CONTROLLED BACKMIXING SYSTEMS: POST GRAVITY BELT THICKENER AT READING STW AND PRE THP AT OXFORD STW

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Abstract

A stable dry solids feed to digesters is a crucial parameter to ensure a stable digestion process and optimum gas production. At Reading STW, the dry solids post primary belt thickeners usually vary between 8 and 12%DS (Dry Solids) even though the downstream systems (pasteurisation and digester feed) are unable to cope with sludge this thick as it causes blockages. Alternatively the belts can be "derated" by reducing polymer injection but this leads to poor flocculation and solids capture rate as well as limited control.

The alternative would be to dilute automatically the thick sludge with unthickened Primary Sludge after the belt to keep the Dry Solids at an optimum and controlled level. This method has been used previously on pre-THP dewatering but is now being tested on conventional sludge thickening.

The aim of this paper is to explain the logic behind the project and describe the trial and system installed at Reading STW where three different methods of calculating in real time the dilution were tested and assessed (cake pump torque, sludge dry solids and pipe pressure).

Additionally, the paper will give an overview of similar equipment and processes implemented and tested at Oxford STW (pre-dewatering THP).

Introduction

Mesophilic anaerobic digestion (MAD) is the main process used by the waste water industry to treat sludge. The major advantages of this process are sludge stabilisation (pathogen kill) and VS (volatile solids) destruction resulting in biogas production. The digested sludge, when compliant, can be applied to land and be used as a natural fertilizer.

To achieve the best possible performance this process must be kept under stable conditions. The volume of sludge fed, the %DS content and also the organic loading rate are some of the key parameters that need to be controlled to ensure optimum digestion. An easy way of doing so is by controlling of the %DS content in the feedstock, especially during the thickening, dewatering and dilution steps.

Anaerobic Digester performance can also be improved by using sludge pre-treatment technologies such as Thermal Hydrolysis Process (THP). This system uses steam to bring the sludge at high pressures and temperatures to enhance the hydrolysis of sludge, making the organic matter more easily accessible for the bacteria to digest. To reach the optimum THP conditions (economical and practical) it has been proven that the feed to THP needs to be at 16.5%DS. Thicker sludge can create rat-holing in the THP reactor tank, resulting in uneven heating and inefficient hydrolysis. Sludge at a lower %DS requires a large amount of steam to reach the optimum hydrolysis conditions, making THP less economically attractive.

In this paper different systems for DS control will be presented. The first one, located at Reading Sewage Treatment Works (STW), was implemented on existing assets in order to achieve more stable %DS going to the pasteurisation unit before conventional digestion. A trial was carried out to determine which of the torque, pressure or %DS (given by an online DS meter) was the best parameter to control the dilution. The second system was installed at Oxford STW and is used to ensure a consistent and controlled cake feed DS to the THP storage tank. This system was implemented alongside the installation of the belts.

Reading STW

At Reading STW raw and secondary sludges are thickened before being transferred into the pasteurisation tanks. Due to inconsistent sludge feed to the belts (imports, daily variation, sludge quality), the %DS of the sludge post-gravity belt is not stable. Indeed, depending on the sludge quantity and polymer dose, the %DS can vary between 7 and 13%. Currently, the only ways of controlling the thickness of the sludge are the two positions of the belt (**figure 1**), the polymer dose and the speed of the belt. Those parameters can be changed easily but it has to be done manually so there is no real time control of the %DS of the sludge.

