CONTROL OF PRE-THP DEWATERING AND FEED TO THP USING SLUDGE BYPASS AND BACK-MIXING

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Abstract

Many of the water companies, including Thames Water, are moving towards THP digestion. Controlling the feed to THP and achieving consistency is very important to operations. Sludge too thin will result in the steam demand being very high – increasing Opex costs. Sludge too thick will result in rat-holing of the steam through the sludge, poor hydrolysis and experience shows leads to significant maintenance issues. Being able to control the dry solids of the feed to the THP consistently is critical to successful and cost effective operation.

This paper reports on how this can be consistent feed to THP can be achieved reliably, looking at the whole life cost benefits and the control philosophy necessary.

Keywords

pre-THP dewatering, process control, operational experience

Introduction

Thermal Hydrolysis pre-treatment of sludge prior to digestion offers a significant operational and whole-life cost benefits. Significant amount these are:

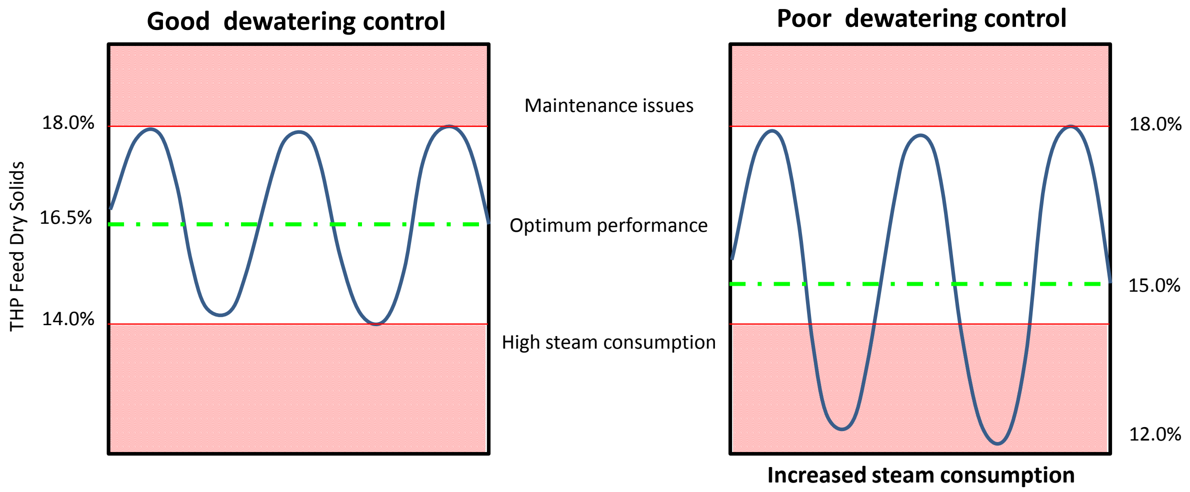
	Conventional Digestion	**THP Digestion**
Organic loading rate	2.5 kgVS/m3/day	6.0 kgVS/m3/day
Biogas production	340 to 375 m3/tds	400 to 450 m3/tds
Pathogen kill	Treated Sludge	Enhanced Treated
Final product dewatering (Belt)	21%	32%
Cake quality to farmers	Acceptable	Significantly preferred
Transport to land	0.152 trucks/tds feed	0.081 trucks/tds feed
Land bank required (NVZ 170kg/ha)	56 ha/tds	46 ha/tds

However, this comes at a cost. Thermal hydrolysis involves getting the sludge to 160° C for 30 minutes which takes a significant amount of energy input – most typically high grade steam. The amount of heat, or steam, required will be a function of the volume of the sludge. While the amount of solids to be treated is set, the volume of water associated with those solids can be varied. Rather than spending a lot of steam input to heat water – if the sludge can be thickened the same amount of solids can be fully treated but requiring much less steam.

