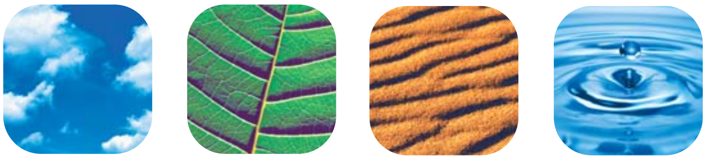
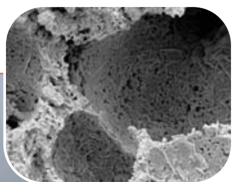


A COMMERCIAL APPLICATION OF
VIROFILTER™ TECHNOLOGY

CASE STUDY: YORKSHIRE WATER, KIRK SMEATON SEWAGE TREATMENT PLANT

The ViroFilter™ Technology treatment system operated effectively without the need for chemical dosing or influent pH adjustment.



The entry road to Kirk Smeaton Sewage Treatment Plant (STP) in West Riding, Yorkshire (left)
A Scanning Electron Microscopic (SEM) image of the interconnected pore space of the ViroFilter™ pellets (above)

VIROTEC

>>> CASE STUDY: YORKSHIRE WATER, SMEATON

BACKGROUND

The widespread dispersal of phosphorus from sewage effluent, industrial wastewater, detergents, and run-off from urban and agricultural land has played a major part in the eutrophication of many freshwater and marine ecosystems in Europe. The relationship between phosphorus and eutrophication has been known for many years, and the role of sewage effluent, above other point and diffuse sources of phosphorus in water pollution, has been well documented.

In order to help tackle eutrophication in inland and coastal waterways, more stringent measures are being applied to agricultural pollution and detergents, and stricter discharge consents are being imposed by environmental regulators on phosphate (PO_4^{3-}) concentrations in effluent from Sewerage Treatment Plants (STP's). Phosphate consents (or licenses to discharge treated effluent into rivers) have dropped (or will drop in the next one to two years) from typically between 5.0mg/L and 10mg/L to ≤2.0mg/L. These limits may be further tightened to <1.0mg/L in more eco-sensitive areas.

The need for stricter consents is supported by research in the United Kingdom on lowland river catchments, which has concluded that phosphate in sewage effluent presents a greater eutrophication risk to the environment than agricultural run-off. The research has found that at 54 monitoring sites throughout the UK, there is a strong correlation between soluble phosphate emissions and algal growth, with sewage effluent being the main source of pollution. It has also been shown that municipal wastewater has a high eutrophication effect, even after biological treatment, and that a significant deterioration of an STP's phosphate removal efficiency occurs after heavy rainfall. Similarly, inadequate control of aeration that might occur over weekends when operators are not present or during rain events also has an adverse effect on phosphate removal efficiencies. Hence the need for stricter operational standards and innovative ways to supplement biological and physical treatments.

Perhaps more importantly, research conducted by the Centre for Ecology and Hydrology in the UK has shown that the removal of phosphates from the effluent streams of smaller, rural STP's could be even more important than from larger works, because as smaller STP's are typically closer to headwaters and therefore their discharge of phosphate has a more profound impact on downstream nutrient loadings in rivers and along sensitive tributaries.

These and other findings have lead to a significant increase in the number of water bodies designated as "sensitive" to algal growth and toxic blooms, with 297 sensitive areas having been declared in England alone since 1994. Added to this challenge for smaller STP's, whose effluent discharges represent the largest environmental impact, is the fact that smaller sites are often unmanned but are the plants that increasingly attract the tightest consent levels due to their eco-sensitive location in farmlands and at inland headwaters.

The move to more tightly control phosphate concentrations in discharge water and other sources of nutrient contamination has come from the Department of Environment, Food and Rural Affairs

>>> CASE STUDY: YORKSHIRE WATER, SMEATON

(DEFRA), the Water Services Regulation Authority (Ofwat), and the UK Technical Advisory Group (UKTAG), as well as from the water framework Directives of the European Union. For example, UKTAG has advised the government that currently 65% of England's rivers fail current phosphate limits, with lakes being more sensitive to contamination. UKTAG predicts that up to 70% of English lakes and up to 25% of Scottish lakes risk failure of phosphate limits. In the UK, UKTAG has estimated that 50% of phosphate contamination originates with agriculture, 35% from sewage, and 7% from industry.

