Analysing and Removing Phosphate in Sewage Treatment

The removal of Phosphate during the sewage treatment process has become a crucial area of interest as more and more works have Phosphorus discharge consent. With the ever increasing use of detergents containing phosphate the problem is growing.

The removal of phosphate from the effluent of a sewage works comes under the Urban Waste Water Treatment Directive (UWWTD) (91/271/EEC) and it requires the control of nitrogen and phosphorus input into water bodies by specifying minimum treatment requirements to be achieved, related to the population equivalent (PE), this being the size of the area served, and the nature of the receiving water.

Requirements:

Total Phosphorus	**2 mg/l as P 10,000 – 100,000 pe**
	1 mg/l as P >100,000 pe
	Or
	80% removal of the influent load

The UWWTD requires measurement of Total Phosphorus concentration, which is determined after oxidation by the measurement of Soluble Reactive Phosphorus (SRP). This is probably the most frequently measured phosphorus determinand and is measured spectrophotometrically by the formation of a phosphomolybdenum blue complex. It is referred to as Reactive Phosphate because some polyphosphates and some organic phosphates can be hydrolysed by the test.

Fig 1: Feed Forward Control involves taking a sample at the inlet prior to the addition of chemicals.

The removal of Phosphate is carried out by dosing metal salts most suitably aluminium, iron and calcium i.e. aluminium sulphate, sodium aluminate, ferric/ferrous chloride, ferric/ferrous sulphate and calcium hydroxide. The addition of aluminium or ferric salts will have the potential to lower the pH of the effluent, although most UK waste waters have sufficient buffering to cope with this effect. Traditionally the metal salts are dosed at a rate determined by a pre-set diurnal profile derived by analysing a series of samples over a period of time or by using a flow proportional control algorithm.

Phosphorus and nitrogen are essential nutrients for the plants and animals that make up the aquatic food cycle and since phosphorus is the nutrient in short supply in most fresh waters, even a modest increase can under the right conditions set off a whole chain of undesirable events in a stream. Typically these can include accelerated plant growth, algae blooms, low dissolved oxygen and the death of certain fish, invertebrates and other aquatic animals.

There are many sources of phosphorus, these being both natural and human. Examples are soil and rocks, waste water treatment plants, run-off from fertilised land, failing septic systems, run-off from animal manure

The natural removal of both Nitrate and Phosphate is the method of choice where applicable. However, in most cases this is not possible and therefore water companies have to resort to chemicals, the most commonly used being Ferric Chloride or Ferrous Sulphate. In some cases where the efficiency of iron is much reduced the use of Aluminium Salts has been successfully applied and works normally in conjunction with an iron salt. In all cases the amount of chemical used is critical for the performance of the works, cost control and meeting the metal discharge consent.

storage areas, disturbed land areas, drained wetlands, water treatment and commercial cleaning products. Orthophosphates applied to the land as fertilisers are carried into the water catchment during periods of heavy rain or snow. The organic phosphates are formed by biological processes and are carried into water courses in discharges from sewage treatment works and other biological processes. Both organic and inorganic phosphorus can be dissolved in the water or exist as a suspension attached to particles in the water column.

Determining the various types of phosphorus has been carried out in laboratories throughout the world for many years, initially employing manual methods but subsequently the analysis has become automated. The most common automated system in use is the segmented flow analyser and this automated chemistry forms the basis of the standard methods of analysis in many laboratories and in line analysers. All the available process analysers are based on the colorimetric analysis of the reaction products which form a coloured complex. The absorbance of which at a specific wavelength is proportional to the concentration (based on the Beer-Lambert Law).

How the sample is prepared affects the result and this is as pertinent to process analysers as it is to the laboratory. The sample preparation in the laboratory should mimic the sample preparation done by the process analyser to ensure a compatible result. The sample treatment used in process monitoring will affect the result and must be born in mind when interpreting the results. In the case of final effluent the result should be the best approximation of total phosphorus because that is the consent criteria, so the less filtration the better. However, the system needs to be protected from potential blockage.

In the case of the crude sewage it is essential to decide what the most relevant determination of orthophosphate is because the chemical removal of phosphate depends on the level of reactive phosphate in the aqueous phase, as this is the fraction that reacts with the chemical. In the case of a feed forward system, where no chemical has been added prior to the analysis of the sample, the reactive phosphate level is the concentration required. When combined with the incoming flow it can give a valid phosphate load value against which the chemical dose can be calculated.

In the case of feed back control the level of "free or available orthophosphate" is the required concentration and this is not as clear cut. Some of the "complexed" phosphate will be released by any of the orthophosphate methods and therefore the most relevant result would be the soluble orthophosphate as determined by filtration to 0.45 micron. In a process analyser this is not easy with this type of sample where the solid levels vary dramatically.

Dosing iron salts at the front end of a works requires a level of control to ensure that the pH of the influent is not made too acidic as this has a detrimental effect on the nitrifying process. This can be performed using one of a number of technologies.

Fixed Profile:

The dose rate of the iron is calculated by taking a series of samples at intervals during the day, which are then analysed and a diurnal profile derived. Once the diurnal has been calculated a profile is entered into the dosing system such that a specific volume of iron is dosed at the time intervals used and this is then used to "control" the dose.