Experience among all of the major suppliers and users of THP has shown that sludge feeding into the start of the THP process itself (Cambi: pulper, Veolia: reactor) up to 16.5% dry solids still hydrolyses well – the steam is still able to penetrate through the sludge well and the volume reduction saves significant amounts of energy. Dry solids below this set-point means increased volume, therefore increased steam demand, therefore increased OPEX costs. Experience has also shown that above 18% the sludge passing through the feed cake tends to rat-hole, does not effectively penetrate all of the sludge, and therefore incomplete hydrolysis and a significant decrease in the benefits of THP pre-treatment. Talking with other THP user it has been found that not only does high feed dry solids decrease digestion performance it has a significant impact on maintenance of the THP plant itself. It would appear that when steam rat holes through sludge above 18% dry solids it splatters – spraying sludge onto the top surface of the vessels where it then bakes on forming a very hardened ceramic surface which is extremely hard to clean off during annual inspections, coats and damages instrumentation, and carries over in flash lines causing blockages of steam lances, etc. Given the current state of THP technology the operational impact of dry solids higher than 18% is significant and needs to be avoided.

Note: Recent developments, both by Veolia and Cambi, call for sludge in the THP feed silo to be 22% dry solids – this is then diluted with hot water (from the waste jacket heat from the CHP engines) down to 16.5% as it is fed into the THP process; which raises the feed temperature of the sludge, reducing the amount of high grade steam required – saving on the overall energy consumption. The sludge does start at 22% but none-the-less the sludge feed into the Thermal Hydrolysis process remains at 16.5%.

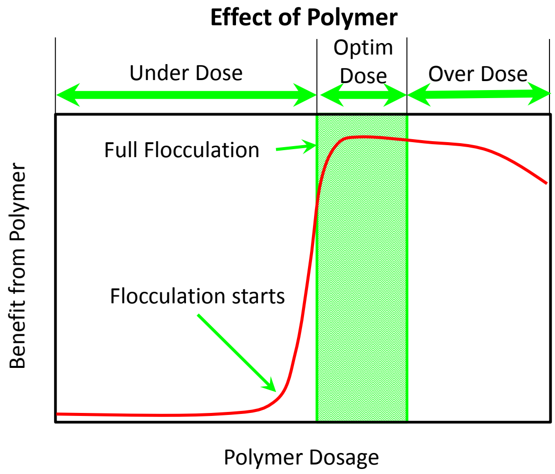
If 18% is the practical maximum – the question then becomes: How well can I control my dewatering plant so that the average is a high as possible without the peaks exceeding 18%. The graphs below show this pictorially – bad control vs good control.



The practical question is how can good control be achieved so that the average is as close to 18% dry solids – without exceeding – thus improving the overall steam consumption.

Dewatering Technology Choices

The question is – can pre-THP dewatering itself be controlled to provide a target dry solids of 16.5% dry solids? Firstly it needs to be said that all dewatering technology generally available on the market relies on polymer addition and flocculation – their differentiation is in how they each separate liquids from solids. By definition then the process is subject to variations in the feed sludge. As the sludge goes thicker – more polymer will be required – as the sludge goes thinner – less polymer will be required. Primary sludge as a rule requires less polymer, SAS requires more polymer. So as the sludge make-up varies so will the polymer dosage required. Fresh sludge requires less polymer, older sludge requires more polymer. Consistent performance requires being able to maintain a consistent point on the optimisation curve (not necessarily the optimum point – but always the same point on the curve).



Belt and Screw Dewatering

From an energy and polymer cost perspective the preferred technology – since there is no benefit from higher dry solids performance. All dewatering is susceptible to variations in sludge – but with belts and screws where is little control to compensate. The feed to THP is raw sludge which generally dewaters very well – typically between 26% to 30% dry solids. Belts can adjust belt speed and belt tension but nothing that will in anyway bring this anywhere near the 16.5% required. Polymer can be adjusted, but the effect of polymer addition is not linear. The graph below shows how when polymer dosage is increase there is no benefit at all until almost near the optimum point when flocculation begins and there is a steep ramp up in benefit. As dosage is increased further the curve flattens out and then slowly drops. Controlling output dry solids by trying to manage this curve is almost impossible – the slightest change in feed sludge and either there isn't enough polymer and the sludge is all over the floor or there is too much polymer and back to 26% to 30% dry solids.

