

Sludge Dewatering Performance - A Survey Of Real Operational Performance

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ABSTRACT

A survey of the literature revealed that it is difficult, indeed virtually impossible, to get meaningful information about the likely performance of dewatering equipment. As a consequence customers have sometimes specified impossible target performances and suppliers have unwisely agreed to them. Dewatering has major consequences for downstream processes, for example sizing dryers correctly is directly dependent upon the amount of water that has to be evaporated, i.e. the dry solids content of the cake. This paper will present the results of a survey of operational sludge dewatering, including the type of equipment, conditioner and type of sludge undertaken with the cooperation of members of Water UK. The results should assist designers and specifiers of sludge treatment processes and enable operators to benchmark the performance of their own equipment.

KEY WORDS

Belt filter press, cake dry solids, centrifuge, polyelectrolyte dose

INTRODUCTION

The inspiration for this paper was a contractual dispute on which I was asked to give an expert opinion. A water company had asked a demanding Specification for the dewatering capability of a Sludge Treatment Centre (STC). My initial impression was that the Specification had been unrealistic, but nevertheless a supplier had contracted to provide an installation that would satisfy it. The reason for the dispute was, of course, that the installation did not meet the Specification.

The water company had provided information about the wastewater treatment works and the sludges that would be fed into it when it became an STC. The sludge make at the STC was predicted to be 60% indigenous, 40% imported and the combined thicken surplus activated sludge (SAS) was expected to be up to 43%. The combined sludges were to be treated by mesophilic anaerobic digestion (MAD), which was due to be upgraded as part of the contract.

The water company specified dewatering by either decanter centrifuge or by belt filter press (BFP); a mix of dewatering technologies was not permitted. There was an existing BFP which was available to be refurbished if the Contractor considered it suitable for inclusion in a BFP solution. Each dewatering unit, including the standby, was to have the same hydraulic capacity. The specification said that the dewatering plant was to be capable of operating 24 hours per day and 7 day per week producing 25%DS cake at 95%ile with a polyelectrolyte dose not exceeding 6kg/tDS. To make the task even more difficult, the plant was required to achieve this top-rate performance with only occasional attendance for up to 16 hours per day.

Unsurprisingly, because it would have had the lowest capital cost, the contractor chose a BFP solution and to refurbish the existing BFP. My experience was that this was a totally unrealistic proposition. I had never seen a BFP installation achieving a 95%ile 25%DS when dewatering MAD sludge that had been 60% primary : 40% SAS. Also, I had not seen

a BFP installation that ran with only occasional attendance 24/7 including unattended overnight. But, when we researched the literature we found there was little, if anything, very useful published on the subject. Text books gave vague, generalised ranges. Research and operational papers seldom gave a complete picture. They either described the dewatering equipment or the sludge, but never both in sufficient detail to be useful. Often they described trials when equipment was being cosseted more than can be expected under operational conditions. Papers from the manufacturers of dewatering equipment related to it being operated by the manufacture's expert technicians.

Accordingly it seemed that it would be useful to all parties if there were data in the public domain about how dewatering really performs in operational situations. I put the proposition to Water UK's specialist network on biosolids and its members agreed to provide data. Unfortunately, at the time of writing, I am still awaiting data from the majority of members.

FACTORS RELEVANT TO DEWATERING

Cake dry solids is affected by the type, size and number of dewatering machines. The majority in use today are belt filter press, centrifuge, plate and frame press and plate and frame diaphragm press; predominately the first two. Dewatering equipment separates the solid and liquid fractions of the sludge and therefore performance is affected by how much solids they have to handle (solids loading) and how much water has to be conducted away (hydraulic loading).

Dewatering performance is also very much affected by the type of sludge. For example the proportions of sludge from primary settlement and whether the secondary treatment is biological filter (humus sludge) or activated sludge (surplus activated sludge) or whether the wastewater treatment was by extended aeration and whether there are imported sludges.

