reduction of the overall level of chloride to consumers with the PGWS.

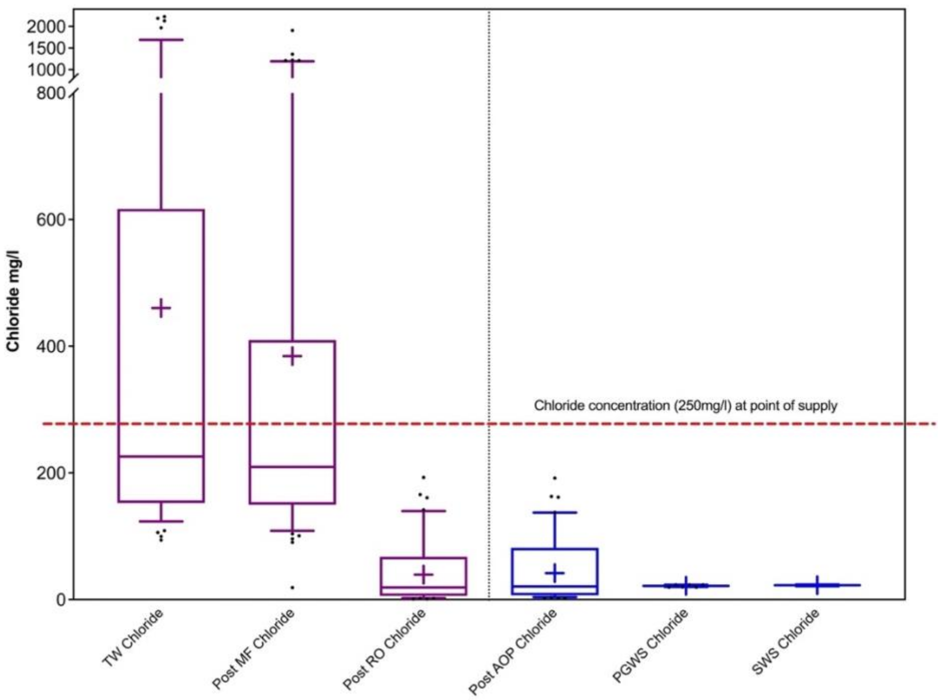

Figure 16 A graph displaying chloride data from the pilot and potential raw water for drinking water treatment

Metals

Arsenic and Chromium both have minimal values and are well below WSReg values for all three sources noted. Aluminium levels are the lowest in the pilot plant followed by the surface water source. The groundwater source has a range of values some of which exceed the WSReg value and would need to be reduced during water treatment. The benefits of source blending again could be beneficial for the groundwater source (PGWS) to supply the future reservoir in respect to Aluminium.

