ADVANCED PHOSPHATE REMOVAL FOR SMALL AND MEDIUM-SIZED MUNICPAL WASTEWATER TREATMENT PLANTS USING VIROSEWAGE™ AND VIROFILTER™ TECHNOLOGY

TECHNICAL PAPER

Trickling filter

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BACKGROUND

In order to help tackle eutrophication in inland and coastal waters, strict discharge limits are being imposed by environmental regulators with regard to phosphate (PO_4) concentrations in effluent from wastewater treatment plants (WWTP). Worldwide phosphate consents on final effluent discharges from WWTPs are being increasingly tightened, particularly in Europe, USA and Australia. These consents (or licenses to discharge effluent into creeks or rivers) have dropped or will drop from typically between to 5.0mg/L and 10mg/L to 2.0mg/L, but may be further tightened to <1.0mg/L in more sensitive areas.

As a result, 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 PO_4. Finding the best application to reduce PO_4 can often be problematic, particularly when extremely low consents are required, and associated costs can be high.

The need for stricter consents is supported by studies in the United Kingdom on seven lowland river catchments, which have concluded that phosphate in sewage effluent presents a greater eutrophication risk to the environment than agricultural run-off. These studies have shown that the removal of phosphates from the effluent streams of smaller rural WWTPs could be even more important than from larger works, as smaller WWTPs are typically closer to headwaters and therefore their discharge of phosphate has a more profound impact on downstream nutrient loadings in creeks and rivers and along sensitive tributaries.

The challenge for the water industry is to identify treatment options for phosphate removal which can cost-effectively achieve these high quality treatment standards. Added to this challenge for smaller (<2,000 equivalent population) WWTPs, whose discharges could represent the largest impact, are the fact that these WWTPs are often largely unmanned, are increasingly attracting the tightest consent levels due to their eco-sensitive location in farmlands, but often have the highest per kilogramme of phosphate removal costs to pay.

Virotec Global Solutions has been working with water treatment companies for the last six years applying its patented and unique ViroFilter™ Technology. This 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, and is a fully automated flow-through system which does not require constant operator supervision. ViroFilter™ Technology has been approved for application by environmental regulators in many countries, including United Kingdom, USA and Australia.

DISADVANTAGES OF CURRENT METHODS

As well as representing a significant cost, current methods for phosphate removal have a number of disadvantages when considered for use in small to medium-sized WWTPs.

> Chemical Dosing

Whilst generally effective (<2.0 mg/L phosphate can sometimes be achieved), chemical dosing by direct addition requires accurate and variable dosing equipment as effluent quality and quantity vary according to diurnal and seasonal flows, with appropriate influent and effluent pH adjustment requiring sophisticated control systems. Chemical dosing also requires strict health and safety handling controls due to ferric chloride being a hazardous chemical and requires regular operator intervention; chemical dosing also typically requires increased space and bunded storage requirements. Treatment using chemicals for phosphate removal also results in a higher sludge olume production, imposing additional sludge treatment costs and disposal problems. The fear of overdosing, which could result in iron carry-over into the final discharge, also presents a significant environmental risk.

> Biological Treatment

Biological treatment requires a steady, biodegradable carbon source in the effluent, such as brewery or food waste. Incorporating biological treatment may involve the restructuring of a works' treatment process and typically requires chemical dosing as a back-up for fail safety.

What is required, therefore, is a simple-to-install, low maintenance, and passive treatment alternative to such conventional approaches for phosphate removal. For any alternative to be viable in the competitive market of wastewater treatment, it must also be cost-competitive. ViroFilter™ Technology from Virotec offers such an alternative.

VIROFILTER™ TECHNOLOGY OVERVIEW

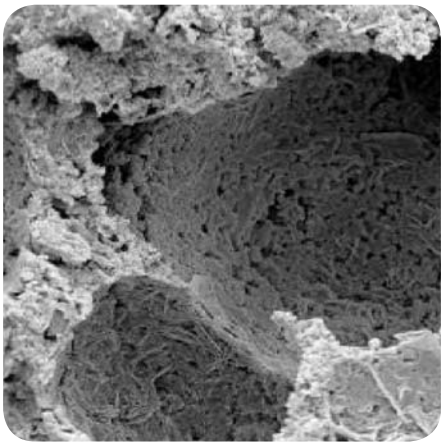
ViroFilter™ Technology is a "flow-through" system, eliminating the need for sludge treatment, thickening and filter cake pressing, reducing the footprint required to treat higher levels of phosphate, and providing an effective and simple system. The technology can also be used as a final polishing step, prior to effluent discharge. Phosphate removal occurs by a variety of ionic and precipitation reactions within the porous pellet matrix. The pellets also act as an immobilisation substrate for bacteria to promote biological activity.

ViroFilter™ Technology uses a porous pellets media, which comes in a range of particle sizes, typically 5-10mm, 10-20mm, or 20-25mm.

ViroFilter™ Technology offers a solution to the problems highlighted above. By passing secondary effluent through the pelletised media (see Figures 1 and 2), effective phosphate removal to low concentrations can be achieved with no requirement to add flocculants or adjust influent pH. This reliable and cost-effective approach offers a solution for many of the problems associated with conventional chemical dosing, producing an effluent reduced in COD, BOD, suspended solids, odour and colour, and successfully binds excess iron released in the effluent, therefore preventing iron carry-over.

As shown in the example of a typical filter configuration (see image lower page 4), the technology provides a simple "flow-through" system at the back end of the treatment process. The immobilised pellet bed allows for variations in hydraulic flow and phosphate concentrations, and upstream chemical dosing is not required. The technology results in a significantly reduced level of sludge production and thereby lowers disposal costs.