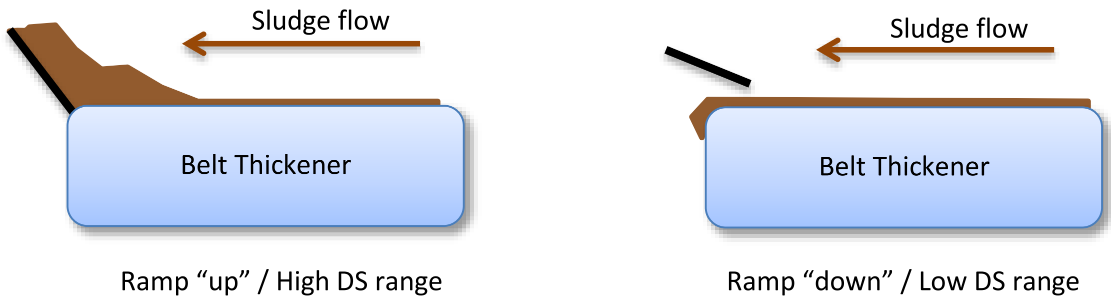


Figure 1: Poor DS control: two different manual settings

Process description

At Reading STW, 9tDS of indigenous primary sludge (PS) is generated every day by the lamella process and an average of 6.5tDS of primary sludge is imported. The blend (at 2-4%DS) is thickened by two belt thickeners which are working 8 hours per day (in total). The secondary activated sludge (SAS) is thickened continuously from the aeration lanes, each of the two SAS thickeners are working 23 hours per day (9tDS/day). After thickening, the sludge are mixed and transferred into 2 storage tanks, before being pumped into the pasteurisation unit. The average retention time of the sludge in the pasteurisation unit is 7.5hours. Sludge is then fed into one of the four egg-shaped digesters on site.

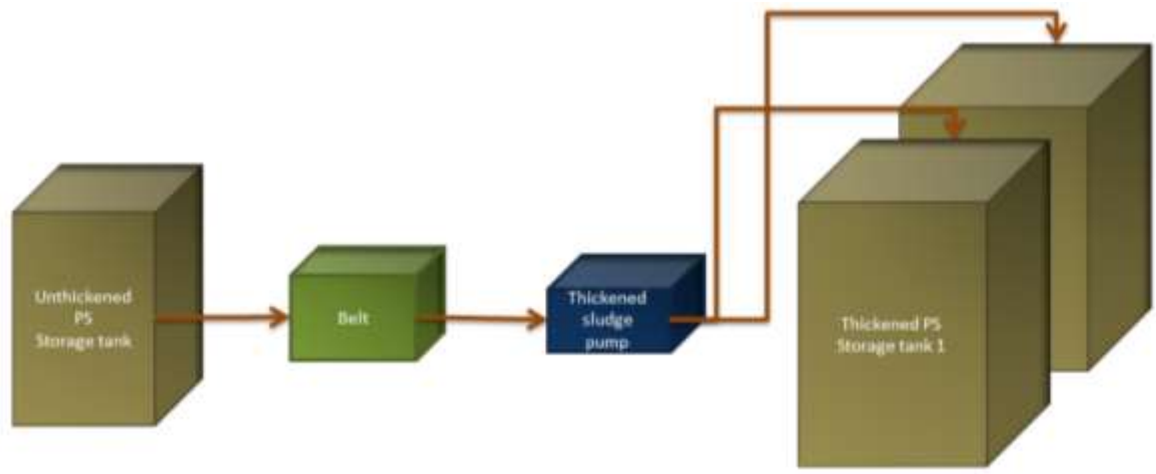


Figure 2: PS thickening system

Problem due to poor DS control

As mentioned above, there is currently no system to enable an on-line control of the DS. When too thick, the sludge usually generates blockages in the pipework and pumps and prevents the sludge from being transferred into the pasteurisation tank and the digester. This leads to non-negligible costs for Thames Water. Blockages in the pipework after the belts occur around 5 times a year, and it can cost up to £800 to unblock. In total, this kind of events can cost up to £16,000 a year at Reading STW. These blockages also generate other problems such as belt downtime, reduced sludge throughput, reduced thickened sludge generation and lost time for operators.

Ultimately, a controlled and stable dry solid post thickening (around 7%DS) will ensure a constant output, resulting in better performance from pasteurisation and digestion processes.

Project set up

As mentioned above, poor DS control can generate problems. It is then essential to be able to control the %DS coming out of the belts. To achieve this, a new process configuration was implemented at Reading STW, as shown in **figure 3 and 4**.