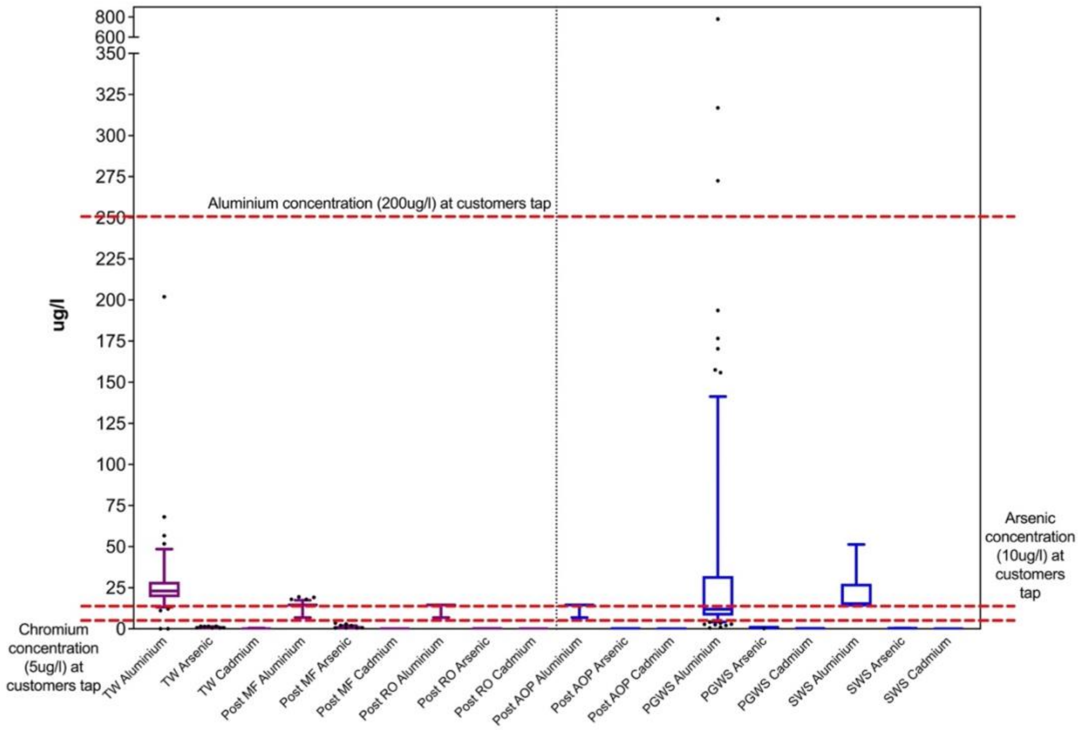

Figure 17 A graph displaying metal data from the pilot and potential raw water for drinking water treatment

Pesticides and PFOS

Pesticides have been widely used in the UK and some of these have been identified as toxic and are no longer used in the UK, Aldrin and Heptachlor are two such pesticides and have stated limits on the WSReg and were also available on all the raw water datasets, and so were selected as parameters for comparison. The Per- and polyfluoroalkyl substances or PFAS group of chemicals commonly referred to as ‘forever chemicals’ are of current interest and PFOS (Perfluorooctane sulfonic acid) is chemical within this group. As this data was available in the dataset for all three raw water sources it was also selected for comparison.

Although all three compounds were detected (see Figure 18) in the Treated Wastewater, following RO along with PGWS and SWS all recorded levels were at or barely over the limit of detection (note ng/l levels and PGWS had higher limits of detection than the other two water sources). The water quality for these three compounds across all three raw water sources is excellent.

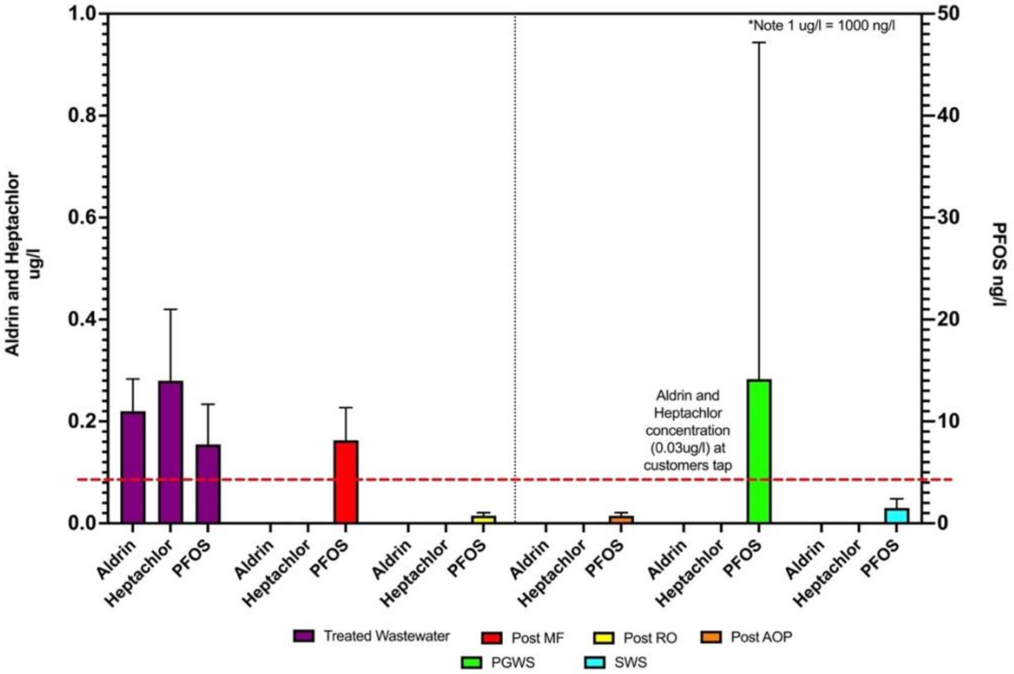

Figure 18 A graph displaying aldrin, heptachlor and PFOS data from the pilot and potential raw water for drinking water treatment