Where phosphate discharge consents of <1.0mg/L or <2.0mg/L are required, removal efficiency of PO_4 is approximately 80% per pass (per filter bed volume). Bed residence times are typically between four and 12 hours, depending on influent PO_4 levels and consent (or treatment target) levels. PO_4 removal capacity is greater than other conventional filter media, with beds typically designed to last between two and three years. More effective and longer term removal efficiencies when the system is configured as a two- or three-bed system in series, allowing removal effectiveness to below 1.0 mg/L are also achievable. A minimum phosphate removal capacity of 14 grams of phosphate per kilogramme of pellets is typical of loading capacity. This loading capacity equates to bed (or filter) longevities of one to seven years, depending on influent phosphate levels, customer and site requirements, including flow rates, site consent levels, and system design criteria.



This photograph shows the highly porous nature of the ViroFilter™ pellets and the good interconnection between pores. Large internal and external reactive surfaces add to the efficient removal of contaminants.

In addition to PO_4 removal through ViroFilter™ Technology, the system 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.

The ViroFilter™ Technology treatment system is packed with the pelletised media, and can be fitted "in-line" with existing secondary treatment systems to ensure that phosphate discharge consents are readily met. The immobilised pellet treatment beds can either be configured for horizontal-flow, 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) may be retro-fitted to accommodate the system.

ViroFilter™ Technology can be designed to employ any upwardly or downwardly flowing filter configuration, of which this is an example

The only requirement is that the secondary effluent is evenly distributed across the pellet bed to maximise contact with the active internal and external surfaces of the media. Use of an immobilised bed allows variations in hydraulic flow and phosphate concentrations, leading to ease and simplicity of operations under varying conditions.

ViroFilter™ Technology, when used at small to medium-sized WWTPs, can be deployed as a standalone solution for tertiary treatment, or for final "polishing" of effluent at larger works. Variable bed designs and configurations can include horizontal flow beds, vertical flow beds, trickling filters, and include flexibility in design, duty and standby configurations, parallel or series operation, and can be retro-fitted to existing assets (such as reed beds, lagoons, or disused sludge drying beds).

The image (left) example of a lagoon being retro-fitted in this way to contain the pellet media.

For sensitive locations, ViroFilter™ pellets can be further enhanced for greater phosphate removal, reducing phosphate levels to below 0.5mg/L, and "spent" or fully-charged pellets can be reused in agriculture, as they are "phosphate-enriched".

ViroFilter™ Technology can be retrofitted to existing assets, such as reed beds, lagoons or disused sludge drying beds

The chemical properties of ViroFilter™ Technology pellets are unique, as they can neutralise between 3.5-7.5 moles of acid/kg, have a very high metal binding capacity (up to 1,500 meq of metals/kg), contain a multi-charged surface for potential PO_4 reaction sites, are classified as a product and approved for use in the UK and Australia, and are registered under TOSCA in the United States.

The physical properties of the raw materials in the pellets are also unique in that they have a high charge-to-mass ratio and a high surface area-to-mass ratio, are composed of up to 80% of solid grains 10µm or less in dry powder or slurry, are highly insoluble and non-dispersive in water, display extremely fast settling times when applied as a solid with a specific gravity of 3.2 g/cm3, and produce a stable sediment not a sludge when applied directly to water.

For these reasons, ViroFilter™ Technology can be summarised by the following:

- Uses **environmentally** sustainable range of patented products;
- Is a viable **solution** for acidity, and metal and phosphate problems;
- **Neutralises** acidity;
- **Removes** phosphates (>85%) from wastewater and clean water;
- **Removes** metals (>99%) from wastewater and drinking water;
- **Destroys** objectionable odours;
- **Binds** heavy metals in non-leachable and non-bioavailable form;
- **Binds** phosphates in a slow release bioavailable form;
- Is a **passive**, flow-through treatment using pelletised media thereby allowing for easy operations and maintenance; and,
- **Direct** addition to wastewater creates a dense, easily dewaterable sediment, reducing sludge volumes.

INDEPENDENT RESEARCH

Research conducted by the independent industry association, Water Research Council (WRc) in the United Kingdom, has investigated the kinetics, chemistry and outcomes of applying ViroFilter™ Technology for phosphate treatment. In addition, AquaEnviro, a UK-based consultancy based in Wakefield, have conducted extensive independent field trials on ViroFilter™ Technology for a large UK regional water company at a municipal wastewater treatment plant in the UK. This section outlines the findings of these independent research studies.

> Water Research Council

Objectives

The objectives of the research were to examine the hydraulic characteristics of the flow-through bed design, evaluate the influence of filter bed residence time on phosphate removal efficiencies, calculate PO_4 removal efficiencies and filter bed lifetimes, and other "side benefits" for COD, BOD, and suspended solids removal efficiencies. The findings of the research as they relate to this Technical Paper are presented below.

Design

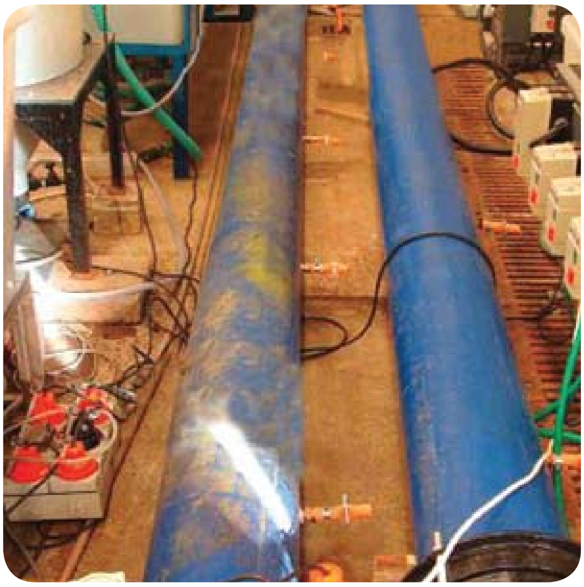
In this research, the WRc constructed horizontal pipes (0.2m diameter x 6m length constructed from medium density polyethylene) were set up and labelled "Reactor A" and "Reactor B". End caps were bolted onto the pipes using Viking Johnson flange adaptors. The inlet and outlet ports had internal diameters of 12mm, and were at a height of 50mm and 150mm, respectively, above the base of the pipe. The difference in height between the inlet and outlet ports was required to maintain a constant liquid level and minimise any short circuiting that could occur within each Reactor.