Centrifuges

Centrifuges in this circumstance do have more effective control. By feed-back and automatic adjustment of bowl and scroll speed the centrifuge performance can be "de-rate" achieve lower dry solids. Having said that, even with dynamic automatic control, the centrifuge performance is still sensitive to changes in sludge quality - the location where this has worked the best has a very significant upstream liquid sludge buffer capacity which smooths out any changes in sludge giving a much more consistent feed – where the upsteam buffering is less than 24 hours variations in sludge quality are a significant control issue and do lead to variability in cake output.

<u>Note</u>: There is proposition that the same results can be achieved by dosing less polymer. While it is true that lower dry solids can be achieved – it is at the expense of very high solids in the return liquors – which simply puts solids back around through the treatment works again and very significantly increases to OPEX of the treatment works.

Plate Press Dewatering

Plate press dewatering is favoured where higher dry solids are a premium – which is not so in this case. And plate presses do not have the ability to produce a uniform cake of lower dry solids.

High Dry Solids Dewatering

The control system on a Bucher press does calculate the dry solids of the cake continuously and does have the facility to end each cycle on achieving a set dry solids. But it hardly makes sense to pay much higher CAPEX when the same results can be achieved by much more conventional and lower cost technologies.

Back-Mixing

There is an alternative to be considered. Following any of these dewatering technologies the cake is dropped into a cake transfer pump to be transferred into the THP Feed Silo. These are generally progressive cavity pumps. These cake pumps are also designed as back-mix pumps – able to take two different materials, mix them uniformly, and then pump the mixture.

The first location where this was used was at Chertsey. Chertsey has 2 x 2m belt presses for pre-THP dewatering. With raw sludge feed, depending on the primary/SAS feed ratio, the cake from the belts is between 26% to 30% dry solids. Chertsey is one of the original Cambi plants at a time when the target feed dry solids 14%. To get from 26% to 30% dry solids final effluent was added to the dewatered cake – allowing the cake transfer pump to back-mix the water into the cake – and pumping the 14% mixture into the THP feed silo.

<u>Practical Note</u>: The original solution was simply to add a hose into the open cake hopper. While this works – the mixing is not optimal – the cake forms a pile, the liquid sits in a puddle, and when the cake transfer pump kicks in it ends up taking a bit of water, then a bit of cake, then water, then cake. This is not satisfactory. The cake pump manufacturers have an injection point specifically designed for back-mixing which introduces the liquid into the body of the cake hopper, directly at the auger – so that the liquid is fully back-mixed with the cake prior to being pumped in the stator/rotor.

The flow of the water needs to be controlled so that when the cake transfer pump stops, the water flow stops. The water flow only takes place when the cake transfer pump runs.

Additional Benefit of Back-Mixing

By monitoring either the torque of the cake transfer pump or the pressure in pipeline at the outlet of the cake transfer pump – the dilution / back-mixing can be accurately controlled. If the dewatered cake increases in dry solids, the torque on the cake transfer pump and the pressure in the pipework will increase. By increasing the dilution rate the mixture can be maintained at a fixed dry solids. If the dewatered cake becomes wetter, it will pump easier, the torque on the cake transfer pump and the pressure in the pipework will decrease. By decreasing the dilution rate the mixture can be maintained. With a good P&ID loop it is possible to maintain the cake dry solids going forwards to within +/- 1% dry solids. Even though the pre-THP dewatering may fluctuate – the back-mixing control system will constantly adjust the amount of dilution added to maintain a consistent dry solids feed to THP – for optimum THP performance.