As a consequence of these developments, water companies are faced with the prospect of having to implement additional treatment methods in order to supplement their traditional biological, chemical and physical processes for reducing phosphate. However, finding the best application to reduce phosphate can be problematic, particularly when extremely low consents are required and when the Sewage Treatment Plant (STP) is at a remote, unmanned location.

VIROTEC TOTAL SOLUTION

ViroFilter™ Technology is unique in that it provides a treatment option that does not require the handling of hazardous or unsafe chemicals, is completely compatible with existing plant operations, equipment, and processes, is cost-effective when compared with other chemical dosing systems for phosphate removal, and is a fully automated flow-through system that does not require constant operator supervision.

The primary focus in the application of ViroFilter™ Technology relates to its ability to reduce Total Phosphorus (TP) and heavy metal concentrations in final discharge effluent; it can also play a role in reducing Biological Oxygen Demand (BOD), Total Suspended Solids (TSS), and turbidity-colour-clarity. More modest reductions in nitrogen concentrations (specifically, Total Nitrogen [TN], ammonia [NH_3-N], and Total Kjeldahl Nitrogen [TKN]), have been reported. The introduction of VirotecFilter™ Technology into the UK and elsewhere in Europe has focused mostly on the removal of phosphate from secondary treated wastewater using pelletised media in a filter.

ViroFilter™ Technology is applied as a stand-alone filtration system. The filter system is packed with the porous pelletised ViroFilter™ media, and is fitted "in-line" with existing secondary treatment systems. The treatment beds or filters can be configured for horizontal flow or upward vertical flow or as a trickling-filter to suit each specific location, and any redundant assets (such as lagoons, disused drying beds, or redundant trickling filters) can be retrofitted to accommodate the system. Layout alternatives include flexibility in design (such as submerged horizontal-flow reed beds, intermittently submerged vertical-flow beds, or biological or percolating filters), duty and standby configurations, and parallel or serial operation.

ViroFilter™ Technology offers a solution to many of the problems highlighted in relation to phosphate removal at small and medium-sized STP's. The Technology does so by passing secondary treated effluent through the pelletised media, thereby binding phosphate in the pellet matrix. The Scanning Electron Microscopic (SEM) image in Figure 1 shows the general porous nature of the

>>> CASE STUDY: YORKSHIRE WATER, SMEATON

ViroFilter™ pellets (macro-porosity) and the interconnection between pores (micro-porosity). Large internal and external reactive surfaces add to the removal of contaminants. Phosphate removal occurs by a variety of ionic and precipitation reactions within the pellet matrix; it has also been proposed that the pellets act as substrate for bacteria to promote biological activity.

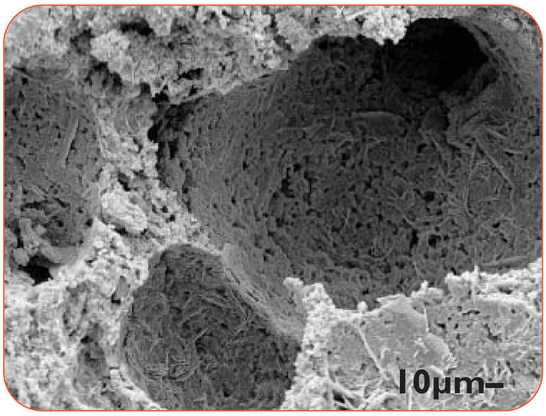


Figure 1: A Scanning Electron Microscopic (SEM) image of the interconnected pore space of the ViroFilter™ pellets

With ViroFilter™ Technology, effective phosphate removal to low concentrations can be achieved with no requirement to add flocculants or adjust influent pH. In addition to phosphate treatment, the Technology offers a solution for many of the problems associated with conventional chemical dosing, producing an effluent reduced in Biological Oxygen Demand (BOD), ammonia, suspended solids, odour and colour, and successfully binds excess iron released in the effluent, therefore preventing iron carry-over. The pellet bed allows for variations in hydraulic flow and phosphate concentrations, and upstream chemical dosing is typically not required. The system also allows for the simultaneous removal of any trace metals, such as cadmium, zinc or nickel, which are often found in municipal wastewater due to industrial effluent being discharged into the sewer.