Sample ports were spaced at a distance of 0.5m from the inlet side of the Reactor, and at intervals every 1.0m thereafter to obtain a P removal profile along the full length of each Reactor. The first and last 0.5m of each Reactor was filled with 10mm gravel to assist flow distribution and simulate the flow distributors used in reed beds installed at small WWTP. Figure 5 shows the filter configuration as they were used in the trial.

Virotec is able to engineer the pellets used in its ViroFilter™ Technology with specific characteristics for different applications, and in a variety of graded sizes. The size must ensure that pores will adsorb P and not rapidly block up from the accumulation of suspended solids present in the final effluent. Selection of the media size was partly based on what had previously been used on the laboratory scale to enable a comparison of the results at the two different scales and also on reed beds, which have media sizes between 2.0 and 12 mm. The majority of the media chosen for this project was 2.0-8.0mm in size, except for the first 2m of Reactor B, which was filled with pellets in the size range from 5.0-12mm.

> Stage 1 – Parallel Operation

For the main period of the project (23 weeks for Reactor A and 22 weeks for Reactor B), the two filters were operated as two independent Reactors in parallel. The pH of the wastewater entering Reactor A was reduced from an average of 7.4 down to pH 6.5-6.8 by dosing hydrochloric acid into a mixing tank prior to pumping the influent into the filter. The influent entering the Reactor B was not pH adjusted. A direct comparison of the performance between the two systems could therefore be made in terms of P removal efficiency.



The ViroFilter™ Technology design used by the WRc

> Stage 2 – Series Operation

In the final five weeks of operation, the configuration in the Reactors was changed to in-series operation, and acid dosing was discontinued to investigate the effect of path length on P removal.

The effluent from Reactor A was pumped into Reactor B before passing to the drain. The start-up flow rate for both Reactors was designed to give an HRT of four hours, which is shorter than the HRT that would be used for a full-scale bed. This HRT maximised the phosphate loading onto the bed to better evaluate P removal capacity within the time restrictions of the project. As the effluent P concentrations began to rise in each Reactor, the influent flow rates were dropped to reduce the applied P load and thereby maintain effluent P concentrations of less than 2.0mg/L. The flow rates tested during parallel operation were adjusted to achieve HRTs between four and 12 hours, and during in-series operation the overall flow rate through both reactors was set to achieve HRTs of between 12 and 16 hours.

> Monitoring

Daily monitoring of the temperature and flow rates through both reactors (including the acid dosing pump) was performed. Influent and effluent samples were taken weekly from each filter for the analysis. Samples from each port down the length of the reactors were taken daily and combined once a week to give a five-day composite sample. The composite samples were analysed for Total-P concentration to give a profile down each reactor. The settled sewage used in the tests is domestic in origin and the soluble orthophosphate was usually over 95% of the Total-P. The pH of the samples down the length of the reactors was also measured on a spot sample basis. The odour of the influent and effluent samples was qualitatively compared once a week but there were no unusual odours generated.

> Bed Retention Times and Phosphorus Removal

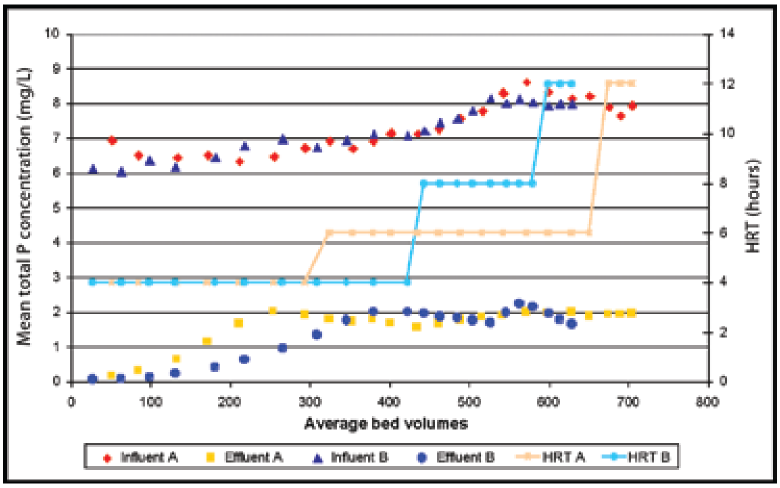
Table 2 presents the influent and effluent composite Total-P concentrations during the period of parallel operation. The data are presented as three-week rolling averages to show the gradual increase in influent P levels from 6.0mg/L to 9.0mg/L during the trial. Midway through the trial the hydraulic retention time or "HRT" in Reactor A was increased from four to six hours and that of Reactor B from four to eight hours, to maintain a low effluent P concentration. Towards the end of the trial, the HRT in Reactor B was increased to between 11 and 12 hours to control effluent P.

> Results

Table 2 shows the relationship between influent Total-P levels versus effluent Total-P levels as a function of the number of bed volumes (i.e., the number of times effluent passed through the ViroFilter™ Technology filter beds on a per bed volume basis). This comparison is then matched to the residence time the influent remained in contact with the pellet media, represented as HRT. It was found that as HRT was increased from three to eight to 12 hours due to higher levels of influent P, removal efficiencies remained the same, although effluent P levels predictably rose.

Results from long-term laboratory trials using ViroFilter™ pellets and trends observed in the WRc research suggest that up to 2,000 bed volumes of PO_4 rich effluent can processed by one filter when used in an upward flow design. For such an application, HRT is approximately six hours (however, reed bed applications may be as long as 24 hours). In this configuration, >80% P is removed in a single pass, with a further 80% P removed in each subsequent pass.

