

Full Scale Phosphorus Recovery in Severn Trent Water

Wild, R¹, Wickens, D¹, Moxey, P¹, Behar, P²

¹Severn Trent Water, ²NMC Nomenca

Corresponding Author Tel. 07775818925 Email Robert.Wild@severntrent.co.uk

Abstract

Stoke Bardolph Sewage Treatment Works serves a population of approximately 700,000 in the Nottingham area. Additionally it acts as a regional sludge centre. As part of a strategy to comply with a new total Phosphorus limit of 1 mg/l and increase the number of products recovered from our wastewater resources, it was decided to reduce recycled Phosphorus in the post-digestion sludge liquors. Struvite recovery by the Phospaq® process was selected to achieve this, as part of a combined liquor treatment plant with the Anammox® process for ammonia removal.

Keywords

Bio-P, BNR, Digestion, Liquors, Phosphorus, Recovery, Sludge, Struvite

Introduction

Stoke Bardolph Sewage Treatment Works (STW) is Severn Trent Water's second largest works. It serves the city of Nottingham, in the East Midlands region of the UK. The domestic population treated by the works is approximately 500,000 and the sewerage system, like most in the UK, combines foul and storm flows together. In addition to the domestic population of the area there is a significant trade load contribution of approximately 200,000 population equivalent. Much of this is spread across the catchment but there is one large trader located adjacent to the treatment works which produces a high strength COD waste which enters the site separately.



Figure 1: Stoke Bardolph STW pictured before capital works

The site comprises of conventional preliminary (screening & grit removal), primary (settlement) and secondary (Activated Sludge Process & final settlement) treatment with on-site anaerobic digestion of sewage sludge to produce treated biosolids which are recycled to agricultural land. The site discharges treated final effluent into the river Trent, which is visible in the background of Figure 1. The existing permits include limits of 25mg/l for BOD and 5-10mg/l for ammonia. The latter is a summer-winter seasonal permit.

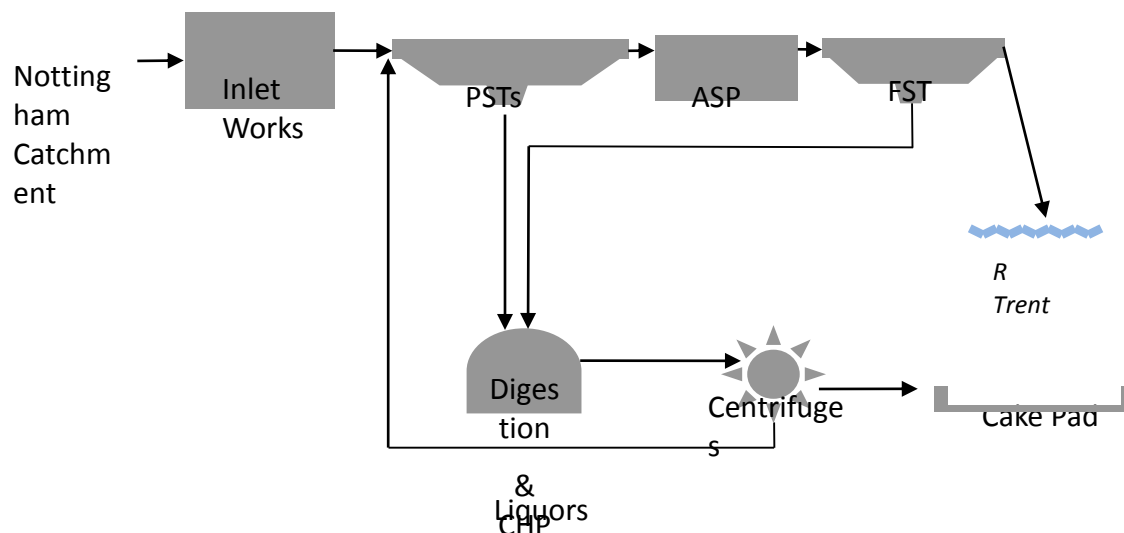


Figure 2: Process schematic for current plant layout

In 2014 the site received a new 1 mg/l total phosphorus limit (under Urban Wastewater Treatment legislation) so a project was launched to address this along with some significant capital maintenance requirements. Much of the existing site shown in Figure 1 dates from the 1950s. This includes most of the secondary treatment assets which are reaching the end of their asset life.