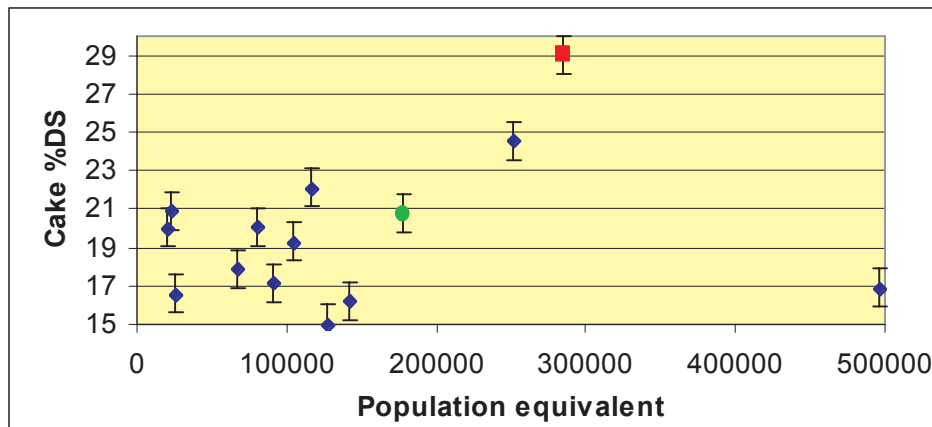


Figure 1: Company A dewatering data for MAD sludge, all BFP except for one centrifuge; one site had thermal hydrolysis before the MAD (survey undertaken in 2001; error bars ± 1 standard deviation)

In general sludge produced by aerating suspended biomass is difficult to dewater because the extracellular polymer holds water and also protects the contents of the cells from degradation. Humus sludge from trickling filters is relatively easier to dewater - because, before they have been sloughed off, the biofilms have been mineralised and grazed. Extended aeration without primary settlement is especially problematic because it is difficult to stabilise by anaerobic digestion and it is difficult to dewater, which makes stabilisation by composting or dry lime systems difficult/expensive. Liming the liquid sludge from extended aeration ['liquid lime'] prior to dewatering has proved effective, it kills *Escherichia coli* and seems to control odour.

The method of sludge stabilisation is another factor. Although the European sludge directive (CEC, 1986) permits the use of untreated sludge provided it is worked into the soil as soon as reasonably possible, in many Member States, including the UK, sludge must be treated before it can be used on agricultural land. Some treatments (e.g. composting and dry lime stabilisation) are performed on dewatered raw [untreated] sludge, other methods of stabilisation treat the liquid sludge (possibly after thickening) prior to eventual dewatering. Thermal drying and incineration can also be performed on dewatered cake. Thermal drying is evaporating water so the more water that can be removed by mechanical dewatering, the less that has to be evaporated using high-grade energy. The extent of water removal also critically affects the cost of incineration, if the cake is dry enough it will generate enough heat when it burns to evaporate residual water, i.e. it will be autothermic, if is wetter than this threshold supplementary fuel will be needed. Water vapour also contributes to the volume of emitted gas that requires [expensive] clean-up.

The liquid sludge fed to dewatering could be untreated raw sludge, or stabilised sludge from mesophilic anaerobic digestion, autothermic thermophilic aerobic digestion, thermophilic aerobic digestion, thermophilic anaerobic digestion or two phase anaerobic digestion, also called enzymic hydrolysis. The sludge might have been treated prior to anaerobic digestion by pasteurisation, thermophilic aerobic pasteurisation, thermal hydrolysis, ultrasound, or some other means of mechanically disintegrating the secondary sludge. All of these have an effect on the factors that determine dewaterability, such as the surface charge characteristics and particle size distribution in the liquid sludge.