TABLE 2: INFLUENT AND EFFLUENT P CONCENTRATIONS FOR TWO MUNICIPAL WASTE WATER FLOWS



As shown in Table 3, the WRc data demonstrated a PO_4 loading capacity of approximately 6.0 g/kg of pellets due to the limited length of the research. However, long-term laboratory trials have indicated that this is as much as >14g/kg (14kg/m3) when pellets are exposed to PO_4 for longer times. In both cases, loading rates are in excess of 90%. These levels of PO_4 loading capacity are significantly higher than for alternate methods. For example, the WRc have reported the following:

> Sand and Gravels

It has been estimated that the adsorption capacity of a tertiary horizontalflow reed bed filled with the most efficient sand would be used up in a period of about six months, while for less efficient sands P removal would only continue for two months. For example, P removal rates of 0.4kg/m3 for horizontal-flow reed beds and 0.4kg/m3 for vertical-flow reed beds are not uncommon. It has also been shown that a study on the P removal capacity of 62 sand-based sub-surface flow constructed wetlands in Germany, Austria and Switzerland found that while 50% of all the horizontal-flow units had an average P output concentration of less than 2.1mg/L, the vertical-flow units had an output concentration of 3.3 mg/L. This indicates 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, neither reed bed design has proven inadequate.

> Expanded Clay

It has been shown that lightweight expanded clay aggregates (known as Norwegian Leca/Filtralite) in reed beds have a P removal capacity of about 0.5 kg/m3. This approach has the advantage over most mineral media that once P removal capacity has been reached and the media requires 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 expanded clay are extremely low and do not favourably compare with ViroFilter™ Technology.

> Calcite Media

Tests indicate that this type of media has a P sorption capacity of about 2.0kg P/m3, significantly less than the >14kg/m3 cited for ViroFilter™ Technology. A study found that the P removal capacity in calcite filters was about tenfold lower than that found under laboratory conditions. It was reported that the formation of bio-films on the calcite and the short retention time in the filter may explain its reduced effectiveness for P removal.

In both the WRc research and long-term laboratory trials, no phosphate breakthrough in the filter has been observed. As found with other applications of the technology when applied as a direct addition into the waste stream, evidence of odour removal on passage through the ViroFilter™ bed is to be expected.

TABLE 3: CUMULATIVE P LOADING RATES AND REMOVAL EFFICIENCIES

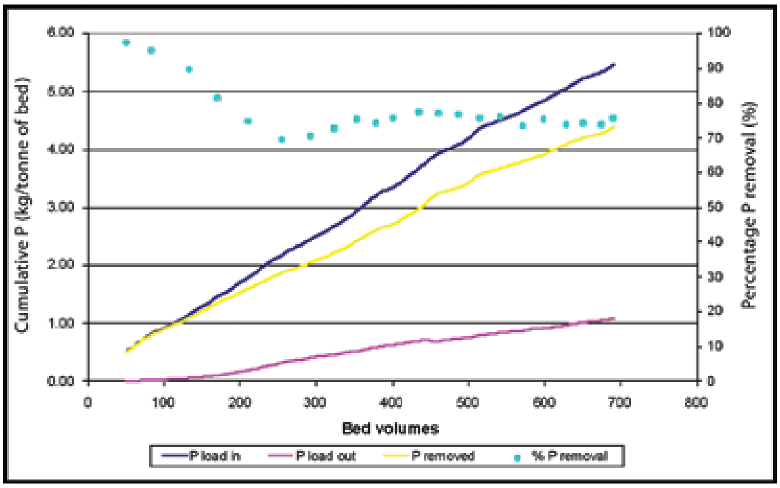


TABLE 4: INFLUENT AND EFFLUENT LEVELS BEFORE AND AFTER VIROFILTER™ TECHNOLOGY WHEN INFLUENT LEVELS ARE AN AVERAGE OF 8.0MG/L

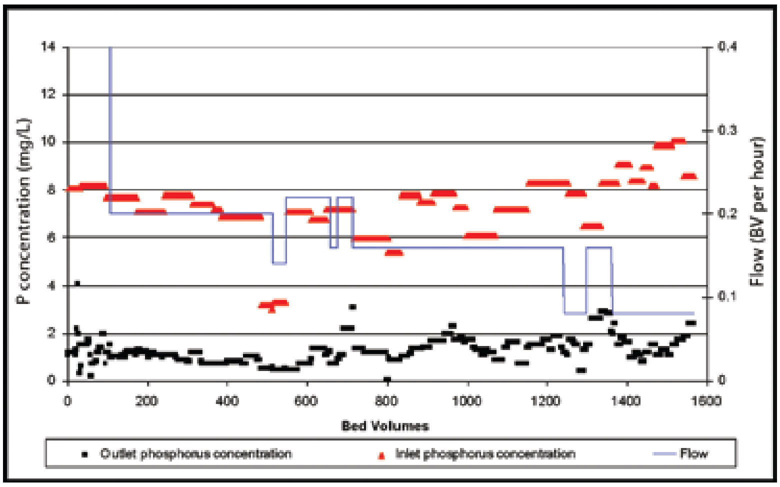
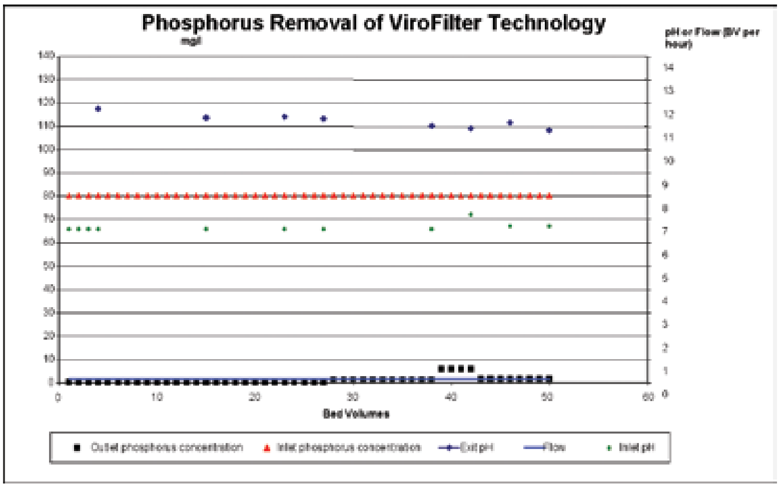


Table 4 shows the total P concentrations in both the influent and effluent as a function of time. It can be clearly seen in this Table that effluent P levels below 2.0mg/L can be routinely reached when influent P levels average 8.0mg/L. These influent levels are very typical of most P levels at the tertiary stage of treatment in small and medium-sized WWTP. These removal levels were also observed when influent P averaged 80mg/L, as shown in Table 5.

