SUSTAINABLE SLUDGE DEWATERING- VOLUTE® DEWATERING SCREW-PRESS

Inman, D.[1], Skelton, H.[1], Mannion, R.[2] and Beagrie, R.[3]
[1]Anglian Water Services, [2]Evergreen Engineering; [3]Amcon (Europe)

Abstract

With a large number of rural sewage treatment works spread over a wide area, sludge handling in the Anglian Water region incurs considerable costs. Sludge handling requires resources in terms of energy, maintenance, chemical demand and transport, and if new or more innovative ways to process sludge can be found, significant saving would be realised, which would contribute to the company's sustainability targets.

The paper presents results of a trial conducted by Anglian Water's Innovation Team investigating a type of low-energy dewatering technology – the Volute® dewatering screw-press. For dewatering conventional SAS only, the Volute produced a transportable cake of 20.8% DS, whilst adding primary (raw) sludge to produce a 90:10 SAS:raw mixture by mass, provided a cake of 22.5% DS, and 60:40 mix produced a cake of 34%DS.

Keywords

Volute, dewatering, screw press, municipal sludge, biosolids, innovation, energy, surplus activated sludge

Introduction

A number of technologies exist for removing water from sludges to produce either a thicker sludge or a cake. Existing technologies used for this purpose include drum thickeners, screw presses, gravity belt thickeners, and centrifuges. Whilst all these technologies are widely used by UK water companies, issues around reliability, blockages, maintenance, and energy costs, mean that there is a continual drive for innovation.

Apart from the issues already mentioned, dewatering secondary activated sludge (SAS) to a thicker sludge or transportable cake remains one of the key sludge handling challenges for UK water companies. Biological sludge is known to have properties that make it difficult to dewater such as high bound water content and compressibility (Sorensen and Hansen, 1993; Katsiris and Katsiri, 1987). In Anglian Water, the preferred approach is either to thicken to a 2 to 4% sludge using a drum or belt thickener, or to add raw sludge to produce a 20 to 25% cake using a centrifuge.

Centrifuges can be used for dewatering SAS but require the addition of sludge from Primary Settlement Tanks (PSTs), referred to as raw sludge, in order to produce a transportable cake. Before adding the raw sludge, the SAS first needs to be pre-thickened which requires a polymer dosing step. The raw sludge is then blended lending a more fibrous matrix to the sludge without which the centrifuge will be unable to produce a cake. Another dose of polymer is added to the mix prior to entering the centrifuge.

Anglian Water's Innovation team recently conducted trials on a low energy dewatering process called the Volute dewatering screw-press. The technology has been developed and used in Japan for over 20 years and has 2027 municipal and industrial installations worldwide.

The Volute has a number of innovative design features that improve its functionality when compared with other screw press technology. The two main innovations are: (i) a funnel shaped inner screw that causes increased pressure on the sludge cake and leads to improved dewatering and (ii) alternate moving and fixed rings that keep the Volute clog-free. Figure 1 shows the screw and ring configuration and how they operate.

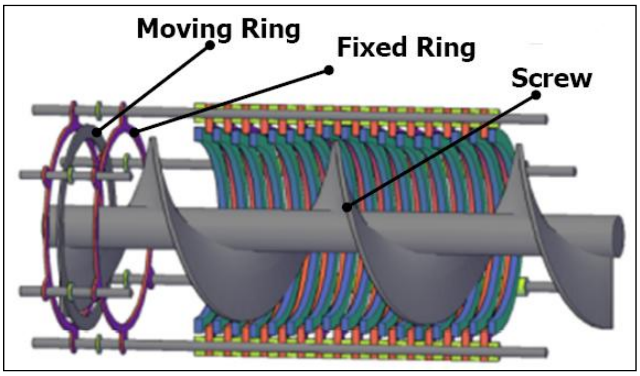


Figure 1: The two main innovations are: (a) a funnel shaped inner screw that causes increased pressure on the sludge cake and leads to improved dewatering and (b) alternate moving and fixed rings that keep the Volute clog-free.