Note: The set-point for torque or pipe pressure which corresponds to 16.5% dry solids will vary according to the particulars of each site – the absolute number isn't what is important – the control system simply needs to be able to maintain an operator set set-point which the operator will set according to sampling carried out – increasing or decreasing the set-point depending on measured results.

Full Potential of Back-Mixing

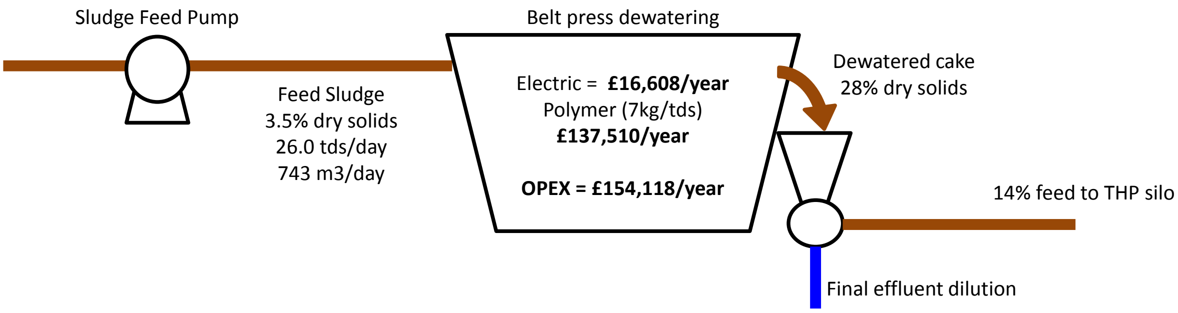
Final effluent for dilution is 100% water – or at least 99.998% water.
When the industry refers to sludge – we talk about sludge being 3% dry solids. What we loose site of is that sludge is also 97% water. In terms of back-mixing what is the difference between 100% water and 97% water? Why can't sludge be used rather then water?

Cambi came up with this modification at Chertsey and it has worked fantastically. A "bypass" line was installed, taking sludge from the feed line to the belt press, from before the belt press feed pump – through a variable speed progressive cavity pump and then into the body of the cake transfer/back-mix pump. The process works fine and because of the inverter driving progressive cavity pump is now fully automatable.

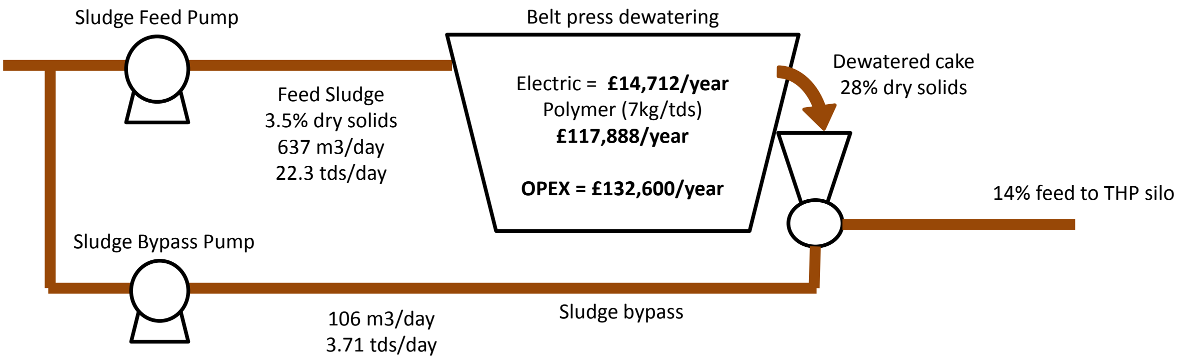
The significance of using sludge comes when looking at a mass balance.

Case Study – Chertsey
Chertsey = 26 tds/day at 3.5% dry solids.
Option 1 uses final effluent dilution to produce controlled 14% dry solids feed to the THP.
Option 2 uses a sludge bypass and back-mixing to achieve the same.