General Water Quality Parameters

The parameters found within “General Water Quality” largely involve aspects of broader parameters relating to water quality and/or the visual appearance or taste of water which, although important, may not be linked to health. Turbidity and UV_{254} are the selected parameters as they can give a very direct indication of appearance and where a clear, particle free water is desired these parameters are ideal. Such a clear water source would be represented by having a low turbidity and high UV transmission. Figure 19 indicates that all three raw water sources have relatively good values for water treatment processes. The visual quality of the purified recycled water after the RO membrane process is consistently excellent which produces an extremely clear water which is a desirable characteristic for blending with other raw water sources.

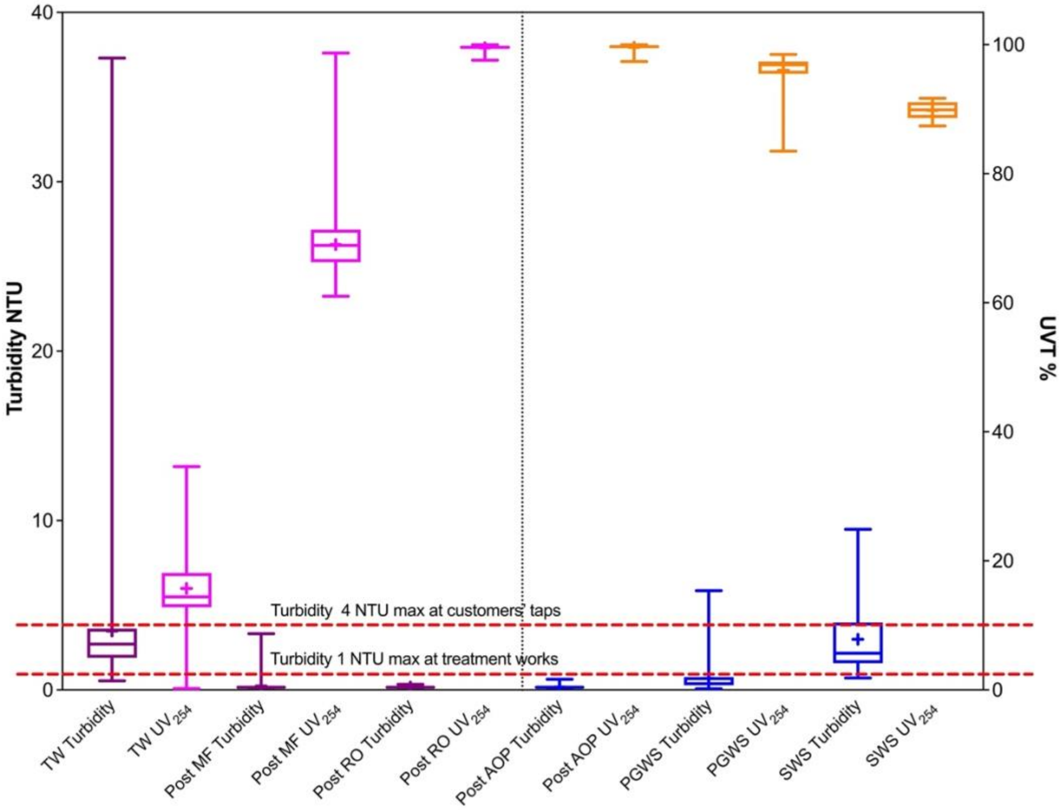

Figure 19 A graph displaying turbidity and UVT_{254} data from the pilot and potential raw water for drinking water treatment

Summary of Pilot Plant Parameter Data

Overall, the data for both the purified recycled water and the groundwater source both proposed as raw water sources for the Havant Thicket Reservoir display very good characteristics. In many cases the parameters assessed would already meet Water Supply Regulations (see Appendix for further information) prior to treatment. The two raw water sources (PGWS and Post AOP) have their own characteristics and for the most part would appear to suit blending. The groundwater source would benefit from blending by improving nitrate, microbiological and general water parameters. Whereas the purified recycled water would benefit from blending by improving chloride and phosphate parameters. The raw waters individually and blended would both be suitable as raw water sources for drinking water treatment.