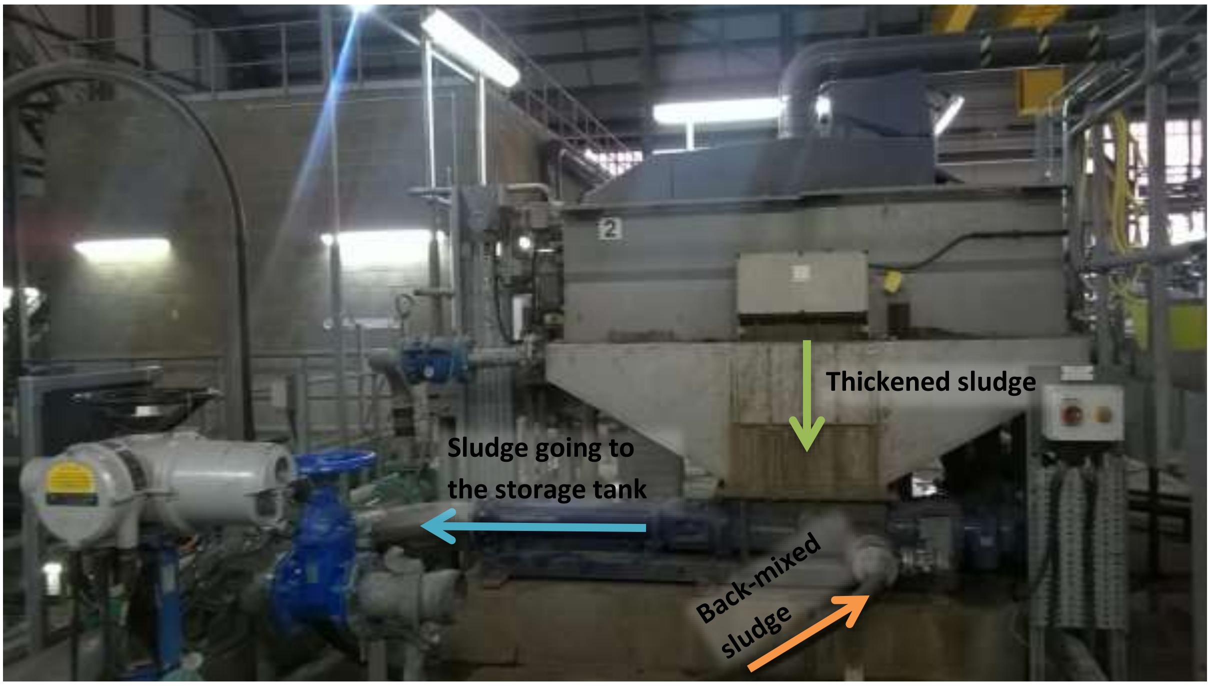


Figure 3: **Belt thickener with unthickened PS injection point**

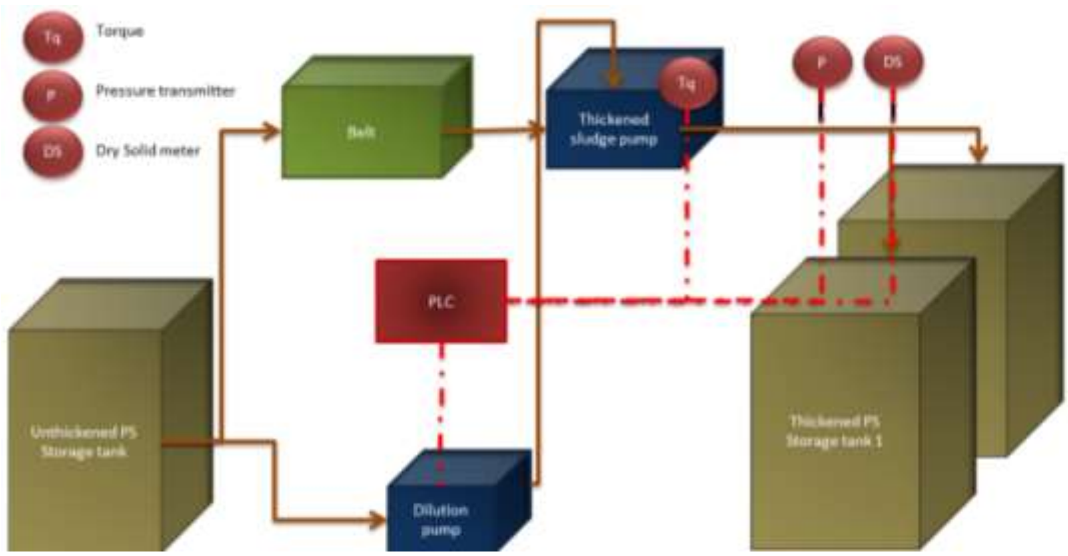


Figure 4: **PS Thickening system after backmixing installation**

Unthickened PS is injected (or back-mixed) into thickened PS in the thickened sludge pump, allowing the DS to match the set point. The dilution required is calculated in real time by measuring either the torque on the thickened sludge pump or the pressure in the pipe (via a pressure transmitter). A DS transmitter was also installed in order to test the performance of this type of equipment with higher dry solids. The parameters measured are continuously fed into a PID loop linked to the PLC (Programmable logic controller) and drive the pump speed based on a selected set point.