Option 1 – with final effluent dilution



Option 2 – with sludge bypass and back-mixing



Opex Savings = £ 21,517 per year

In Option 2, 15% of the sludge flow bypasses the belt press – so avoids the power costs and the polymer costs of dewatering. The Opex savings to Thames Water are £21k per year – not an insignificant savings.

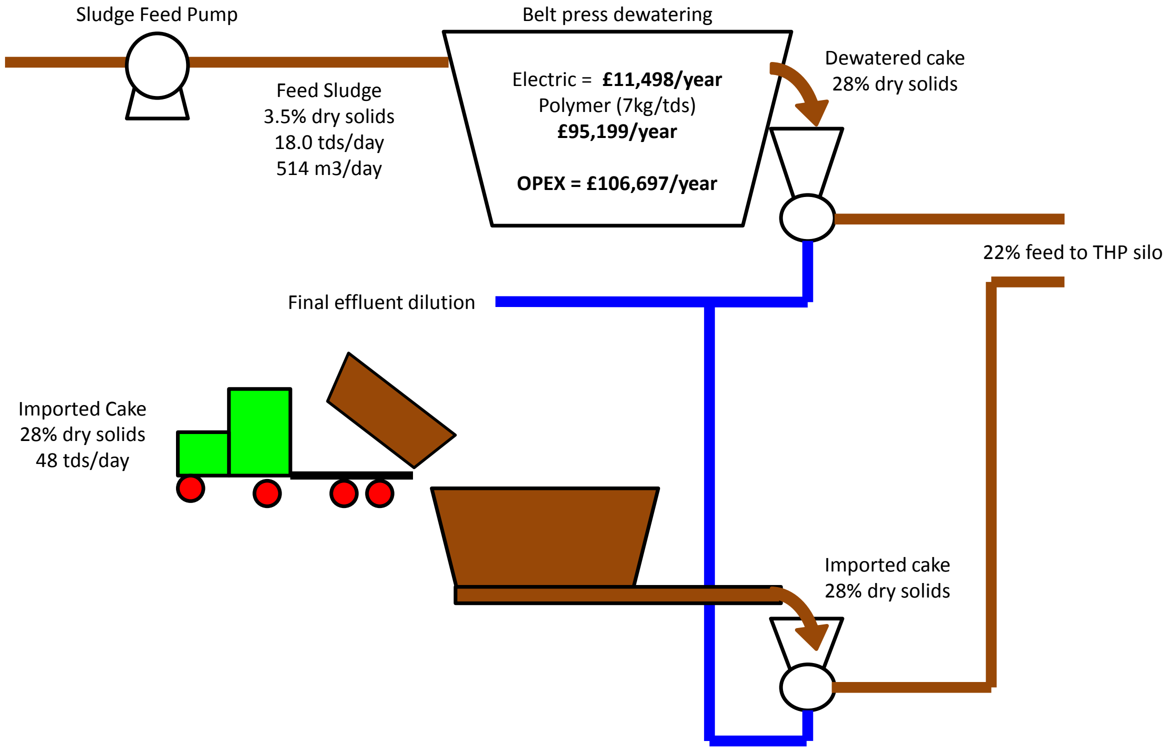
Case Study – Oxford

At Oxford, Thames Water are installing a new Veolia THP plant. The plant is a 67 tds/day plant of which 18 tds/day is indigenous liquid sludge with 48 tds/day of cake imports (sludge which currently is being lime treated.