TABLE 5: INFLUENT AND EFFLUENT LEVELS BEFORE AND AFTER VIROFILTER™ TECHNOLOGY WHEN INFLUENT LEVELS ARE AN A AVERAGE OF 80.0MG/L



The WRc research also showed that total suspended solids were reduced from an average of 12mg/L in the influent to an average of 4.0mg/L in the effluent across both Reactors. However, it should be cautioned that high levels of suspended solids in the influent of wastewater entering the ViroFilter™ Treatment system is likely to result in the clogging of the filter beds, although the longterm effect of this on PO_4 removal is not well understood at this time.

Similarly, it was observed that both Reactors removed an average of 30% COD (reducing COD from an average of approximately 50mg/L to 30mg/L. Both Reactors also demonstrated the ability of ViroFilter™ Technology to reduce BOD. While generally quite low in the influent stream at an average of 5.0mg/L, ViroFilter™ Technology nevertheless reduced these levels by approximately 80% to around 1.0mg/L.

> AquaEnviro Research

Objectives

The objectives of the field trial at a wastewater treatment plant in the UK were:

a. to assess the suitability of ViroFilter™ Technology for phosphate removal from wastewaters in a trickling filter type application;

b. to assess hydraulic retention times ("HRT");

c. to assess the benefits of multistage filtration on lower media contact times than 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 BOD, ammonia and heavy metals from municipal wastewater.

ViroFilter™ Technology Filter Pairing A

Design

Three different filter designs were employed in the field trial.

Filter Pairing A

Filter Pairing A consisted of two filters each containing approximately 0.75m3 of 10-25mm ViroFilter™ pellet media. Each filter had an HRT of six hours. For three 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 the previous image.

Filter Pairing B

Filter Pairing B was 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 the project HRT was subsequently reduced to a total of one hour across the filter pairing (30 minutes in each filter) for a two-week period.

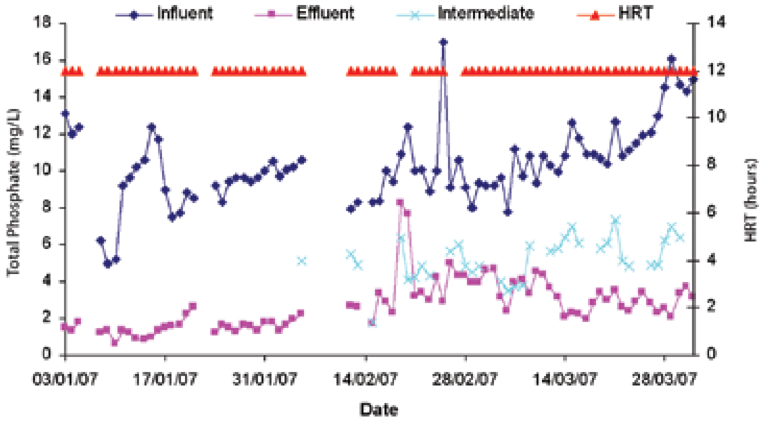
Filter Pairing C

Filter Pairing C contained three small-scale filters, each filter had a residence time of four hours, giving a total 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 situated between the outlet of the first filter and the inlet of the second filter; the second intermediate sample was taken from a sample point situated between the outlet of the second filter and the inlet of the third filter.

Results

Filter Pairing A had a total PO_4 load of 10.3mg/L in the influent, resulted in a total PO_4 load of 5.2mg/L at the intermediate point, and resulted in a final treated effluent total PO_4 of 2.6mg/L, resulting in a 74% reduction of total PO_4. On average approximately 5.0mg/L of total PO_4 was removed by the intermediate stage and 2.5mg/L of total PO_4 was removed by the second (final effluent) stage. This data can be seen in Table 6.

TABLE 6: THIS TABLE SHOWS THE INFLUENT, TWO INTERMEDIATE POINTS, EFFLUENT

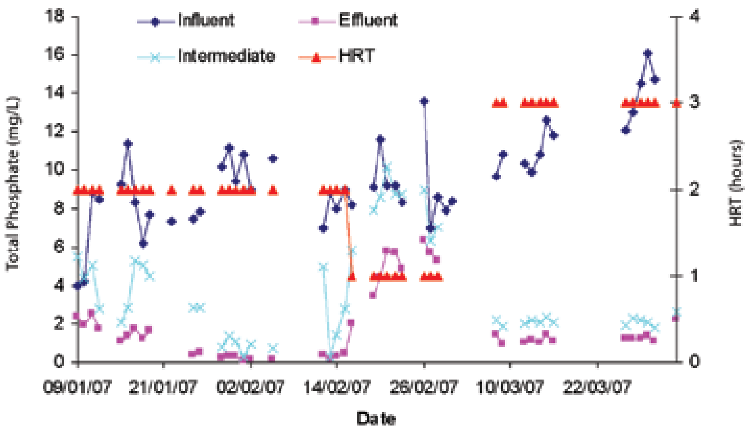


TOTAL PO4 LEVELS IN MG/L AND HRT TIMES FOR FILTER PAIRING A

Filter Pairing A had a total ortho-PO_4 load of 9.6mg/L in the influent, resulted in a total ortho-PO_4 load of 4.6mg/L at the intermediate point, and resulted in a final treated effluent total ortho-PO_4 of 2.1mg/L, resulting in a 77% reduction of total ortho-PO_4. Final effluent pH was on average 9.1. Total ammonia levels were 1.1mg/L at influent, 1.0mg/L at the intermediate point, and 0.86mg/L at effluent, representing a 25% reduction in total ammonia. Similarly, BOD was 6.8mg/L at influent and 4.3mg/L at effluent, a 35% reduction. Reductions in chromium and zinc were also observed.