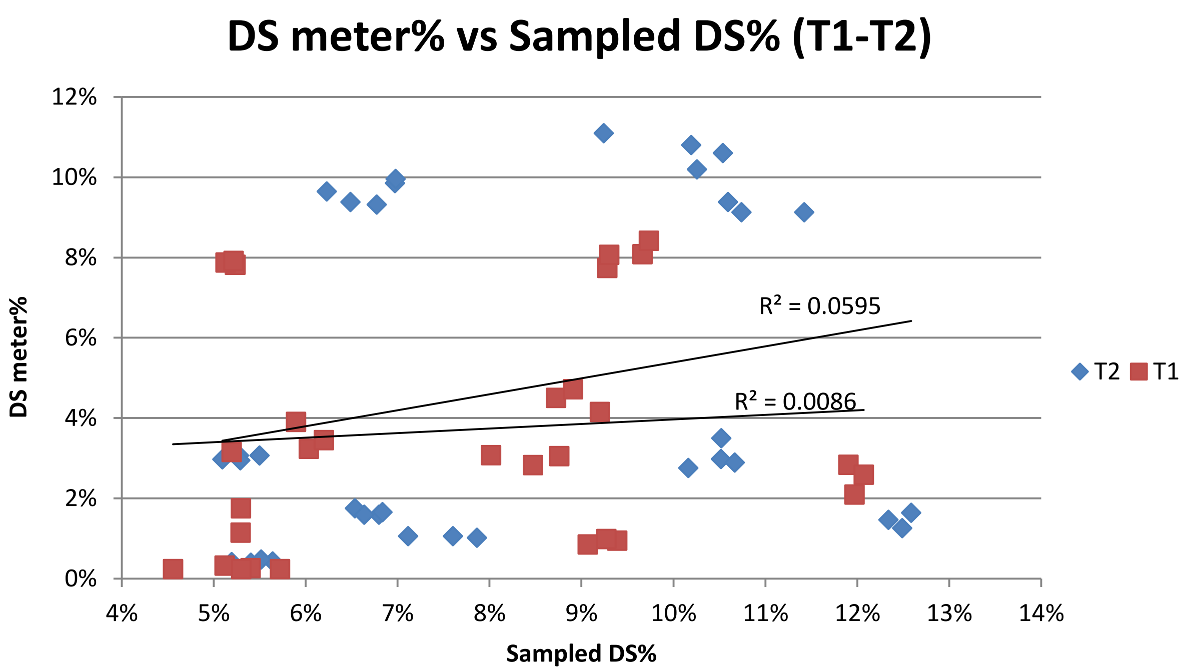
Process calibration

Prior to the commissioning of the automation, it was necessary to calibrate each instrument against a series of different %DS values. Calibration curves were gradually built after extensive sampling in order to help the selection of a set point (pressure or torque) for the automation. Additionally, these curves were useful to pre-establish which parameter (amongst pressure, DS transmitter and pump torque) is the most reliable for DS control.

Graph 1 shows the relation between the DS indicated by the DS meter and 'sampled DS' (the DS measured after the sampling). After the belt thickeners, the sludge can be transferred into two different tanks (T1 being further from the pump).As observed, the DS transmitter does not give a correct estimation of the real DS, whatever the destination tank is. This can be due to different reasons:

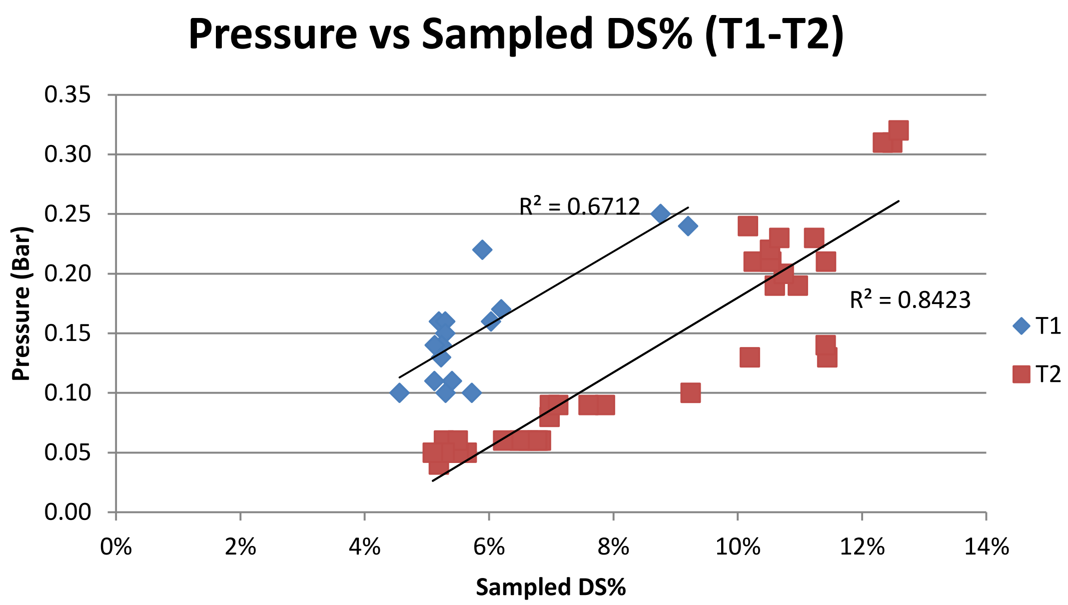
- Long response time of the instrument.
- The position of the DS transmitter in the pipework as it is located between the pump and the inlet of the storage tank (underground) and it is unsure if the sludge is filling the pipe completely or not.
- The DS range measured (too high for DS meter to be accurate)

In this particular case, the DS transmitter cannot be used to control the dilution pump.



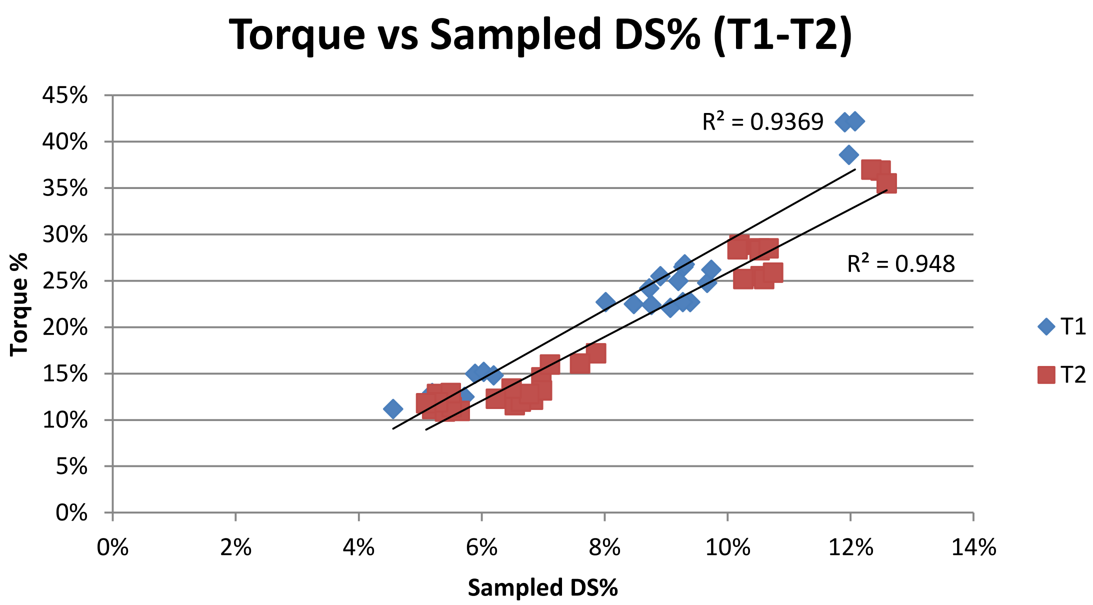
Graph 1: **No correlation found between DS given by the DS meter and the Sampled DS of the sludge**

Graph 2 shows the relation between the real DS (sampled & analysed) and the pressure in the pipework read on the instrument. It was found that the pressure values are affected by the storage tank selection, and, as expected, the pressure in the pipework is lower if the destination tank is the closest one. As seen on Graph 2, a good correlation can be established between the sampled DS and the pressure. The R^2 values are close to 1.