Considerations for Water Recycling at Full Scale

When considering the installation of Full Advanced Treatment (FAT) there are some additional considerations to the Pilot Plant when applying this at full scale, these are described below:

Remineralisation

An additional stage that would be required following FAT is remineralisation, where minerals are actively added to the water. This is because Reverse Osmosis (RO) filters out the majority of the dissolved components including the ones we need in water, for health reasons, some have to be added back in. This is often achieved through the addition of lime and the amount added will depend on the final water specification when taking into account blending.

Water Quality Optimisation

Critical to the optimisation of the full-scale process will be understanding the required water quality for purified recycled water. This will be achieved through understanding; first the requirements of the final drinking water specification, secondly any specific requirements of the reservoir (e.g., preventing undesired plant/algal growth referred to as eutrophication), and thirdly the amount and water quality of the blended source.

When this water quality specification is known optimisation in treatment areas such as those highlighted below can be made:

Membranes

Different membrane designs and suppliers have different technical performances and also differ in the way they are operated. Knowing the purified recycled water quality specification allow designers to select the best membrane and operating configuration to achieve this. For example, taking Figure 19 as an example if chloride is a key design point: there is a range of results for chloride but the higher end of the range would be from Budds Farm WwTW, the selected source for FAT. In such circumstances, an RO membrane with maximum chloride rejection would be selected and likely configured in a straight single pass rather than the CCRO as per the pilot configuration, optimising chloride rejection. This will enable the specific parameters required to be optimised to the specification.

Wastewater Treatment Synergy

The Wastewater Treatment Works (WwTW) were not optimised for water recycling but instead for environmental discharge consents. A way to see improved and more consistent purified recycled water would be to operate the WwTW and FAT in synergy. A good example is inorganic compounds where WwTW have consents based on Total Nitrogen annual averages. This can work well for releases to the environment where output variation has less impact, however, for production of purified recycled water consistency is more critical. A simple change of operating philosophy, to minimise all forms of Nitrogen and maintain consistent performance of the WwTW, will directly relate to improved purified recycled water. Similarly, if some final parameters post FAT are not deemed low enough for the water specification, WwTW upgrades could be made to improve the incoming water for the FAT and as a consequence the final purified recycled water produced. This would be a potential solution if a further phosphate (Figure 15) reduction is required

Practical Operation

At full-scale there an inherent benefit of scaling when comparing cost and carbon cost. In addition to this there are additional practical benefits such as energy recovery which can be implemented post RO to reduce energy requirements across the RO system. By running the pilot, practical learning has provided preparation for full-scale system specification and operation, particularly in the area of UVAOP performance, and will enable opportunity to design the best full-scale FAT design for UK applications.

Future of Water Recycling in the UK

The Full Advanced Treatment (FAT) pilot plant described in this report has provided considerable confidence in these technologies and their configurations that have been established, tested and applied globally. With the challenges of water scarcity in England highlighted, Water Recycling offers a useful and flexible tool to meet the challenges head on. There are a number of Water Recycling schemes planned and in development across the country and it is likely that there will be many more in the future serving the needs of consumers and helping to protect the environment.

Further Information

Hopefully this document has provided some information relevant to the subject of Water Recycling. For those interested in more information on the subject the following links may be of use:

Adapting2Change

To date the author has organised two events to date focussing on new water sources e.g., water recycling and desalination. Content from the conferences and additional material can be found here starting from October 2025:

Adapting 2 Change You Tube Channel

Drinking Water Inspectorate

The drinking water inspectorate has further information on Water Recycling at the link below:

DWI Water Recycling

Global Water Reuse Map

Find out information about global water recycling projects on the map below:

Global Water Reuse Map

Water Reuse Educate

Additional educational material on water recycling can be found below:

Water Reuse Educate

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9. Portsmouth Water. How will Havant Thicket Reservoir operate if the water recycling scheme goes ahead? 2024. https://havant-thicket-reservoir.uk.engagementhq.com/how-will-havant-thicket-reservoir-operate-including-if-recycled-water-is-added-to-it (accessed 19th December 2024 2024).
10. Water Supply Regulations. The Water Supply (Water Quality) Regulations. HMSO; 2018.