According to manufacturers, the above design features mean that the Volute unit can dewater a <1% dry solids sludge to a >19% dry solids cake in a single step, thus reducing the mechanical equipment and associated maintenance required, lowering polymer demand and storage requirements. The Volute also requires lower energy input compared to other process, using around 40% less energy than a belt press and 80% less energy that centrifuge (Amcon, 2008). In preparation for the trial, a review of existing case studies was performed and is summarised below.

Review of existing case study data

Case study data exists from a number of trials of the Volute on both municipal wastewater sludges and water treatment plant sludge. All these trials were conducted in the US.

A joint research project conducted by AMCON and Bureau of Sewerage Tokyo Metropolitan Government over three years finished at the end of 2008 (AMCON, 2008). An ES351 model was used in the trial and a throughput of 300 kgDS/h was achieved with a maximum cake solids achieved of 27%. Table 1 summarised the results from the Tokyo trial.

Table 1: Operation comparison at Tokyo sewage plant (AMCON, 2008)

	Volute dewatering screw-press (ES351)	Belt Press(1unit) & Centrifuge Thickener (3 units)
Feed Sludge	1.5%	4.0%
Throughput (average)	240kgds/h	240kgds/h21%
Cake Solids (average)	22%	21%
Capture Rate (average)	97%	95%
Footprint	32m2	287m2
Water Consumption	475L/h	15,200L/h
Electrical Consumption with sludge pump	5.75 kwh	84.5 kwh

The research at Tokyo also demonstrated that bypassing the sludge thickening process by using Volute technology reduces the phosphorus content in the filtrate by more than 50%. As shown in the chart below (Fig 2), the phosphorus content in the filtrate from Volute (pink line) is lower by more than 50% compared with that of belt press (blue line).

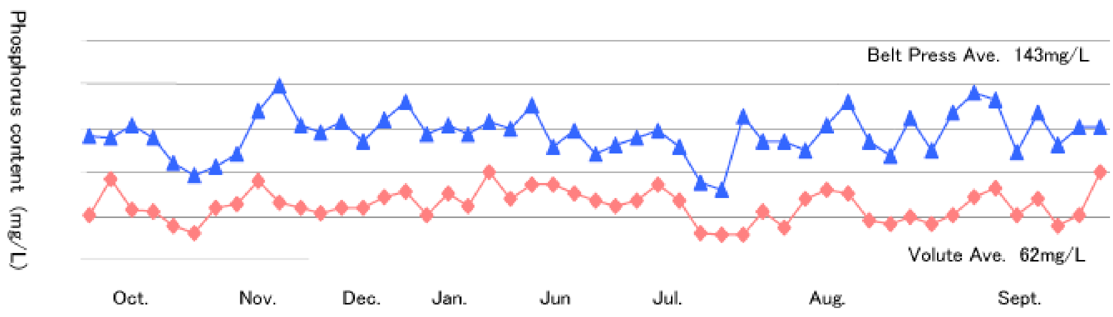


Figure 2: Comparison of phosphorus content in filtrate from Belt press and Volute at Tokyo sewage plant (AMCON, 2008)

The reason stated by the researchers for phosphorus reduction was because, by reducing the steps and therefore time needed to thicken the sludge, Volute dewaters the sludge sooner while still aerobic, keeping the phosphorus inside the microorganisms or the sludge. On the other hand, the existing belt press at this plant requires a pre-thickening process, and during which, the microorganisms releases the phosphorus in the water, which resulted in the higher phosphorus content in the filtrate. Since the filtrate from the sludge treatment process goes back to the beginning of the wastewater treatment process, the lower the phosphorus content in the filtrate the less phosphorous needs to be removed from the wastewater.

A second trial of the Volute Dewatering Screw-Press, this time with model ES 131, was pilot tested at Fallbrook Sanitary District Water Reclamation Facility to determine its effectiveness at dewatering the plant's aerobically digested sludge (Sanchez et al, 2011). The influent solids varied between 0.4 and 0.9% and the press achieved cake as dry as 19.3% solids with all runs over 17%. Analysis of the press filtrate demonstrated a cake solids capture range between 99.0 and 99.5%. The unit operated at a polymer dose rate of between 3 to 11 kg/tonne of dry solids (kg/Tds) with the polymer dose rate having little impact on the cake solids. The ES131 unit has a recommended throughput of 10 to 12 kg of dry solids per hour (kgDS/h). During the trial the unit was run up to 15 kgDS/h and still achieved a cake of 17.5% dry solids.