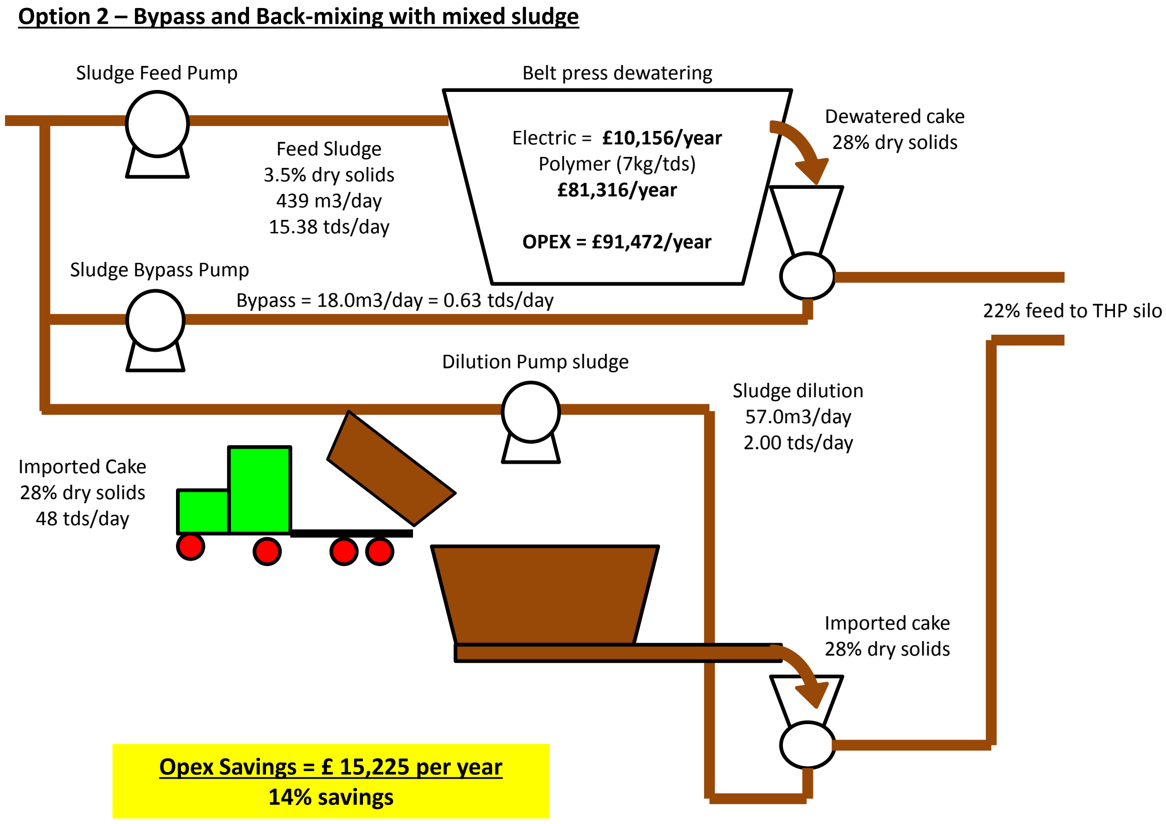
Veolia will be using hot water pre-heat of the sludge prior to THP so the target dry solids into the THP Feed Silo is 22%. This means there is less opportunity for dilution. However, the fact that such a large percentage of the load is imported cake at 28% dry solids means an increase in opportunity.

Option 1 – is to use final effluent for dilution of both the pre-THP dewatering cake and the imported cake – all to achieve a target of 22% into the THP Feed Silo. The flows and Opex for this option are shown on the diagram below.