Where phosphate discharge consents of <2.0mg/L are required, phosphate removal efficiency is approximately 80% per filter pass. Bed residence times are typically between four and 12 hours, depending on influent phosphate concentrations and consent (or treatment target) levels. The phosphate removal capacity of the ViroFilter™ Technology system may be greater than conventional filter media, with beds designed to last between two and three years.

VIROFILTER™ TECHNOLOGY AT YORKSHIRE WATER

ViroFilter™ Technology was presented to Yorkshire Water, one of the largest water companies in the United Kingdom, as an effective and simple "flow-through" treatment system, that can be applied at the back-end of a trickling filter, activated sludge (AS) or BNR plant, reducing the footprint required to treat phosphate to lower levels.

>>> CASE STUDY: YORKSHIRE WATER, SMEATON

Yorkshire Water conducted a four-month trial of ViroFilter™ Technology to evaluate its potential to enhance the removal of phosphate from municipal wastewaters in accord with tightening consent standards in the Yorkshire region. The key objective of the work was to assess whether ViroFilter™ Technology offers a reliable, robust and economically viable solution for a small, rural, unmanned Sewage Treatment Plant (STP) to remain within its phosphate consent.

Figure 2: The entry road to Kirk Smeaton STP in West Riding, Yorkshire

The project was conducted at the Kirk Smeaton wastewater treatment plant in West Riding, Yorkshire. It comprised three separate filter configurations to compare different design scenarios, hydraulic residence times, removal efficiencies and projected filter life-spans.

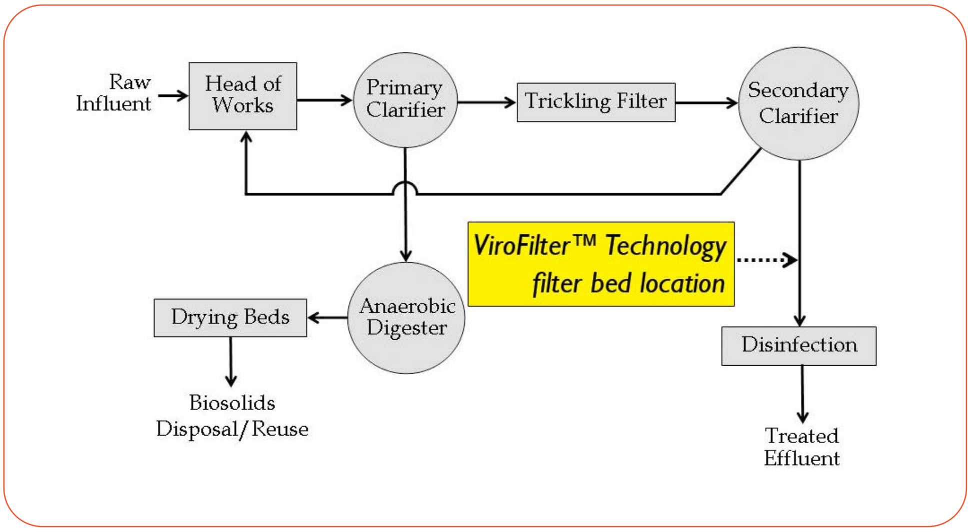


Figure 3: The ViroFilter™ Bed Location at Kirk Smeaton

>>> CASE STUDY: YORKSHIRE WATER, SMEATON

The objectives of the ViroFilter™ Technology project at Kirk Smeaton can be summarised as:

a) to assess the suitability of ViroFilter™ Technology for phosphate removal from wastewater in a trickling filter application;

b) to assess hydraulic retention times;

c) to assess the benefits of multi-stage filtration on lower media contact times against longer media contact times and single filter passes;

d) to assess the longevity of the ViroFilter™ media; and

e) to assess the ability of ViroFilter™ Technology to remove Biological Oxygen Demand (BOD), ammonia and heavy metals from municipal wastewater.