Further pilot testing of the Volute Dewatering Screw-Press was undertaken at the City of St.Petersburg Northeast Water Reclamation Facility (Bierhorst and DeLiso, 2011). The pilot test focused on dewatering sludge from the anaerobic digester which was in the range 3.1 – 4.2%. The press was able to generate cake solids of up to 26.8% on this sludge. Based on this pilot the likely operating point for an installed unit would be in the 20-25% range using a polymer dose of around 9 to 11 kg/Tds. Solids capture rates for the anaerobic sludge dewatering were typically 99.8%. Because the plant may also consider direct dewatering of SAS in future, a brief test was conducted to demonstrate the presses suitability for this by dewatering the SAS which was in the range 1.4 – 1.6%. Cake solids of up to 19.4% were achieved using 9 kg of polymer per ton of dry solids. A calculated solids capture ≥ 99% was found for all samples analyzed for the WAS testing (Bierhorst and DeLiso, 2011.

Piloting of a Volute Dewatering Screw-Press was conducted at the Hulton Treatment Plant in Oakmont, PA to demonstrate its suitability for dewatering the plant's sedimentation sludge (Niglio et al, 2010). The sludge is currently being tankered away in liquid form. Dewatering the sludge would significantly reduce the sludge volume and therefore hauling costs. Three days of testing were undertaken, with 17 separate runs performed and results recorded. Cake solids up to 23.3% were achieved processing an influent sludge of 1.97% which corresponds to a volume reduction of 92%. Over the three days, cake solids averaged at 19.6% and had a low of 17.8%. Analysis of the filtrate for TSS levels was done on samples collected and show and excellent capture % of the unit: ≥98.0% for all three filtrate samples, ensuring easy disposal of the filtrate.

A further pilot test of the Volute Dewatering Screw-Press pilot model ES132 was undertaken at the City of Ithaca Water Treatment Plant on the plant's settled alum sludge (Mele et al, 2011). The press generated cake solids of 45.2%. From total suspended solids analysis on the filtrate, a solids capture of 99.9% in the cake was measured. The graph below (Fig 3) shows the results from the Ithaca and Oakmont trial on clean water sludges.

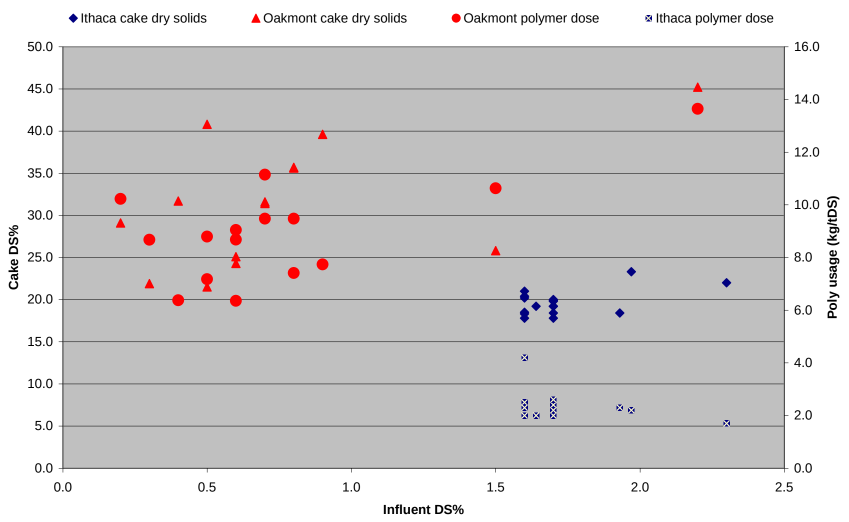


Figure 3: Comparison of clean water sludge dewatering trials at Ithaca (Mele et al, 2011) and Oakmont (Niglio et al, 2010)

Methods & Results

A Volute ES 131 unit was installed at a site in Anglian Water. During the trial, different sludges were imported for testing. A sludge holding tank with a mixer was filled with sludge for each trial. Liquid polymer was dosed via a Polymore dosing unit.