Graph 2: **Pressure versus Sampled DS% for the two different storage tanks**

Graph 3 shows a linear relationship between the thickened sludge pump torque and the sampled DS. The destination tank has a lower impact on the torque of the pump than on the pressure; nonetheless, this parameter should be included as a variable in the automation.



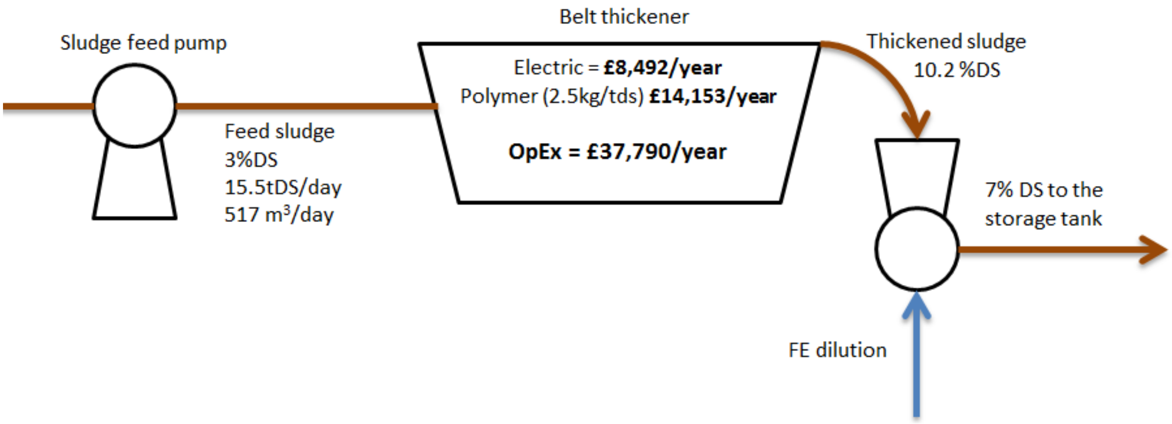
Graph 3: **Torque versus Sampled DS% for the two different storage tanks**

As described on the graphs, these two parameters are both good indicators, but torque exhibits more accuracy. R^2 is higher when the sampled DS is linked to the torque than when it is linked to the pressure.

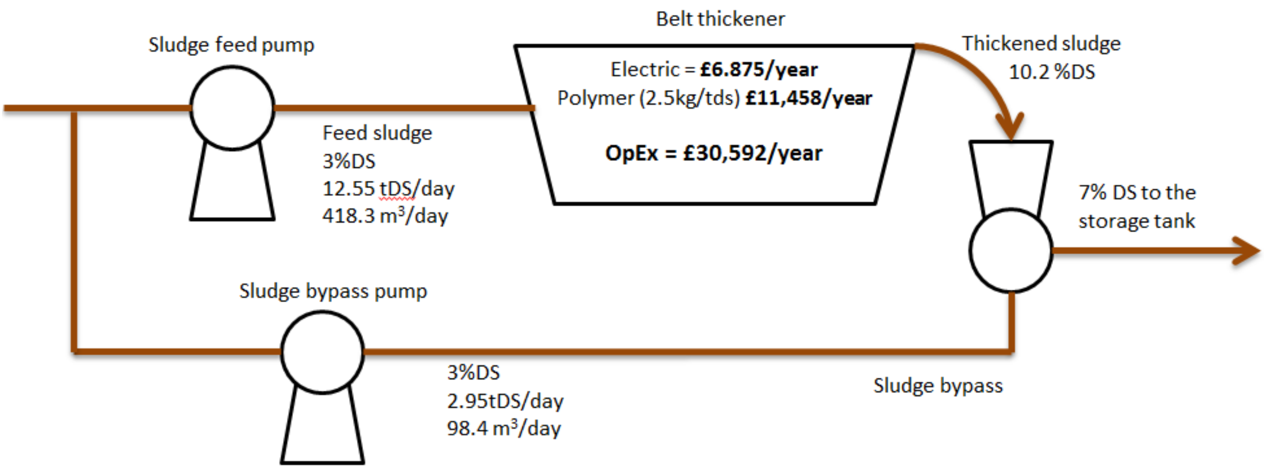
Savings

Different control systems can be implemented, both following the same philosophy. The dilution can be made with final effluent or with unthickend sludge (as previously). The following calculation compares the OpEx benefit of using unthickened sludge instead of Final Effluent.

