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Complex challenge of phosphorus removal

Removing phosphorus from wastewater is going to become even more difficult. MWH Global wastewater experts, **Julie Jeavons** and **Ajay Nair**, review what the new Asset Management Programme 6 (AMP6) consents will mean for the United Kingdom and discuss phosphorus removal lessons that could be learned from Australia and the United States.

Since the introduction of the European Union (EU) Urban Wastewater Treatment Directive in 1991, phosphorus removal from wastewater has been an issue for water companies in the United Kingdom. This challenge has grown with the introduction of the EU Water Framework Directive, which became UK law in 2003. The UK AMP6 now heralds even tighter phosphorus consent limits. Consent values of less than 0.5 milligrams of phosphorus per liter (mgP/l) are now under discussion, while iron limits are being tightened. These consents are achievable by intertwining technical solutions with other factors such as reducing operating costs, minimizing carbon and water footprint, increasing energy production, and overall resource recovery.

Twenty years ago, Australia and the United States saw the environmental impact of phosphorus in receiving waters. It was depleting oxygen in water, encouraging the growth and decomposition of oxygen, depleting plant life, and harming other organisms (eutrophication). This reduced the recreational value of water and drove the need for tighter phosphorus discharge permits.

To meet very low phosphorous targets, MWH was involved in the design of wastewater treatment plants in Sydney – treating 1.3 to 4 million liters of wastewater per day. A range of processes, including biological phosphorous removal methods, is deployed at the Sydney plants. MWH also deployed biological nutrient removal with chemical back up and tertiary filtration at Iowa Hill and Pinery in Colorado, United States to achieve 0.5 and 0.05 mg/l P permit conditions, respectively.

Sustainable “P”

Biological nutrient removal has not been widely adopted in the UK. Instead, chemical dosing is the standard method employed by most UK water companies. This is partially due to the higher number of filter works, but co-precipitation in activated sludge plants or oxidation ditches is also practiced, coupled with the perception that biological excess phosphorus removal and anaerobic digestion are mutually exclusive (although recent studies are showing the effect is not as pronounced as initially considered). By 2015, more than 650 UK wastewater plants will have phosphorus

removing technology – the vast majority chemical dosing. AMP5 will see 360,000 to 572,000 tons of iron products used per year, at a chemical cost of US\$82 million per year (and this does not include additional alkalinity chemicals where this becomes insufficient for nitrification). This is likely to increase during AMP6 as more sites get phosphorus consents and the iron dose is increased to achieve the tighter phosphorus consent limits, but is this sustainable?

The Water Framework Directive and the Water Services Regulation Authority changed emphasis to outcomes rather than outputs. This provided water companies with an opportunity to review the total phosphorus load to a watercourse. By revisiting the cause and effect of multiple phosphate sources within a catchment, it is possible to deliver improved river quality and reduce the cost and carbon footprint of the end-of-pipe solution. Relying on its experience of phosphorus trading in the United States, MWH offers a similar service to UK water clients. Tight phosphorus consents will still be required, but they will be applied where they deliver the most benefit to the environment.

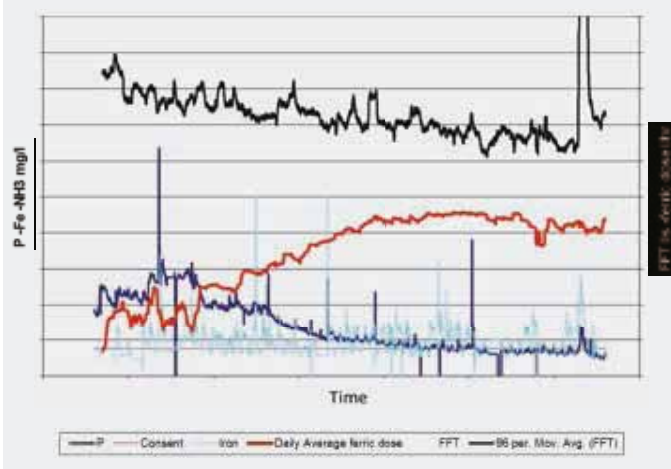


Chemical dosing and flocculation improve filter performance. Photo by MWH

Table 1. Data from Sydney Water treatment plants show what can be achieved with tertiary filtration.

Wastewater Treatment Plant	Consent (50%ile) Total mgP/l	2012 Performance Total mgP/l
Castle Hill	0.3	0.08
Hornsby	0.3	0.08
Penrith	0.2	0.08
Picton	0.2	0.08
Richmond	0.3	0.02
Rouse Hill	0.2	0.03
Wallacia	0.15	0.03
West Camden	0.3	0.06
West Hornsby	0.3	0.07

Consent Profile Graph



Levels of 0.1 mgP/L are achievable using technologies and techniques that have been available and in operation for many years – the proper application is needed, and not just limited to a site-by-site basis.