TREATMENT METHODS

Three different filter designs were employed in the field trial.

> ***Filter Pairing A***

Filter Pairing A consisted of two filters, each containing approximately 0.75m^3 of 10-25mm ViroFilter™ pellet media. Each filter had as Hydraulic Residence Time (HRT) of six hours for a total HRT of 12 hours. For four months, samples were taken from the influent point, the intermediate point between filter #1 and filter #2, and at discharge. This configuration is shown in Figure 4.

Figure 4: ViroFilter™ Technology Filter Pairing A

> ***Filter Pairing B***

Filter Pairing B consisted of a two-stage filter running in series, with each filter holding approximately 20kg of 5-10mm ViroFilter™ pellets. The filters were initially operated with a one-hour residence time in each filter, giving a total HRT of two hours across the filter pairing. During

>>> CASE STUDY: YORKSHIRE WATER, SMEATON

the project hydraulic residence time was subsequently reduced to a total of one hour across the filter pairing (30 minutes in each filter) for a two-week period and then increased to a total of three hours across the filter pairing (one and half hours in each filter).

> *Filter Pairing C*

Filter Pairing C consisted of three small filters, each filter had a residence time of four hours, giving a total Hydraulic Residence Time (HRT) across the filters of twelve hours. The three filters, like Filter Pairing B, contained approximately 20kg of 5-10mm ViroFilter™ pellets. The three filters were designed to replicate Filter Pairing A, except using three filters.

Three composite samples were taken daily, two intermediate samples (the points between each filter) and an effluent sample. The first intermediate sample was taken from a sample point between the outlet of the first filter and the inlet of the second filter; the second intermediate sample was taken from a sample point between the outlet of the second filter and the inlet of the third filter.

RESULTS

Filter Pairing A had a Total Phosphorous (TP) load of 10.3mg/L in the influent, and produced in a TP load of 5.2mg/L at the intermediate point, and a final treated effluent TP of 2.6mg/L, indicating a 74% reduction in TP. On average about 5.0mg/L of phosphate was removed by the intermediate stage and 2.5mg/L of phosphate was removed by the second (final effluent) stage. These data can be seen in Figure 5.

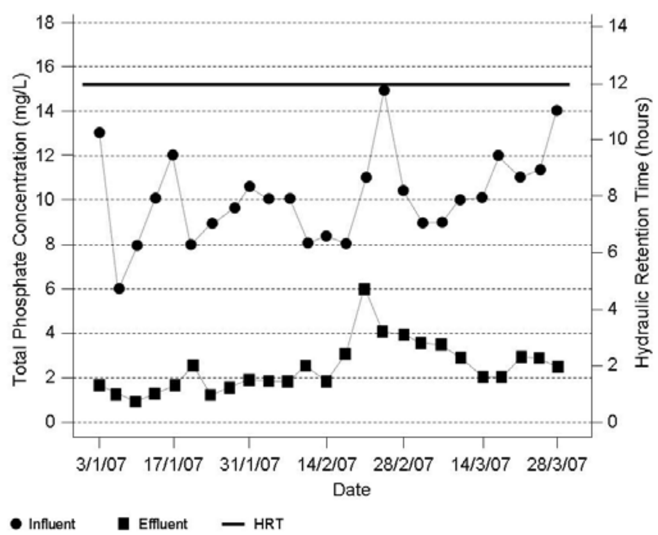


Figure 5: The influent and effluent total phosphate levels and HRT times for filter pairing A

>>> CASE STUDY: YORKSHIRE WATER, SMEATON

Filter Pairing A had an ortho-phosphate load of 9.6mg/L in the influent, and produced an ortho-phosphate load of 4.6mg/L at the intermediate point (between filters #1 filter #2), and a final treated effluent ortho-phosphate concentration of 2.1mg/L, representing a 77% reduction of ortho-phosphate concentration. Final effluent pH was on average 9.1.