Urban and Rural Catchments

Severn Trent Water has developed a waste water strategy focusing on Urban and Rural catchments. Over time it aims to operate an urban or rural philosophy for each catchment area in the organisation, and to incorporate additional value-add opportunities into its business-as-usual operations, such as Phosphorus recovery.

The principle of Rural catchments is to employ low energy, low maintenance, potentially (but not exclusively) low-technology solutions together with working much more closely with local communities to deliver low-impact and low-input solutions to safely take waste water away and protect the local and wider environments.



Figure 3: Internal communications materials showing Rural catchments

Stoke Bardolph on the other hand, due to its size and nature is a clear example of an Urban catchment. The principle of Urban catchments is to maximise the efficiency and quality of operational activities through deploying higher levels of monitoring technology in order to operate a catchment in an integrated way, and by viewing treatment works as “effluent factories.” Whilst the same principles of taking waste water away safely and protecting the local and wider environments are just as true, the scale of operations is likely to create opportunities for the recovery of more resources as part of the wastewater and biosolids treatment process, such as energy or Phosphorus.



Figure 4: Internal communications materials showing Urban catchments

Severn Trent Water's Legacy of Biological Phosphorus Removal and Anaerobic Digestion

Two significant historical aspects of Severn Trent Water operation and design must be briefly considered in order to understand the context of the decision-making process for the capital project as the team started to investigate options.

Firstly, Severn Trent Water is the largest adopter of biological Phosphorus removal (also known as Biological Nutrient Removal or BNR) processes in the UK. The first of these was commissioned in Derby in 2001 and to date there are 15 sites across the organisation that use BNR in order to remove phosphorus from treated wastewater. These represent a large mix of sizes and flowsheets but in total the population served by BNR in Severn Trent Water is approximately 4,000,000, which is equivalent to 45% of the total waste water population served by the company.

Secondly, Severn Trent Water is the only landlocked water company in the UK and as a result of this geographical legacy has an extensively developed landbank. For many years it has treated 100% of its sewage sludge with anaerobic digestion and currently 100% of these treated biosolids are recycled to agricultural land. As a result there are 36 sludge centres across the organisation, with many large treatment works such as Stoke Bardolph being co-located with anaerobic digestion and receiving imported sludges from smaller satellite sites. In these cases digested biosolids are dewatered for recycling in the form of cake with the resulting dewatering liquors being treated in the sewage treatment process.

The Commercial Context of the Project

The commercial backdrop to this project was a requirement for efficiency. For the five-year Asset Management Plan period ending in 2015 (AMP5) the headline efficiencies required were a capital expenditure efficiency of 20% and an operational expenditure efficiency of 12%.

In order to unlock the potential opportunities from our largest projects in the AMP5 period a major works team was set up with the aim of delivering the nine largest waste water non-infrastructure capital projects (at eight sites) is the most efficient way through:

- Better programme management
- Better financial controls
- Better use of shared resources
- Bulk procurement
- Enabling design efficiencies

In addition to this it was recognised that fundamental process selection was likely to identify the largest opportunities for capital efficiency. It can be seen in Figure 4 that Stoke Bardolph represented one of the two largest projects in this programme of work.

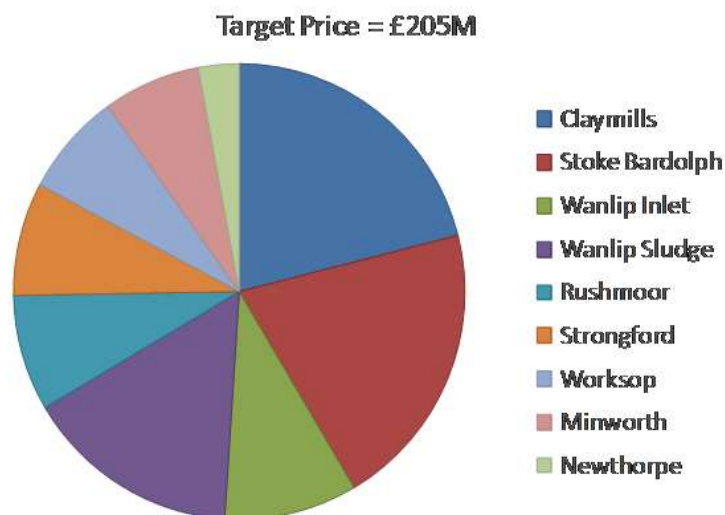


Figure 5: AMP5 major works projects by value

Development of a Solution

The conventional solution for the implementation of a Phosphorus permit on a works of this type is shown in Figure 5. This is based upon a BNR flowsheet and involves significant replacement and extension of the ASP, in total 105ML of anaerobic, anoxic and aerated capacity. The associated capital and operational costs, and carbon footprint, are also high.