Meeting the complex challenge

The higher iron dose rates required to meet tighter phosphorus consents increases the risk of breaching iron discharge limits, which are also tightening. MWH assists water companies with global experience and specific expertise from UK's past three AMP programs.

One commonly held view requires dual point dosing of chemical followed by tertiary treatment to meet the associated iron consent standards below 1 mg/l. The second dosing point, usually prior to secondary clarification, increases the risk of iron carryover in the final effluent – hence the need for tertiary solids removal. This is only necessary where the primary dosing point is ahead of the primary tanks.

MWH's shows that single point dosing into the primary settlement tanks, with good site operation and sludge management, can eliminate the need for additional tertiary treatment where excessively stringent consents are not in place. The final settlement tank design and the quality of the dosing arrangement are key to achieving good quality effluent without tertiary treatment. With suitable tank design, dosing directly into the primary tank delivers greater benefits through increased biogas generation and lower energy consumption within the secondary treatment process. In fact, this is where chemical dosing can offer an advantage over biological phosphorus removal. It increases the effective performance of existing assets – reducing possible future capital costs, and can significantly reduce net operating costs.

Even with excellent design and operational practices in place, there are situations where tertiary filtration – either with or without dosing – will be increasingly necessary, especially where extremely tight phosphorus (from about 0.8 mgP/l) or iron standards are applied.

Plant performance in Sydney

Many different factors must be considered when developing tertiary system design. This includes:

- When to switch to dual point dosing (an economic as well as technical argument)
- Conditioning needed prior to filtration (a key subject in the entire process)
- Type of filtration system
- Dose control and the effect of adding an additional treatment stage

Variations in tertiary system design used in America or Australia illustrate the benefits gained by applying basic chemical engineering principles to deliver the desired outcome, as opposed to a new coverall technology. Levels of 0.1 mgP/L are achievable using technologies and techniques that have been available and in operation for many years – the proper application is needed, and not just limited to a site-by-site basis.

Taking direct guidance from Australian experience, the following rules could help in meeting possible future tighter consents:

- For consents of below 0.5 mgP/l: Two point dosing followed by media filtration (typical sand filters). Great importance is placed on the mixing of chemicals at the second dose point, most commonly with a static mixer.
- For consents of below 0.3 mgP/l: The general rule is the same as above, but with much improved mixing – using flash mixing and a microflocculation period to condition solids before media filtration.
- For even tighter consents of 0.1 mgP/l: The use of polymer and further flocculation is considered necessary. Also, where the solids loading onto the media filtration becomes excessive, then an intermediate clarifier is required.

Data from Sydney Water's treatment plants show what is achievable with well-designed tertiary filtration applying the rules above, and it clearly shows very stringent standards can be achieved (Table 1).

In North America, performance of equivalent filtration processes reflect what has been achieved in Australia – with examples of treatment plants achieving 0.05 mgP/l or less using technologies such as moving bed sandfilters, disc filters, or even tertiary clarification using the Veolia ACTIFLO® process. Colorado's Iowa Hill can achieve a monthly average of 0.015 mgP/l using a tertiary process of chemical dosing and clarification followed by filtration.

Minimizing costs

There is a cost to removing phosphorus using chemicals, although if applied correctly the energy benefits can outweigh these costs.

However, additional optimization of the ferric dose rate has been achieved by controlling the volume of chemical dosed based upon the flow entering the treatment works. By approaching each project on a site-by-site basis, considering the historical trends of flows entering the works, the dose rate can be capped to ensure an operational saving. This is based on collecting and analyzing flow and phosphorus data prior to installation of any chemical dosing. The dose and profile are then fine-tuned on-site during the commissioning period and subsequent operational periods.

MWH implemented a standardized control philosophy in all of its projects with four modes of operation, providing functionality to optimize the ferric dosing to meet the quality requirements of each scheme. The next step in this process is the development of intelligent (SMART) dosing to optimize even further. The use of automated control systems is improving and the right control systems can save thousands of dollars in chemical costs.

Meeting AMP 6, phosphorus challenges

The key to meeting the new, tighter phosphorus challenges of AMP6 is more than bolting new technologies into an existing plant, but includes starting at the source to rationalize the investment required for delivering maximum environmental benefit. From there, the challenges include making best use of the existing assets on each site to meet the required performance level. Once this performance has been secured, additional process should be considered and their design balanced accordingly. Taking this approach, along with a more holistic view, will deliver the overall environmental benefits that the industry and legislator strive to achieve. In this holistic view, the costs can be partially offset if integrated into an energy production facility.

Authors' Note

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