The Volute unit that was used during the trial is shown in the photograph below.

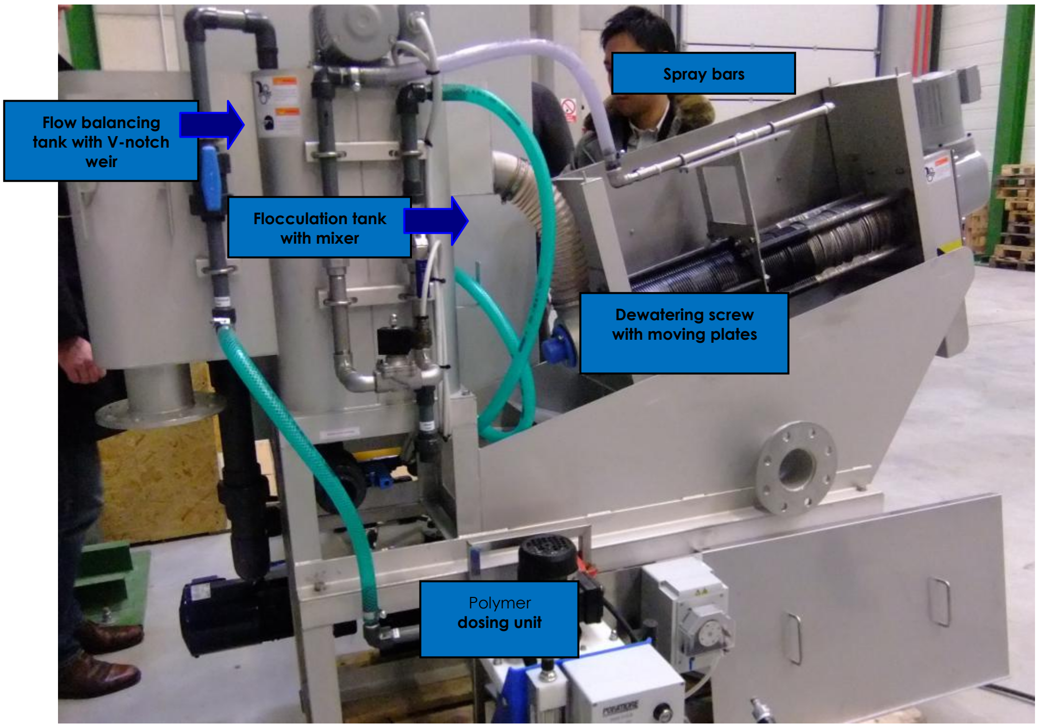


Figure 4: Volute unit (ES131) used during the Anglian Water trial

Sludge first enters a flow balancing tank and from there overflows into a flocculation tank via a V-notch weir. Polymer is dosed into the flocculation tank and mixed. From there the flocculated sludge overflows into the Volute screw via an overflow pipe.

Sludge from five different processes was imported into the sludge holding tank for processing through the Volute. The sludge type and processes on the five sites where the sludge was sourced were:

1. SAS from deep shaft activated sludge process (ASP)
2. SAS from a site with traditional ASP
3. Digested sludge post Enhanced Enzymic Hydrolysis and Anaerobic Digestion
4. Digested sludge post Cambi Thermal Hydrolysis and Anaerobic Digestion
5. Iron sludge from a potable water treatment plant

Samples were collected from three sampling points (feed sludge, cake and filtrate) for analysis. Dry solids analysis was performed in an oven at 105^{0}C for 24 hours on the feed sludge and cake. The filtrate was analysed for Total Suspended Solids content. The polymer dose was adjusted to an optimum level and the dry solids recorded.

Surplus Activated Sludge (SAS) dewatering results

The results for SAS dewatering are shown in Table 2. Influent solids for SAS ranged from 6000-15000 mg/l and tended to require higher polymer dose rates when the feed solids were lower. The polymer dose for the results in Table 2 averaged around 6.5 kg/Tds.