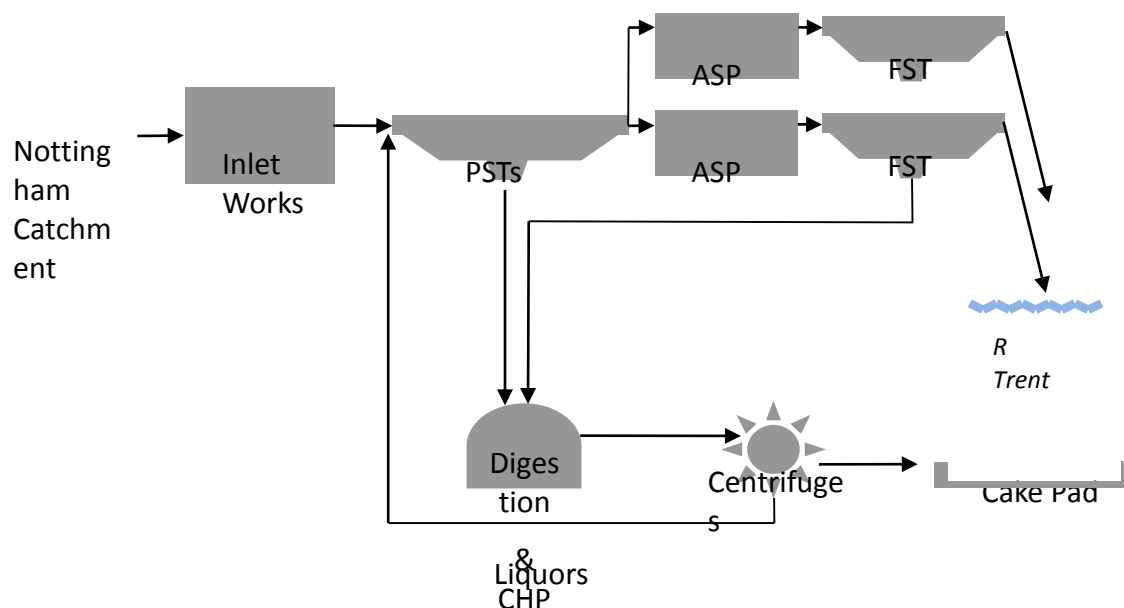


Figure 6: Process schematic for conventional solution

At this stage in the design process Severn Trent Water's Process Design Group started to explore a range of more innovative options in order to deliver a solution that met the financial challenge in a better way, and also started to help deliver part of the vision for an Urban catchment into reality for one of our large strategic sites.

Due to anaerobic conditions during digestion, sludge from a BNR treatment process typically releases a proportion of the Phosphorus contained within it into the liquid phase. In addition ammonia is produced during the anaerobic digestion process and is also present in a soluble form. As the digested sludge is subsequently dewatered, the resulting liquors are therefore high on both Phosphorus and ammonia. The loads associated with these can typically represent 30-50% of the total load treated in secondary treatment for both substances, rising to as much as 80%.

A further complication from Phosphorus and ammonia-rich liquor streams is that of problem Struvite (Magnesium Ammonium Phosphate) precipitation in pipework. This typically occurs in pipework fittings and bends due to small pH changes as gases such as CO₂ come out of suspension due to localised pressure drops, the resulting conditions being optimal for the chemical reaction resulting in solid inorganic precipitates which adhere to the internal surfaces of pipes. Eventually this results in blocking, which is a significant maintenance burden as well as leading to increased energy costs as pumping becomes more difficult in the obstructed pipes.



Figure 7: Problem Struvite precipitation in existing Stoke Bardolph liquor pipework

By breaking the recycle loop it is possible to reduce the treatment capacity required by secondary treatment. Liquor treatment is common practice in the water industry for ammonia removal, however breaking the Phosphorus loop is newer territory. For each of these return loads, both removal and recovery were considered with processes being selected on a whole life cost basis including:

- The capital cost of the liquor treatment assets
- The capital cost reduction of the resulting secondary treatment process
- The operational cost impacts of both
- The value of any recovered product (in both cases as inorganic fertiliser)
- Nuisance costs of unblocking pipework

From an initial feasibility level appraisal it was decided that Struvite recovery in combination with ammonia removal was the optimum combination of processes as it allowed the size of the ASP to be reduced to with a significant resulting capital cost. The loading of the ASP and settlement tanks was also increased and the process was extensively modelled using Biowin, GPS-X and computational fluid dynamics software to confirm performance. The result of this was that the size of the ASP reactor could be reduced to 70ML.