Option 1: With final effluent dilution:



Option 2: With unthickend sludge dilution:



OpEx Savings = £7,198 per year

Compared to the base case without control, both of these configurations show advantages as they provide a stable system and avoid blockages in the pipework. Nonetheless, it is most interesting to use a dilution with unthickend sludge as less sludge needs to be thickened and thus less polymer is required.

More than the OpEx saving, the main interest of the backmixing is to provide a reliable, robust and controllable sludge feed and ensure better performance from pasteurisation & digestion plants. A good DS control should also allow higher throughput because of better stability of the digestion process that follows.

Project update

At the moment, the automation is being installed and the dilution pump needs to be commissioned. The data will be presented in a future paper.

II. Oxford:

A similar backmixing system is currently set up at Oxford STW where Thames Water is commissioning a Veolia THP plant – Biothelys thermal hydrolysis process. The plant is designed to treat 67tDS/day, among which 18tDS/day is indigenous liquid sludge and 48tDS/day consists mainly of cake imports. This process enhances the biodegradability of sewage sludge leading to an increase in biogas generation and a greater VS destruction during the anaerobic digestion.

The sludge stream is presented on the **figure 5.**

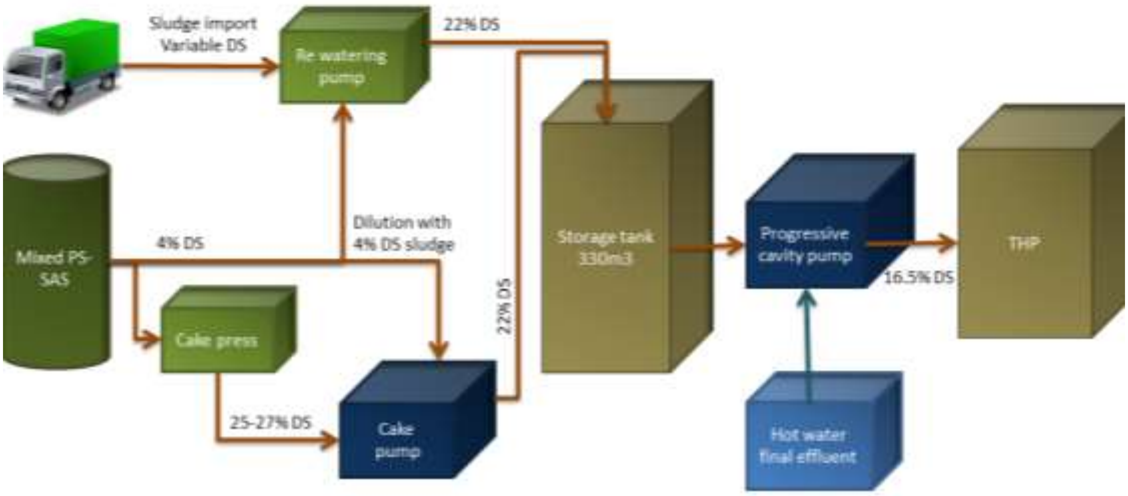


Figure 5: Oxford sludge treatment

Three different backmixing systems are employed in this part of the process.

Raw sludge dewatering - THP feed

- Purpose

The indigenous sludge (18tDS/day) is treated by a back mixing system to bring the DS up to a value where it is suitable for THP. The sludge post cake press lies in the range of 25-27%DS which is too thick to be transferred to the pre-THP storage tank. Regardless of the sludge origin, all of the cake entering the storage tank must be a consistent %DS to maintain sludge homogeny. It is not an option to set the belt thickeners to produce a cake at the optimal 22%DS due to the fine margins associated with polymer dosing. Thus a control system must be implemented to maintain a stable cake consistency.