Flow Proportional Dosing:

The other commonly used dosing control protocol is the "capped flow proportional" system. In this method the inlet flow is measured and the dose calculated at fixed concentration of phosphate and the dosing system controlled to this dosing rate. To prevent wastage the dose is capped at a certain flow rate which is normally attributed to a "storm flow" condition. The initial concentration of phosphate is again arrived at by taking samples over a period of time and calculating an average value.

Feed back control:

This is the procedure in which the chemical is dosed into the process upstream of the monitoring system and the concentration of the phosphate remaining in the sample determines the level of dose to be used either upstream or downstream of the monitor. This concept can control the chemical dose more accurately than either the fixed profile

or the flow proportional dosing. The disadvantage of this procedure is that the chemical has already been added and so over dosing can still occur.

There are additional complications in the determination of the phosphate level in the dosed sample as the accurate determination of the available or free phosphate i.e. that which is not bound to the solids either organically or as a metal phosphate, depends on the filtration level of the sample and the acidity of the analytical reaction.

Feed Forward Control:

With this method a sample is taken at the inlet prior to the addition of chemicals. The advantage of determining the level of phosphate on the inlet is that the dose rate of the iron or aluminium salt can be calculated and the dosing system controlled using the combined flow and phosphate concentration. The combined output generated allows the operator to adjust the dose for site-specific conditions particularly adjusting the "P to Fe" ratio until the dose is optimised. This optimisation requires monitoring the final effluent to ensure that the phosphate levels are within the EA consent; and once the optimisation has been done there is no need to monitor the final effluent.

By using feed forward control the dose responds to actual changes in phosphate levels and provides an active dosing regime, whereas the commonly used "diurnal profile" cannot respond to changes in the inlet. This can result in either over dosing or under dosing, both of which have financial consequences. This process also allows the dosing system to be turned off for periods when the level of phosphate coming into the works is either very low or below the actual final consent level particularly during storm/high flow conditions.

A question that is frequently asked is how can crude sewage be sampled reliably with minimal maintenance at the inlet? Partech Instruments has a positive answer to this question as it has developed a sampling system that requires minimal maintenance and provides the analyser with a reliable representative sample. The sampling system is a critical part of the dosing control system, as the analyser requires an optically clear sample to accurately determine the orthophosphate level. The sampling system has been designed to cope with low flow and low sample levels; grit, ragging and turbulent flow all of each of which were encountered during the extensive field trials.

As well as low maintenance the sampling system has been designed to be as simple as possible, which helps with operator confidence and also keeps the cost to a minimum.

Between November 2005 and November 2006 successful trials were run at several sites in the UK and resulted in the placement of orders for two Partech Feed Forward controller systems in 2006, one on a commercial site and the other on a Wessex Water site.

The system supplied to Wessex Water was installed on the inlet channel in February 2006 and was linked to a Michael Smith Engineering dosing package controlling the dose of chemical using a flow proportional signal. The original algorithm had a cap applied to cope with storm flow conditions which reduced the dose by 30% during storm / high flow conditions.

Initially the Partech controller was set up to dose at a ratio of approximately 3.5 to 1 (Fe to P). This equated to the dosing rate used by the original system. A final effluent phosphate monitor was installed to check the effect of the dosing control changes and monitor compliance. In the first three months after installation changes were made to the Partech controller to give the customer absolute confidence that the sampling system was working and no samples were being "lost". At the end of this period the customer insisted on running the system for a further three months without losing a sample before handing the system to operations. This was achieved and resulted in the following site maintenance of the system:

Analysis frequency:	twice per hour
Calibration frequency:	once per day
Reagentchange/replenishment:	every 6 weeks
Sample filter cleaning:	once per month
Fe to P ratio:	2.4 to 1 winter, 2.8 to 1 summer

After a further 6 months changes were made:

Analysis frequency:	once per hour
Calibration frequency:	once per two days
Reagentchange/replenishment:	every 8 weeks
Sample filter cleaning:	once per month
Fe to P ratio:	2.4 to 1 winter, 2.8 to 1 summer

Fig 2: The sampling system is a critical part of the dosing control system, as the analyser requires an optically clear sample to accurately determine the orthophosphate level.

When first installed the system was on a monthly service visit by Partech. However, this was gradually reduced and today Partech is only required to perform an annual service. Since installing the system the volume of iron salt has been reduced by 30% and the phosphate and iron compliance has never failed.

Conclusions

The employment of an "active" control system at the inlet to a treatment works can have the following affect:

• Tighter and more effective control of chemical dosing which responds to routine and non-routine events.

• Saving on dosed chemical expected to be in the range of 10-40% depending on the status of the works as far as optimisation is concerned.

• Less likelihood of consent failure of both residual chemical – iron or aluminium – and phosphate.

• Reduced sludge production.

• Reduced potential for corrosion of the works due to over-dosing of iron.

• The control system will have a payback period relative to the size of the works and volume of the chemical being used and is not expected to be viable on small work.

• Reliable, robust dosing control system exists.

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