Filter Pairing B had a total PO_4 load of 9.6mg/L in the influent, resulted in a total PO_4 load of 3.6mg/L at the intermediate point, and resulted in a final treated effluent total PO_4 of 1.8mg/L, resulting in an 81% PO_4 reduction in total PO_4. On average approximately 6.0mg/L of total PO_4 was removed by the intermediate stage and 2.0mg/L of total PO_4 was removed by the second (final effluent) stage. Final effluent pH was on average 8.6. This data can be seen in the following Table 7.

TABLE 7: THIS TABLE SHOWS THE INFLUENT, TWO INTERMEDIATE POINTS, EFFLUENT TOTAL PO4 LEVELS IN MG/L AND HRT TIMES FOR FILTER PAIRING B



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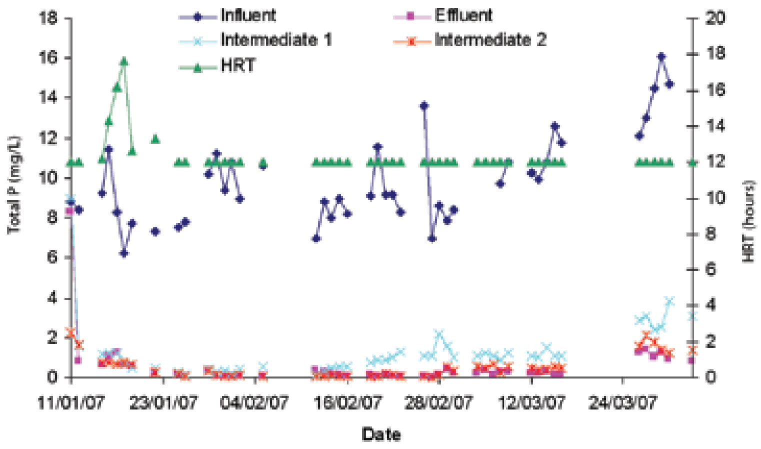
Filter Pairing C had a total PO_4 load of 9.6mg/L in the influent, resulted in a total PO_4 load of 1.1mg/L at the first intermediate point, resulted in a total PO_4 load of 0.5mg/L at the second intermediate point, and resulted in a final treated effluent total PO_4 of 0.37mg/L, representing an 81% reduction in total PO_4. On average approximately 6.0mg/L of total PO_4 was removed by the intermediate stage and 2.0mg/L of total PO_4 was removed by the second (final effluent) stage. Final effluent pH was on average 8.6. This data can be seen in Table 8.

Filter Bed Life

Extrapolating the results obtained from Filter Pairing A the longevity of the ViroFilter™ Technology system can be estimated as follows:

TABLE 8: THIS TABLE SHOWS THE INFLUENT, TWO INTERMEDIATE POINTS, EFFLUENT TOTAL PO4 LEVELS IN MG/L AND HRT TIMES FOR FILTER PAIRING C



Assuming the ViroFilter™ media removes 14g/kg (a previously determined estimate), and Filter Pairing A holds a total of 1,500kg in the two filters, there is the potential to remove 21,000g. The total amount of P removed over the duration of the study was thus calculated to be 2,035g. If 21,000 – 2,035.21 = 18,965g (i.e., amount of P still to be potentially removed by the ViroFilter™ media), then it can be calculated that at a 12-hour HRT the average removal of P over the duration of the study was 0.0066g/L. Multiply this by the flow/day = 0.0066 x 3000 litres = 19.8 g/d removal of P. Therefore by dividing the amount of P still to be removed by the average amount removed per day: 18,965 / 19.8 = 958 days or 2.5 years remaining life for the ViroFilter™ media. Utilising the same principle, with regard to a polishing filter using an HRT of six hours and a removal of one gram the estimated lifetime of the media would be approximately 9.5 years.

In summary, this research found the following:

a. ViroFilter™ Technology removed total phosphate and total ortho-phosphate to approximately 80% from wastewaters in a trickling filter type application;

b. HRTs for the trial showed that Filter Pairing B (two hours) and Filter Pairing C (12 hours) resulted in PO_4 discharge levels below 2.0mg/L;

c. multi-stage filtration resulted in greater PO_4 removal rates;

d. the estimated bed life of the ViroFilter™ media was between 2.5 and 9.5 years depending on HRT and levels of

PO_4; and,

e. ViroFilter™ Technology was effective in removing 35% of BOD, 25% ammonia and some heavy metals from municipal wastewater.

These findings are largely consistent with the application of ViroFilter™ Technology when applied as a direct addition to municipal wastewater after biological treatment but before secondary clarification, as shown in Table 9. For example, the following chart shows the results of applying ViroFilter™ Technology (called ViroSewageTM Technology in the Australian market) to a small municipal WWTP in Queensland. Rates of PO_4 removal, as well as BOD, total suspended solids, turbidity, colour, odour, and clarity have been measured. Note, the reductions of nitrogen observed in this data do not appear to apply to ViroFilter™ Technology. Dosing for these results occurred at dosing location 2 as shown in Figure 7.