Ammonia concentrations were 1.1mg/L in the influent, 1.0mg/L at the intermediate point, and 0.86mg/L in the effluent, representing a 25% reduction in total ammonia. Similarly, Biological Oxygen Demand (BOD) was 6.8mg/L in influent, and 4.3mg/L in the effluent. Reductions in chromium concentrations (0.019mg/L reduced to <0.01mg/L) and zinc (0.05mg/L reduced to <0.02mg/L) were also observed.

Filter Pairing B had a Total Phospherous (TP) load of 9.6mg/L in the influent, and produced a TP of 3.6mg/L at the intermediate point (between filters #1 filter #2), and a final treated effluent TP of 1.8mg/L, representing an 81% TP removal.

On average, about 6.0mg/L of phosphate was removed by the intermediate stage and 2.0mg/L of phosphate was removed by the second (final effluent) stage. Final effluent pH was on average 8.6. These data can be seen in Figure 6.

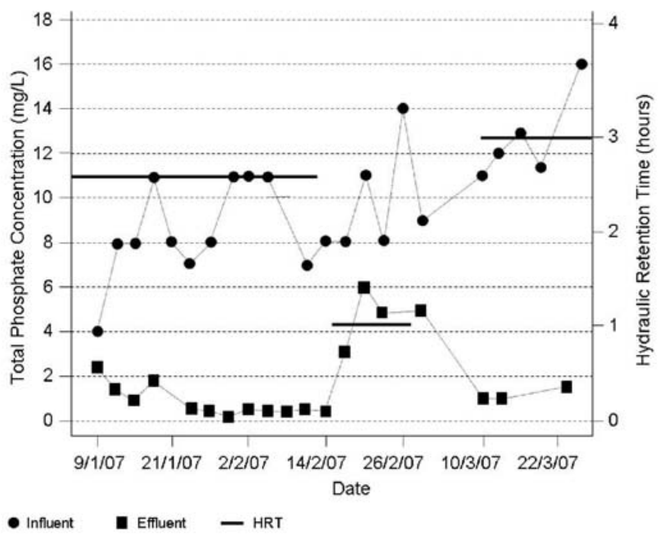


Figure 6: The influent and effluent total phosphate levels and HRT times for filter pairing B

Filter Pairing C had a TP load of 9.6mg/L in the influent, and produced a TP load of 1.1mg/L at the first intermediate point, a TP load of 0.5mg/L at the second intermediate point, and a final treated effluent TP of 0.37mg/L, representing a 95% TP reduction. On average, about 6.0mg/L of phosphate was removed by the intermediate stage and 2.0mg/L was removed by the second (final effluent) stage. Final effluent pH was on average 8.6. These data can be seen in the following Figure 7.

>>> CASE STUDY: YORKSHIRE WATER, SMEATON

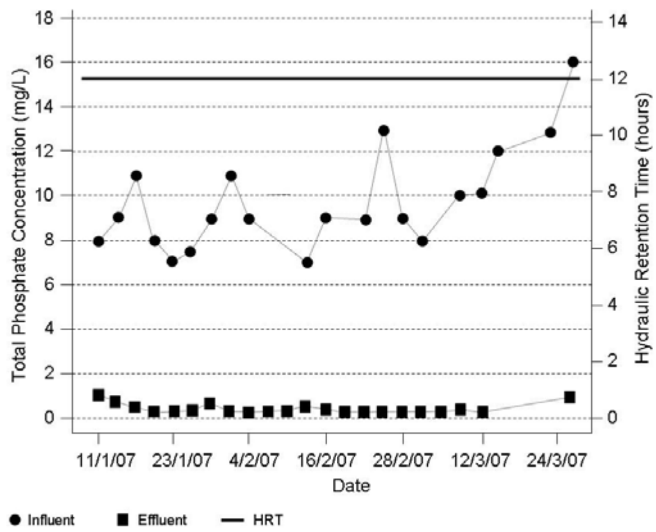


Figure 7: The influent and effluent total phosphate levels and HRT times for filter pairing C