- Control philosophy

Thickened SAS and PS are combined in two blending tanks (DS at 4-5%) and pumped to the pre de-watering feed tank. From this tank sludge is transferred into one of the three belt presses to be dewatered from 4-5 to 25-27 %DS. Un-thickened sludge is back-mixed to the thickened cake to maintain the DS content of 22% prior to THP. The specific setup can be outlined in **figure 6**. The control of this backmixing is based on the current of the cake pump and processed by a PLC unit. The same control is applied to all the three belt presses, and a similar scheme is to be used at Reading STW. Re-wetted sludge is then transferred to the pre-THP storage tank.

Figure 6: cake dilution system

- Benefit of the control

The control is necessary for the process to function effectively but also brings about a number of other benefits both in sludge use and operational savings. Initially there was the option of back-mixing with either final effluent or un-thickened sludge. The final effluent option requires far more treatment and therefore has a higher OpEx cost (£106,697/year) than the un-thickened sludge alternative (£91,472/year), (Fountain, P. and Strange, G., 2013).

Imported cake

- Purpose

Oxford also receives 48tDS/day of imported cake. The DS of this cake varies depending on its provenance, but is always higher than 22%, and usually around 28%. Un-thickened sludge is mixed with the cake in a re-watering pump to obtain a sludge at 22%DS. The quantity of un-thickened sludge to add is set depending on the DS of the cake measured by the torque of the pump. Sludge is then transferred to the THP storage tank.

- Control philosophy

Cake is delivered by tanker and then transferred into the sludge cake reception unit. Cake is then simultaneously pumped and re-wetted with sludge to reach 22%DS prior to storage in the pre-THP buffer tank.

Each site is unique when considering the cake quality, and as a result cake coming from different site requires a different dilution rate. It is therefore necessary to implement a control system which will function in the same manner as the indigenous re-wetting system with control using the pump current.

- Benefit of the control:

Oxford STW sludge reception centre receives on average around 48tDS/day of cake. It is important to be able to handle dry cake as this reduces transport volume and hence costs. **Table 1** displays the savings considering each import truck has a capacity of 28m^3. Having a re-wetting system on site allows the reception of cake at a higher %DS (around 28%), and saves around 2 trucks per day. Assuming the transport cost being 22£/m^3 , the total savings will be £1029/day, which represent a non-negligible value (£375,585 per year)

Table 1: Benefits obtained while transporting a dryer cake

%DS	sludge imported m3/day	truck/day
28	171	6
22	218	8

Pre-THP re-watering

- Purpose

DS feed to the THP tank is one of the keys parameter to ensure an optimal hydrolysis process and it must be maintained within the range of 14-16%DS. At lower DS the steam consumption is too high making the process less economically viable, at higher DS problems such as blockages and rat-holing can occur leading to incomplete hydrolysis.

- Control philosophy

From the THP pre storage tank, sludge is screw fed into a hopper equipped with a mixing mechanism and final effluent injection point. Hot water final effluent is recovered from waste heat derived from the CHP system. It is used to dilute the sludge to 16%DS and increase the sludge feed temperature to 30°C. The dilution rate is proposed to be controlled by a Berthold DS meter. The sludge is then pumped to the THP reactor where it is pre-heated with the steam flashed from a paired reactor. The steam is then injected to reach the optimum conditions (165°C, 6 bar).

- Benefit of the control

Usually the control of the DS before the THP is controlled by torque or pressure. In Oxford the goal is to try a new piece of equipment. Nonetheless, if it appears that the control is not accurate enough with the DS meter, the torque will be used to monitor the dilution rate.

Conclusion

Regarding the results obtained during the sampling period at Reading STW, it has been established that the torque seems to be the best parameter to control the backmixing even if the pressure shows very acceptable results. The automation still needs to be implemented then the performances of this process will be assessed and presented in a future report.

In Oxford the belts have been running for the commissioning period, and they have operated successfully, although there has not yet been enough running time for sufficient data with respect to the backmixing system. Once the THP will be running, the use of a DS meter can be experimented to control the re-watering.

Acknowledgment

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References

FOUNTAIN, P., STRANGE, G., 2013. Control of pre-THP dewatering and feed to THP using sludge bypass and back-mixing.18th European Biosolids & Organic Resources Conference & Exhibition