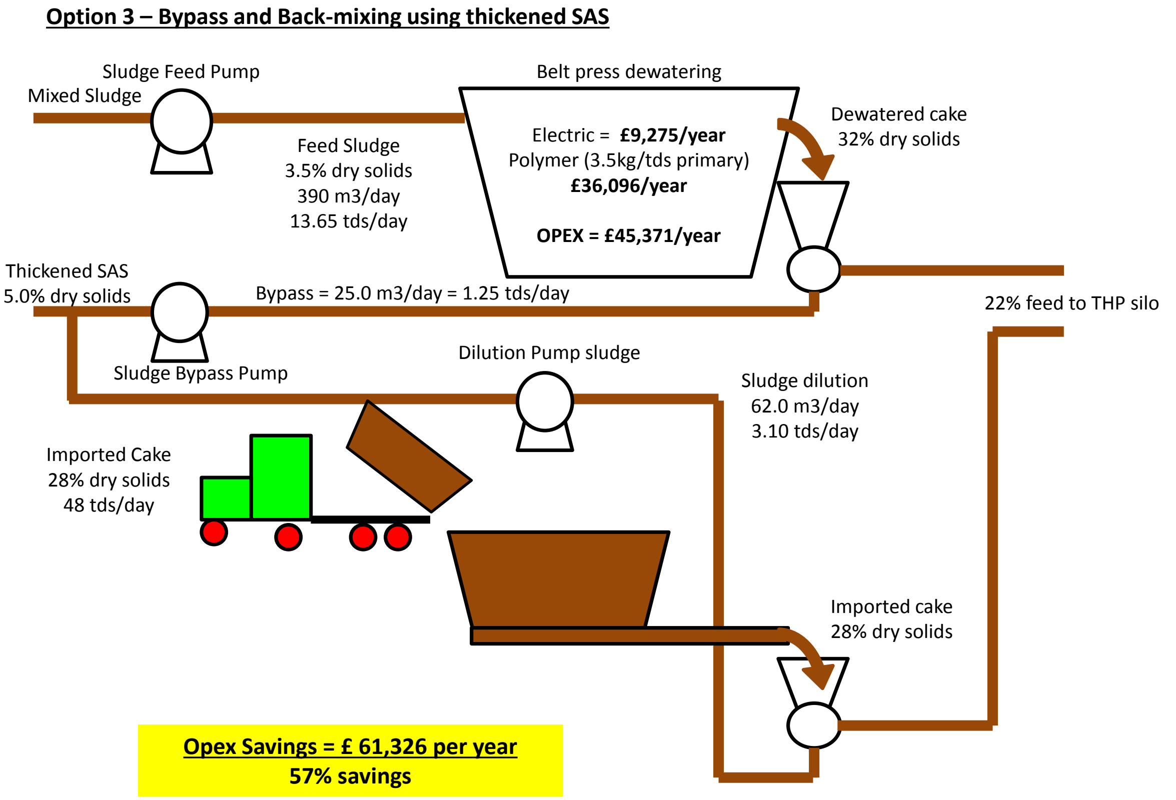
Option 1 – with final effluent dilution



Option 2 – is to use the feed sludge to the pre-THP dewatering – as is the case at Chertsey. The flows and Opex for this option are shown.



Option 3 – would to particularly select the thickened SAS for back-mixing. There are two advantages to this: 1) that thickened SAS will be of a higher dry solids so the same volume contains more solids, and 2) SAS requires more polymer for pre-THP dewatering and achieves a lower dry solids result then primary; so removing as much SAS as possible from the pre-THP dewatering feed will mean less polymer required and higher cake dry solids.



In the case of Oxford – there was not an existing tank which could provide sufficient buffer capacity to match the flows of imports and pre-THP dewatering. So Option 3 was not implemented. However, the concept is being retained for consideration on future projects.

Summary

1. THP feed needs to be well controlled at 16.5% dry solids. The tighter the control the better the economics of THP and the better the performance of THP and digestion.
2. Belt presses and screw presses for pre-THP dewatering are not able to "de-rate" reliably to give 16.5% dry solids.
3. Centrifuges are able to "de-rate" to give 16.5% dry solids, if feed-back and automatic control are provided for bowl and scroll speeds – and greater than 24 hours liquid sludge buffer are provide upstream to ensure consistency of feed sludge to dewatering.
4. However, much better control and significantly better economics can be achieved by over-dewatering and then bypassing and back-mixing sludge with cake in the thickened sludge transfer pump.
5. Consideration should be given to what sludge is used for this purpose as not all sludges are the same. There may be opportunity to achieve additional benefits.