Table 2: Volute cake dry solids results for surplus activated sludge (SAS)

Sludge type and process	**Cake dry solids (%)**		
	Minimum	**Maximum**	**Average**
SAS from deep shaft ASP	16.7	18.5	17.5
SAS from traditional ASP 1	15.6	21.6	19.0
SAS from traditional ASP 2	18.3	20.7	19.7

Further tests were performed by adding either raw or co settled raw sludge to the SAS in the sludge holding tank, and the graph in Figure 5, below, shows the results for different mix ratios. As a reference the cake dry solids achieved by a centrifuge on a 50%: 50% mix is shown.

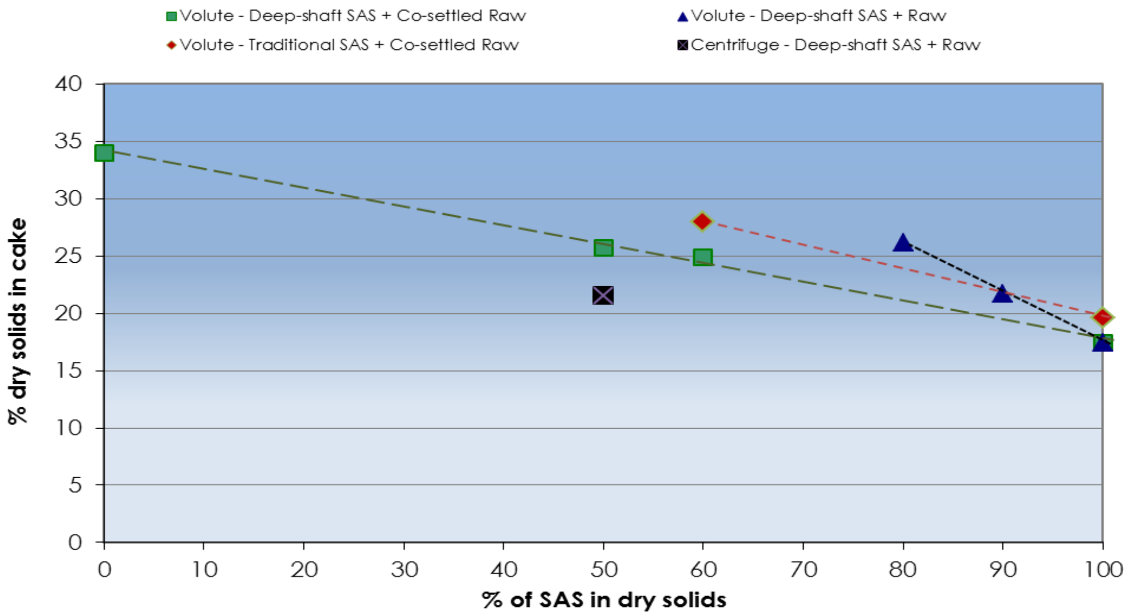


Figure 5: Volute cake dry solids results for mixing raw sludge with SAS at different ratios; centrifuge cake dry solids for 50:50 mix is shown for comparison

Co settled raw sludge is produced by transferring SAS into the PSTs on site where it is settled along with the raw solids. Dewatering co settled sludge on its own produced a 34% DS cake. Sludges were mixed at an 80:20 ratio (SAS:raw) based on the dry solids content. For the site with no co settlement, an 80:20 ratio produced a 25% dry solids cake. For co settled sludge, which contains some SAS, mixing 50% co settled sludge with 50% deep shaft activated sludge produced a 25.7% cake).

Figure 6 (below) shows how, when combining SAS and raw sludge, a lower polymer dose is required to produce the same % dry solids cake as the quantity of raw is increased. Fig 5 also shows the current performance of a centrifuge using a 50%: 50% SAS: Raw mixture as a comparison. The polymer dose for the centrifuge (8.6 kg/Tds) in Fig 6 includes the polymer dose for thickening. The same polymer, Kemira Superfloc SD 2081, was used on the centrifuge and throughout the Volute SAS trials.