At this stage a further dimension had to be considered in the form of the high strength COD-rich waste stream coming from the adjacent trader. The geography of the site

meant that this was most practically combined with the digested sludge liquors for treatment before return to the head of the works, therefore this had to be part of the specification for liquor treatment.

The Chosen Solution

Once the nominal solution had been decided upon, suppliers were selected based upon a combination of technical and commercial criteria. Of those assessed, three combinations of processes met Severn Trent Water's technical requirements and Paques were chosen as the successful supplier with deployment of the Phospaq and Anammox treatment processes. As part of this solution an Upward flow Anaerobic Sludge Blanket (UASB) reactor was chosen to treat the COD load from the trader. The final flowsheet is shown in Figure 8.

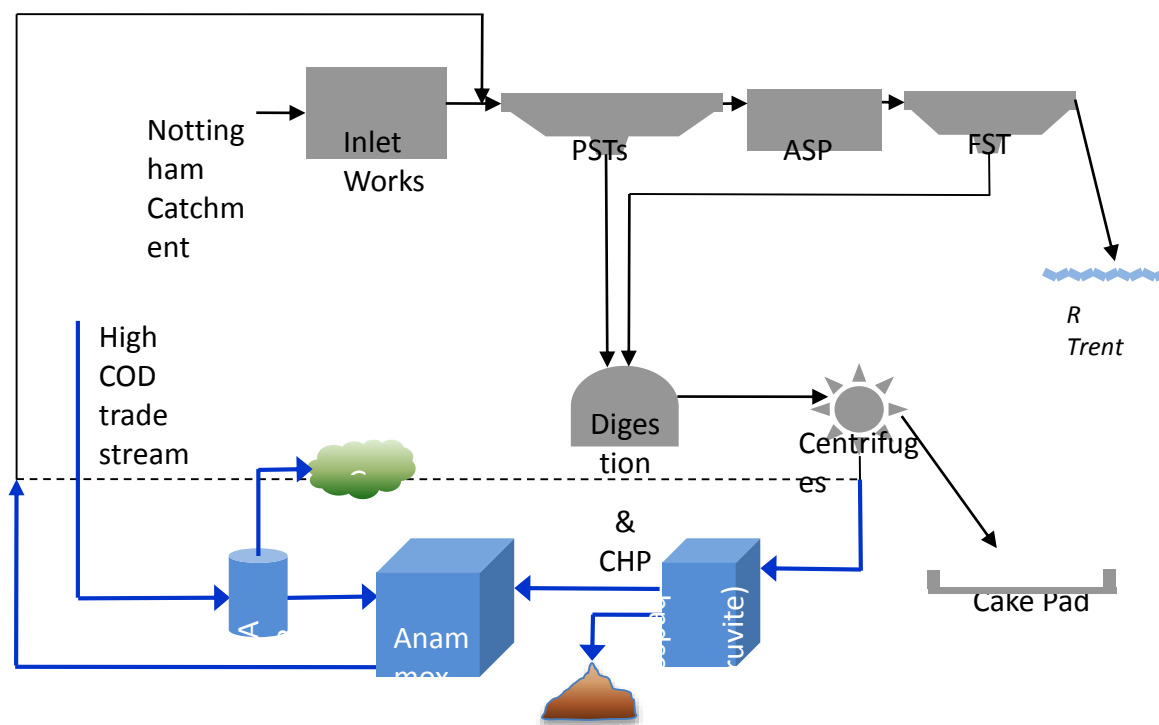


Figure 8: Process schematic for innovative solution

The liquor treatment process can be considered in three steps. Firstly, the high strength COD stream is treated in order to protect the Anammox plant from the COD. Secondly, the Phospaq process recovers Struvite from the digested liquors in order to protect the Anammox plant from the Phosphorus load. Thirdly the Anammox process removes ammonia from the remaining liquors in order to protect the much-reduced ASP. As there is already digestion and Combined Heat & Power (CHP) on site the relatively small amounts of gas produced from the UASB is fed to the CHP engines to maximise recovered resources from the process.