FILTER BED LIFE

Prior applications and laboratory trials have demonstrated a loading capacity of about at least 14g/kg (14kg/m^3). These findings suggest loading rates in excess of 90%. These levels of phosphate loading are higher than for alternate methods. For example:

> ***Sand and Gravels***

It has been estimated that the phosphate adsorption capacity of a tertiary, horizontal-flow reed bed filled with the most efficient sand would be depleted in a period of about six months, while for less efficient sands Total Phosphorous (TP) removal would continue for only two months. Typical phosphate removal rates for horizontal-flow and vertical-flow reed beds are 0.4kg/m^3.

The TP removal capacity of 62 sand-based, sub-surface horizontal-flow constructed wetlands averaged of 2.1mg/L, and vertical-flow units have a typical output TP concentration of 3.3mg/L. These findings suggest that vertical-flow beds with an average operating time of five years were less effective than horizontal-flow units with an average operating time of 8.5 years. For removal levels below 1.0mg/L, both reed bed designs are inadequate. Moreover, it has been shown that bottom ash has a phosphate removal capacity of 0.06g/kg, steel slag 0.38g/kg, blast furnace slag 0.40–0.45g/kg, fly ash 0.62g/kg, shale 0.75g/kg, laterite 0.75g/kg, and zeolite 1.0g/kg.

> ***Expanded Clay***

Lightweight, expanded clay aggregates (known as Norwegian Leca/Filtralite) in reed beds have a total phosphorus removal capacity of about 0.5kg/m^3. Clay has the advantage over other mineral media that once the phosphorus removal capacity has been reached and the media requires

>>> CASE STUDY: YORKSHIRE WATER, SMEATON

replacement, it can be used as an agricultural fertiliser if waste management licensing permits. This advantage also exists with ViroFilter™ media, but the removal rates for clays are extremely low and do not compare favourably with those observed with ViroFilter™ Technology.

> *Calcite Media*

Calcite media has a Total Phosphorous (TP) absorption capacity of about 2.0kg/m^3. In practise, the TP removal capacity in calcite filters is about tenfold lower than that found under laboratory conditions. The formation of bio-films on the calcite and the short retention times in the filter explain its reduced effectiveness for TP removal.

CONCLUSION

Using the results obtained from Filter Pairing A, the longevity of the ViroFilter™ Technology system can be estimated. Assuming ViroFilter™ media remove 14g/kg, and Filter Pairing A holds a total of 1,500kg, the ViroFilter™ media has the potential to remove 21,000g of phosphate. The total amount of phosphate removed over the duration of the project was calculated to be 2,035g, thus the filter system had the potential to remove a further 18,965g. From this it can be calculated that at a 12-hour Hydraulic Residence Time (HRT) the average removal rate of phosphate over the duration of the study was 6.6mg/L.

By calculating the amount of phosphate removed in a year, it was determined that the ViroFilter™ Technology system would remove phosphate at the observed rate for 958 days, giving the filter a projected lifespan of a further 2.5 years. Utilising the same principle, with regard to a polishing filter using an HRT of six hours and a lower removal rate, the estimated lifetime of the ViroFilter™ system is about 9.5 years.

ViroFilter™ Technology is a sustainable wastewater treatment technology. The "spent" media, once fully charged with phosphate, can be reused as a soil remediation treatment media, as a soil amendment agent, or as an additive to brick and concrete manufacture as a fluxing agent or colorant. The Technology, utilising a flow-through treatment design, offers a viable alternative to conventional chemical dosing for phosphorus removal from secondary effluent.

The ViroFilter™ Technology system provided a robust, low-maintenance means of achieving phosphorus removal to extremely low levels. The system was easily fitted to the existing plant, and achieved effluent total phosphorus concentrations of 1.0mg/L-2.0mg/L. The ViroFilter™ Technology treatment system operated effectively without the need for chemical dosing or influent pH adjustment. This removed the need for chemical handling and storage, and reduced operator intervention requirements, thereby reducing cost and risk. Where necessary TP concentrations can be lowered further by placing as many additional ViroFilters in series as required.