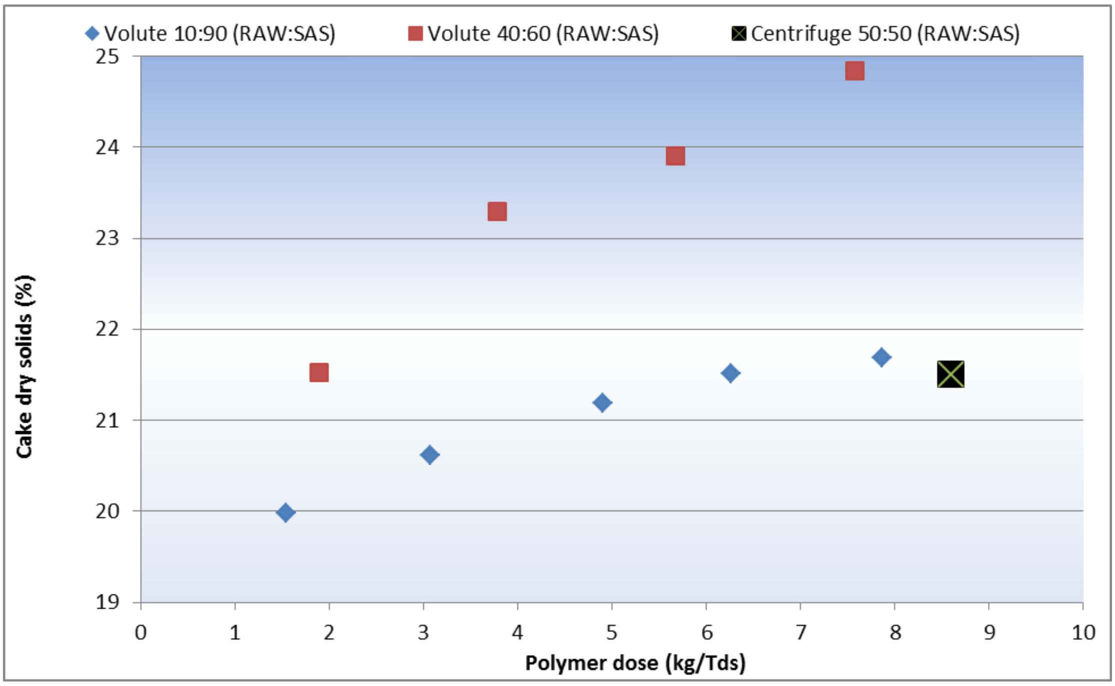


Figure 6: **Polymer dose impacts on cake dry solids for different SAS: Raw mixtures; centrifuge polymer dose and cake dry solids is shown for comparison**

The above findings presented in Figs 5 & 6 (above) have implications for future biosolids strategy cost reduction. Firstly, removing the thickening step that is required for centrifugation means that the polymer demand when using a Volute is 50% lower. Secondly, the Volute reduces the amount of raw sludge required to be imported in the cake production process which means that raw sludge can instead be transported directly to sludge treatment centres for anaerobic digestion, thus avoiding double handling and significant transport costs.

Filtrate samples were collected and analysed for solids capture. Solids in the filtrate ranged between 283-740 mg/l and it was observed that higher solids occurred in the filtrate when either the sludge had been stored for over 5 days or insufficient polymer was dosed. Solids capture results are shown in Table 3.

Table 3: Volute filtrate analysis for SAS showing % solids capture

Sludge type and process	Filtrate solids capture (%)		
	Minimum	Maximum	Average
SAS from deep shaft ASP	97.7	98.8	98.3
SAS from traditional ASP 1	97.8	98.1	98.0
SAS from traditional ASP 2	98.7	98.9	98.8

The results show the Volute can be reliably expected to achieve a range of solids capture of between 97.7% and 98.9% for SAS, which corresponded to 200 to 1000 mg/l during the trial.

The higher solids capture of the Volute is thought to be due to a combination of lower shear (the Volute screw turns at between 1.5 and 2 rpm) and the self cleaning discs (Fig 1) that prevent solids escaping from the inner screw.

Anaerobic sludge dewatering results

Anaerobic sludges from advanced digestion processes were imported into the sludge holding tank for dewatering. The results are presented in Table 4.

Table 4: Volute cake dry solids results for anaerobic sludge

Sludge type and process	Cake dry solids (%)		
	Minimum	Maximum	Average
Post Enhanced Enzymic Hydrolysis digested	23.6	30.8	27.5
Post Cambi digested	23.1	27.7	25.1

Anaerobic sludges dewater best using a branched polymer. These polymers are, however, only available in powder form which were not suitable for use with the Polymore dosing unit supplied with the ES131 Volute model.