Half a tonne of Phosphorus (as PO_4) is recovered each day.

The Financial Journey

As explained above, the biggest impact from the chosen solution is on capital expenditure. The Stoke Bardolph project has beaten the 20% efficiency target by achieving around 30% capital efficiency compared with the conventional solution that the AMP5 business plan was based upon. The role of Phosphorus recovery was to unlock some of this efficiency

The financial journey is summarised in Figure 9. From an operational cost perspective the chosen solution offers a benefit over the conventional solution of £165k per year. It is interesting to note that at this time the value of the Struvite is not particularly high. This is to be expected as the market for recovered Phosphorus in the UK is relatively immature (other than the recycling of biosolids and organic wastes). By way of a comparison even though it is a relatively small volume the financial value of the biogas from the UASB reactor is slightly higher.

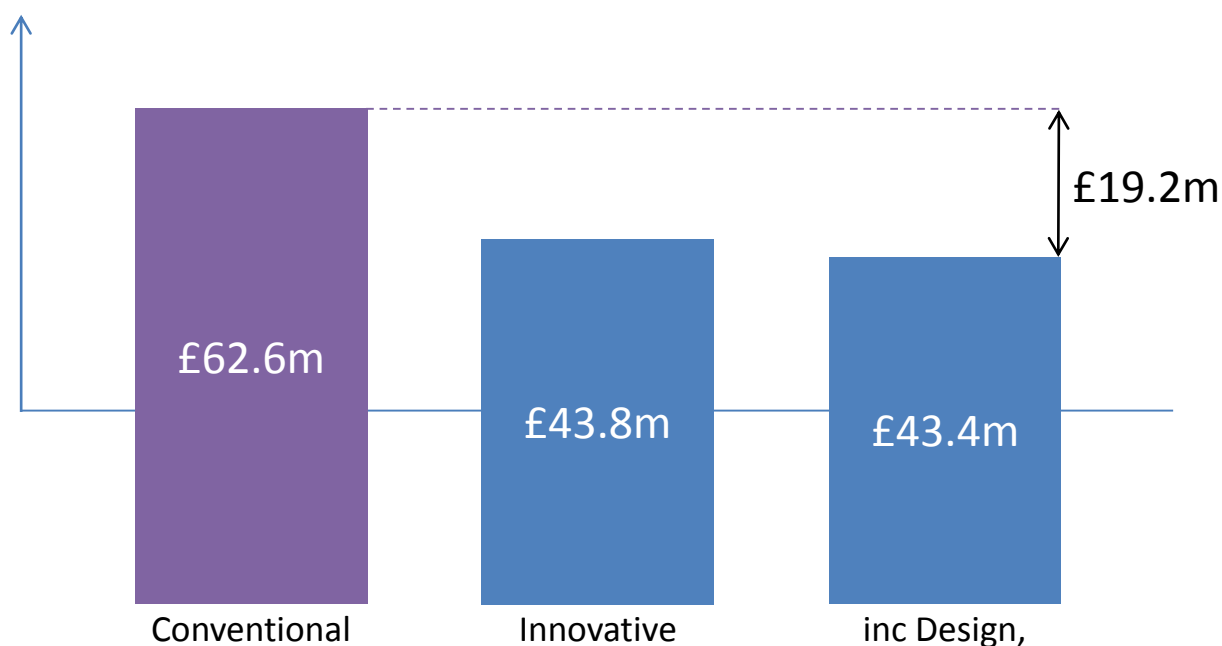


Figure 9: Capital efficiency resulting from process selection

Conclusions

Stoke Bardolph is the largest Phosphorus recovery plant in the UK at the time of writing. Considering the asset base in Severn Trent Water and the likely size at which it is currently sensible to consider Struvite recovery, there are five other potential candidate sites in the organisation at the moment. However, it can be seen above that the adoption of Phosphorus recovery as a technology is currently still dependent upon its ability to enable other more significant savings as part of an advanced flowsheet.

At the moment whilst few would argue that recovering Phosphorus does not sit well as an activity within the hierarchy of wastes, it would appear that the economics are not favourable enough for it to be undertaken as an activity in its own right. In the short to medium term its future would therefore appear to be linked to other investment drivers, however the learning acquired in its pragmatic deployment now will be of increasing value in years to come.