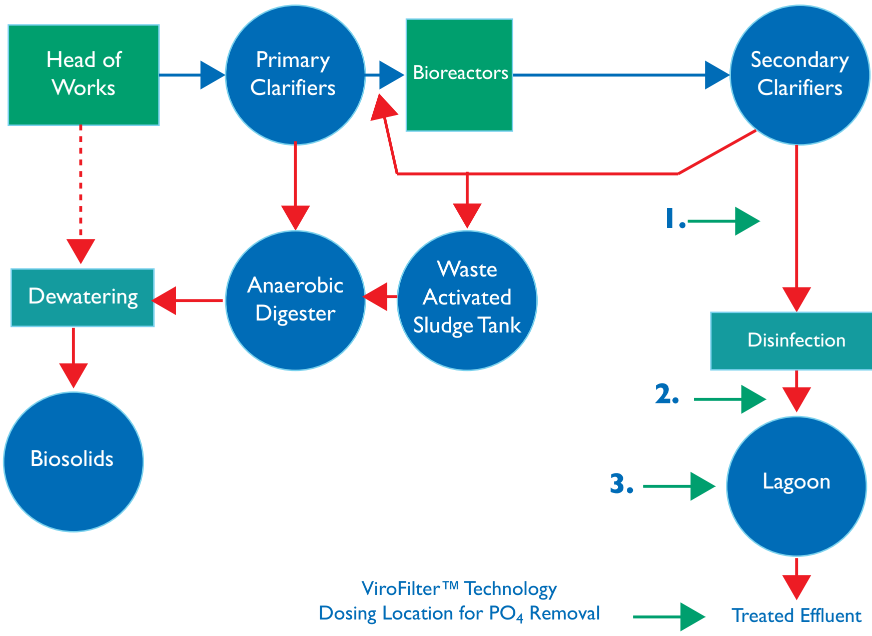
TABLE 9: INFLUENT AND EFFLUENT LEVELS BEFORE AND AFTER VIROSEWAGE™ TECHNOLOGY WHEN COMPARED TO CONVENTIONAL SEWAGE TREATMENT

Paramet00 kL/dayer	Raw Sewage	After Conventional Treatment	After ViroSewage™ Technology Treatment
Hydraulic Capacity	2000 EP	2000 EP	3000 EP
Hydraulic Throughput	400 kL/day	500 kL/day	600kL/day
Total Suspended Solids	365 mg/L	20 mg/L	3.3 mg/L
Biochemical Oxygen Demand	411 mg/L	30 mg/L	10.3 mg/L
Total Phosphorus	53 mg/L	14 mg/L	0.05 mg/L
E-Coli	26,000,000 cfu	10,000 cfu	7,000 cfu
Total Nitrogen	66.3 mg/L	13 mg/L	4.0 mg/L
Total Metals	0.6 mg/L	0.6 mg/L	0.2 mg/L
Colour	125 PCU	35 PCU	10 PCU
Turbidity	276 NTU	16 NTU	1.2 NTU
Clarity	20 mm	200 mm	2,200 mm
pH	8.0 - 9.7	6.8 - 7.3	7.0 - 7.2
Odour Level	Extremely High	High	Extremely Low
Bio-solids quality for composting	-	Poor	Very Good

APPLICATIONS

ViroFilter™ Technology has been successfully applied at the treatment locations shown in Figure 7. ViroFilter™ Technology can be applied at a point after secondary clarification but before disinfection as a filter for removing total PO_4 before final discharge to a lagoon or reed bed (location 1). ViroFilter™ Technology can be applied at a point after disinfection as a filter for removing total PO_4 before final discharge to a lagoon, reed bed, river or creek (location 2).

FIGURE 9: VIROFILTER™ TECHNOLOGY CAN BE APPLIED AT THREE POINTS IN THE WWTP



ViroFilter™ Technology may also be applied as a tertiary treatment stage in a retrofitted lagoon or reed bed (location 3).

ViroFilter™ Technology is flexible and can be scaled to any application. The following example is for a small WWTP using a retrofitted lagoon configuration.

Design parameters for the ViroFilter™ Technology system:

> Projected equivalent population = 1,600;
> Flow of 400m3/day;
> Influent concentration: 6.0-8.0mg/L (total P); and,
> Effluent concentration: 2.0mg/L (total P).

System size:

> 200m3 required for optimum contact time, assuming a 12 hour HRT; and,
> Pellets size range of 10-25mm.

Configuration:

> 2 x 100m3 beds running in series, to optimise system size and operation;
> System operated in horizontal flow mode; and,
> System retrofitted to existing lagoon.

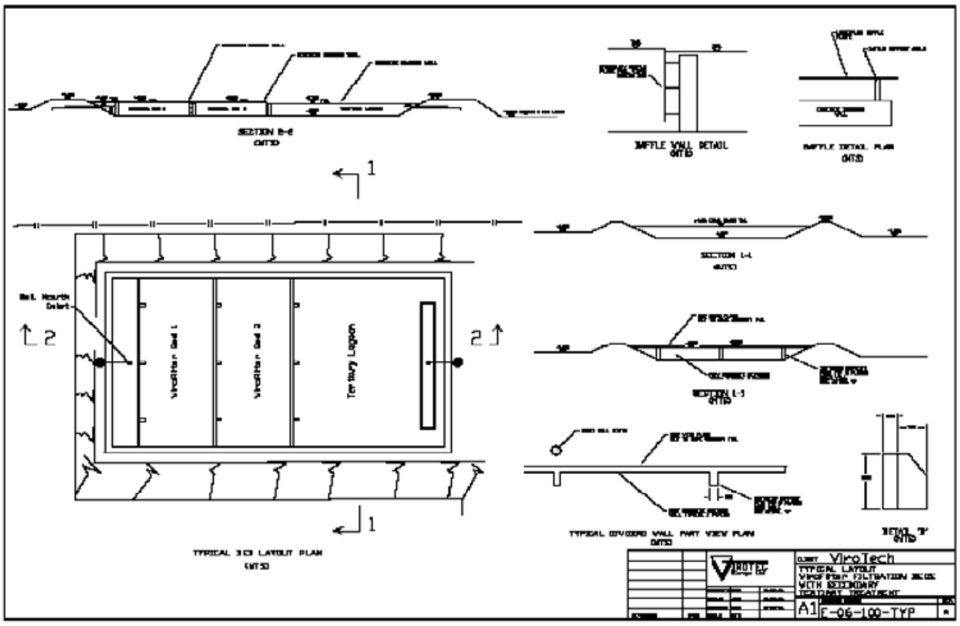
Longevity:

> Three years to replacement of media.