For the Enhanced Enzymic Hydrolysis sludge, a ready mixed linear chain polymer, SNF Flopam ES 640 LH, was therefore used instead of the branched powder poly. The optimum polymer dose for the Volute was 8.5 kg/Tds. For comparison, the cake produced by the centrifuge using a branched polymer on the Monsal sludge was between 28 and 31% dry solids, at a polymer dose of around 6 kg/Tds.

For the Cambi sludge, the SNF Flopam ES 640 LH polymer failed to form a good enough floc for dewatering. Containers of the mixed powder polymer used for centrifugation, BASF 8140, were therefore collected and dosed manually. The polymer dose used for the Volute and centrifuge was between 2 and 4 kg/Tds.

Solids capture ranged from 96.3% to 97.6% which was equivalent to between 670-1030 mg/l.

Due to the constraints on polymer dosing (type and dose rate), both the cake dry solids and filtrate results for anaerobic sludge should be considered sub-optimal. For any future trial it is advised a suitable poly dosing unit that can prepare and dosing branch chain powder polymer be used. Under those conditions it is possible that the results in Table 4 could be improved upon.

Potable water sludge dewatering results

Sludges from potable water treatment works were imported into the sludge holding tank for dewatering. The results are presented in Table 5.

Table 5: Volute cake dry solids results for potable water sludge

Sludge type and process	Cake dry solids (%)		
	Minimum	Maximum	Average
Iron sludge from settlement lagoon	17.9	24.7	22.2
Iron sludge from DAF	17.7	20.7	19.2

The lagoon sludge was tested instead of fresh iron sludge because, for operational reasons, it was not possible to disturb the process stream at the time of the trial. The lagoon sludge will contain micro-organisms from biological degradation which is likely to make it more difficult to dewater that fresh potable water sludge. The % dry solids achieved provides indicative evidence that a cake of over 25% dry solids can be produced by the Volute from Iron sludge which is fresh from the process.

The DAF sludge was a particularly problematic sludge which had persistently blinded plates of a plate and frame press on the potable water site. In addition to producing a 20.6% dry solids cake, the Volute achieved a solids capture rate of 99.8%.

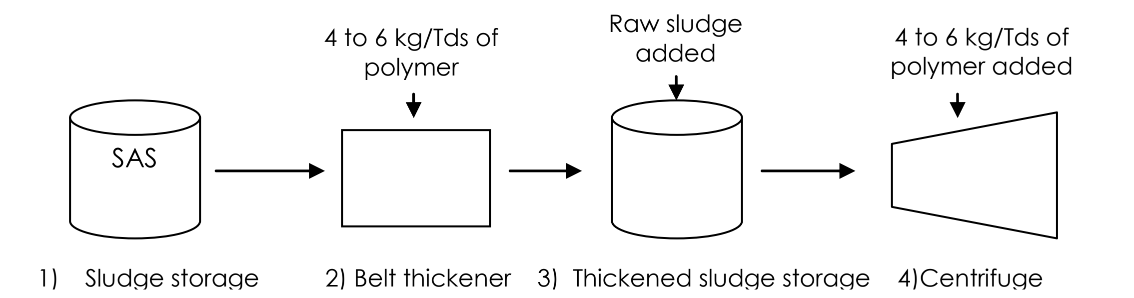
Discussion

The trial demonstrated that the Volute can effectively dewater surplus activated, anaerobic and clean water sludge to a transportable cake. For dewatering conventional SAS only, the Volute produced a transportable cake of 20.8% DS, whilst adding primary sludge to produce a 90:10 SAS: raw mixture provided a cake of 22.5% DS.

For the trials on SAS, the source sites were of interest because they do not have PSTs and so have no indigenous raw sludge on site, meaning that raw sludge needs to be imported in order to produce a >20% DS cake. As evidenced by the trial, using the Volute for SAS dewatering would require a lower proportion of raw sludge imports, thus reducing sludge haulage costs.