Appendix

Table 1 shows a summary of some of the Prescribed Values and Concentrations from the Water Supply Regulations[10] with rows highlighted in green of particular relevance to the document. Further information on Drinking Water Standards can be found on the [Drinking Water Inspectorate website](#).

Table 1 Summary of Prescribed Concentrations and Values from the Water Supply Regulations[10]

Schedule 1 Prescribed Concentrations and Values				
Table A Microbiological Parameters				
Item Number (internal Ref)	*Parameters*	*Concentration or value (max unless specified)*	*Units of measurement*	*Point of compliance*
1	*Enterococci*	0	number/100ml	Consumers' taps
2	*Escherichia coli*	0	number/100ml	Consumers' taps
Table B Part 1: Directive Chemical Parameters				
3	Acrylamide	0.1	µg/l	Residual monomer concentration
4	Antimony	5	µgSb/l	Consumers' taps
5	Arsenic	10	µgAs/l	Consumers' taps
6	Benzene	1	µg/l	Consumers' taps
7	Benzo(a)pyrene	0.01	µg/l	Consumers' taps
8	Boron	1	mgB/l	Consumers' taps
9	Bromate	10	µgBrO3/l	Consumers' taps
10	Cadmium	5	µgCd/l	Consumers' taps
11	Chromium	50	µgCr/l	Consumers' taps
12	Copper	2	mgCu/l	Consumers' taps
13	Cyanide	50	µgCN/l	Consumers' taps
14	1, 2 dichloroethane	3	µg/l	Consumers' taps
15	Epichlorohydrin	0.1	µg/l	Residual monomer concentration
16	Fluoride	1.5	mgF/l	Consumers' taps
17	Lead	10	µgPb/l	Consumers' taps
18	Mercury	1	µgHg/l	Consumers' taps
19	Nickel	20	µgNi/l	Consumers' taps
20	Nitrate	50	mgNO3/l	Consumers' taps
21	Nitrite	0.5	mgNO2/l	Consumers' taps
22	Nitrite	0.1	mgNO2/l	Treatment works
23	Pesticides	0.03	µg/l	Consumers' taps
24	Heptachlor	0.03	ug/l	Consumers' taps
25	Dieldrin	0.03	ug/l	Consumers' taps
26	Heptachlor	0.03	ug/l	Consumers' taps
27	Other pesticides	0.1	µg/l	Consumers' taps
28	Pesticides: total	0.5	µg/l	Consumers' taps
29	Polycyclic aromatic hydrocarbon	0.1	µg/l	Consumers' taps
30	Selenium	10	µgSe/l	Consumers' taps
31	Tetrachloroethene and Trichloroethene	10	µg/l	Consumers' taps
32	Trihalomethanes: Total	100	µg/l	Consumers' taps

33	Vinyl chloride	0.5	µg/l	Residual monomer concentration
Table B Part 2: National Requirements Chemical Parameters				
34	Aluminium	200	µgAl/l	Consumers' taps
35	Colour	20	mg/l Pt/Co	Consumers' taps
36	Iron	200	µgFe/l	Consumers' taps
37	Manganese	50	µgMn/l	Consumers' taps
38	Odour	Acceptable to consumers and no abnormal change		Consumers' taps
39	Sodium	200	mgNa/l	Consumers' taps
40	Taste	Acceptable to consumers and no abnormal change		Consumers' taps
41	Tetrachloromethane	3	µg/l	Consumers' taps
42	Turbidity	4	NTU	Consumers' taps
Schedule 2 Indicator Parameters				
43	Ammonium	0.5	mgNH4/l	Consumers' taps
44	Chloride	250	mgCl/l	Point of supply
45	*Clostridium Perfringens (including spores)*	0	Number/100ml	Point of supply
46	Coliform bacteria	0	Number/100ml	Consumers' taps
47	Colony counts	No abnormal change	Number/1ml at 22°C	Consumers' taps, service reservoirs and treatment works
48	Conductivity	2500	µS/cm at 20°C	Point of supply
49	Sulphate	250	mgSO4/l	Point of supply
50	Total organic carbon (TOC)	No abnormal change	mgC/l	Point of supply
51	Tritium (for radioactivity)	100	Bq/l	Point of supply
52	Turbidity	1	NTU	Treatment works