Two options for implementation of ViroFilter™ Technology typically apply:

> A complete turnkey installation by Virotec; or,
> The design of a ViroFilter™ Technology system by Virotec and the water company, and the fabrication, installation, and commissioning of the ViroFilter™ Technology system by either the wastewater company or Virotec, with the supply of know-how, technical advice, troubleshooting and technical support by Virotec.

CONCEPTUAL SCHEMATIC DESIGN OF A VIROFILTER™ TECHNOLOGY TREATMENT SYSTEM APPLIED AS A LAGOON OR REED BED RETROFIT

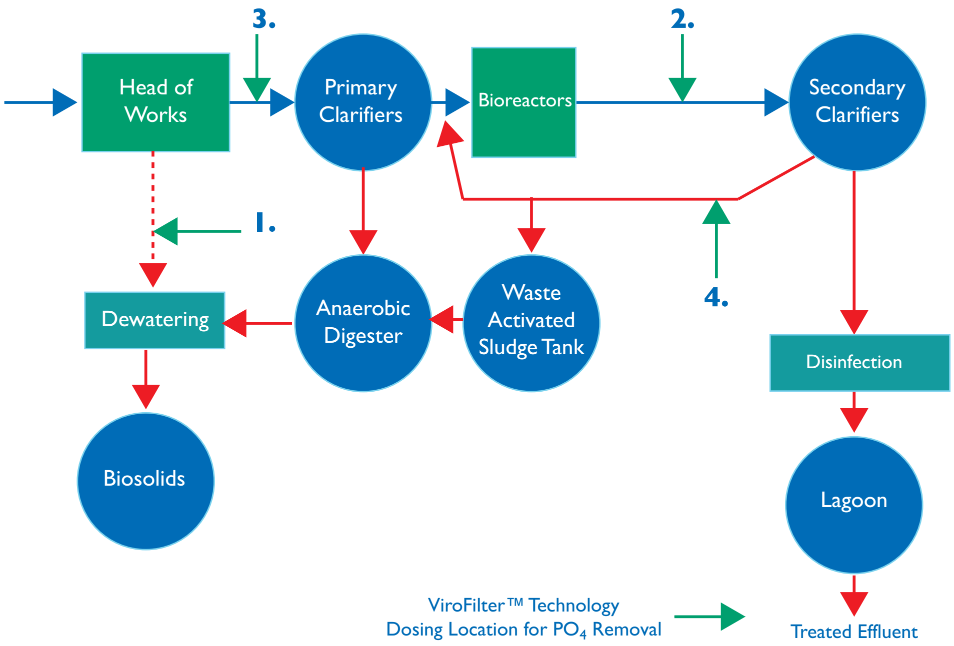


If applicable, ViroFilter™ Technology can also be implemented to treat the extremely high levels of phosphate found in centrate ("filtrate"), liquor from the centrifuge which is typically returned to the head of works or primary clarifier (as shown in Figure 10). This centrate is extremely high in phosphate, often as high as 300-500mg/L, and its return to the head of works loads the plant with nutrients which puts great additional strain on the biological treatment phase and the secondary clarifier, thereby adding to the likelihood of phosphate to be present at higher levels in the discharge water, thus making compliance with low consents even harder. An example of a centrifuge dewatering system can be seen in the image (right), in this application, the ViroFilter™ reagent is dosed by direct addition to dosing location 1 in Figure 10.

Similarly, ViroFilter™ Technology can be applied as a direct addition of chemical additives in slurry form with dosing at any one of the following dosing locations in Figure 10.

ViroFilter™ Technology can be dosed as a slurry to the sebtrate line (or 'filtrate' line) to reduce very high loadinfs of PO_4 in the plant

FIGURE 10: VIROFILTER™ TECHNOLOGY CAN BE APPLIED AT THESE FOUR DOSING LOCATIONS IN THE WWTP WHEN DOSED AS A DIRECT ADDITION.



CONCLUSIONS

ViroFilter™ Technology is a sustainable approach to removing PO_4 from wastewater, creating reusable products; the "spent" media, once fully charged, has the potential to be reused as a soil remediation treatment media and soil amendment agent, and as an additive to brick and concrete manufacture as a fluxing agent or colorant. Removal of media from the filter or retrofitted lagoon or reed bed can occur easily by suction.

ViroFilter™ Technology, a passive pellet flow-through treatment system, offers a viable alternative to conventional chemical dosing for phosphorus removal from secondary effluent. The ViroFilter™ Technology treatment system provides a robust, low-maintenance means of achieving effective phosphorus removal to extremely low levels, with very competitive longevity of the system. It is easily fitted (or retro-fitted) to existing treatment systems, and achieves effluent concentrations of 1.0mg/L-2.0mg/L total phosphorus. A ViroFilter™ Technology treatment system will operate effectively without the need for chemical dosing or influent pH adjustment. This removes the need for hazardous chemical handling and storage, and reduces operator intervention requirements.

Example of dosing ViroFilter™ Technology as slurry at location 2 in Figure 10, into the Return Activated Sludge ("RAS") line at Brisbane Water, Australia

ViroFilter™ Technology is particularly cost competitive for small and medium-sized works, with a clear cost differential (particularly over chemical dosing) for works of population equivalents of up to 10,000.

ViroFilter™ Technology's competitive phosphate removal costs and low maintenance requirements make it a robust and cost-effective solution to meet strict discharge consents set for phosphorus by regulators, especially at smaller, sometimes remote or inaccessible, wastewater treatment works.

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