With many rural sites spread over a large area, the reductions to sludge processing made possible by the Volute are potentially significant. The trial provided evidence that raw sludge import requirements, polymer dosing, and storage are all reduced for the Volute compared to a centrifuge. The sludge-to-cake steps for both processes are shown in Fig 7.

Centrifuge sludge-to-cake process steps



(i) Volute sludge-to-cake process steps

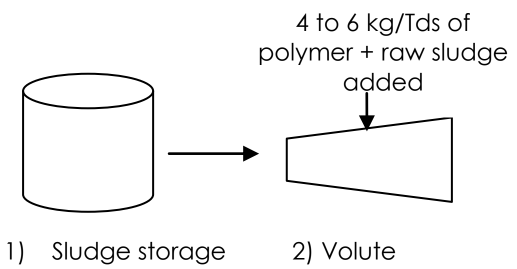


Figure 7: Sludge-to-cake process diagram for (i) centrifuge and (ii) Volute

A further perceived benefit of reducing the process steps, shown in Fig 7, is shorter storage times meaning less release of phosphorus from biological cells which can increase during long periods of storage, especially in anaerobic conditions. Any released phosphorus ultimately ends up in the filtrate to be returned to the head of the works. With increasing pressures to reduce P levels in final effluent, reducing the re-release of phosphorus would be beneficial in terms of compliance risk.

Low solids in the Volute filtrate, as indicated in the trial results, will reduce pressure on treatment processes. As mentioned above, liquors from dewatering equipment are traditionally returned to the head of the treatment works and if the solid load is high, this can negatively impact on operation and in the worst case, can affect compliance.

Although not measured directly during the trial, energy input requirements for the Volute are around 80% lower than for centrifugation. The next step for Anglian Water will be to complete a full embodied and operational energy/carbon balance for the Volute compared to existing installations.

Conclusions

The findings from the Anglian Water Volute trial are as follows.

1. The Volute dewatering screw-press can dewater:
    a. SAS from traditional ASP to an 18.5% dry solids cake and can achieve >20% dry solids cake if sludge is dewatered fresh and polymer dose is optimised

   b. Advanced anaerobic digested sludge to 23 to 30% cake
   c. Clean water sludge to a 19 to 25% cake, depending on the storage and source of the sludge.
2. Addition of 10% raw primary sludge to the SAS will increase the cake dry solids content by between 1%DS and 3%DS depending on the source of the raw sludge (e.g. co settled, traditional PST, humus tank).
3. Compared to centrifugation, Volute uses 50% less polymer for SAS dewatering due to there being no requirement for a thickening step.
4. Filtrate capture rate consistently achieved >98% for SAS, >97% for advanced anaerobic digested sludge, and >99% for clean water sludge.
5. Reducing sludge storage and optimising polymer dosing will improve sludge dewatering for the Volute.

The above findings have implications for future biosolids strategy cost reduction. The Volute reduces polymer demand and, perhaps more importantly, reduces the amount of raw sludge required to be imported into cake production centres. This means that raw sludge can instead be transported directly to sludge treatment centres for anaerobic digestion, thus avoiding double handling and significant transport costs.

Further research could include measuring energy usage and phosphorus capture.

References

Amcon, 2008. *Research on Dewatering Mixed Sludge by VOLUTE*

Bierhorst, R., and DeLiso, M., 2011. PW Tech: Report on Piloting of the Volute Dewatering Press at the City of St. Petersburg Northeast Water Reclamation Facility. Process Wastewater Technologies.

Katsiris, N., Kouzeli-Katsiri, A., 1987. Bound Water Content of Biological Sludges in Relation to Filtration and Dewatering. Water Research, p1319-1327.

Niglio, B., Barnett, R., DeLiso, M.I, 2010. PW Tech: Report on Piloting of the Volute Dewatering Press at the Hulton Treatment Plant in Oakmont, PA. Process Wastewater Technologies.

Sanchez, J., Barnett, R., DeLiso, M., 2011. PW Tech: Report on Piloting of the Volute Dewatering Press at the Fallbrook Sanitary District WRF. Process Wastewater Technologies.

Sørensen, P.B., and Hansen, J.A., 1993. Extreme Solid Compressibility in Biological Sludge Dewatering. Water Science & Technology Vol 28 No 1 pp 133–143