The surfaces of sludge particles have a pH-dependent net negative electrical charge which is balanced by dissolved

positive ions (cations) these cations are surrounded by hydration water which limits the closeness of approach of the particles, prevents them interacting gravitationally and keeps them in suspension. To overcome this, conditioning chemicals are added. Originally these were inorganic such as iron, aluminium and calcium that are multi-valent and without hydration shells, for thirty years or more organic polyelectrolytes have been the favoured conditioners, sometimes complemented by inorganic. There is a range of polyelectrolytes with different charge densities and optimum pH to suit individual sludges. Having selected the optimum conditioner, the optimum dose is proportional to the solids content of the feed sludge (kg polyelectrolyte per tonne dry solids). The solids content of the feed is seldom if ever constant so flow proportional dosing, although it is practicable, will seldom be optimal. Additionally the surface properties of the sludge particles change with time. It is reasonable to expect, for example, that the sludge particles when sewers are flushed by rain after a prolonged dry spell during which sludge has settled in the sewers, will differ from times when flow is more continuous. However, I expect that the properties also change on shorter time scales depending on the history of the sludge, even though most treatment processes give significant attenuation of upstream influences. In the light of all of this it is obvious that an occasional CST (capillary suction time) measurement cannot result in continuous optimum dosing, which can only be achieved by real-time feed-back and/or feed-forward from the dewatering liquor and feed sludge (e.g. Häck, 2006).

The degree of stabilisation is another determining factor; in general, the more that the sludge has been mineralised the easier the sludge will be to dewater and the dryer the cake.

RESULTS

Company A

Company A provided data from a survey conducted in 2001 for dewatering of MAD sludge (Figure 1). The number of observations per site was typically 15 (range 4-30). All of the samples were taken directly from the cake outlet of the dewatering machine, i.e. not from a stockpile pad or when the cake was being removed from the works. Figure 1 demonstrates there was no relationship between the size of the treatment works and the dewatering performance. It also shows that none of the works achieved a 95%ile of 25%DS cake from conventional MAD sludge.

One of the works using BFP was notably better than the rest; the average for this works was from 9 samples taken over 10

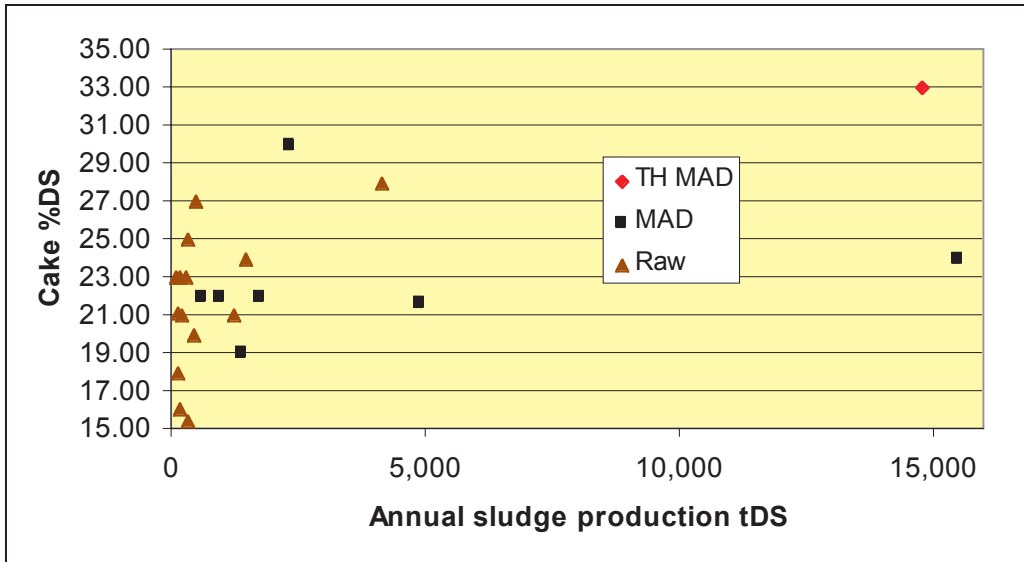


Figure 2: Cake data from Company B's annual return submitted in 2006

weeks (standard deviation=1.35, maximum=27.7, minimum=22.9, median=24.4). The company contact reported that there was a single operator who looked after the digester and the BFP; the BFP received nearly constant attention whilst in use. Only a fraction of the digested sludge went to the BFP (the remainder was lagooned) therefore there was no throughput pressure on dewatering.

Where the sludge had been treated by thermal hydrolysis prior to digestion the cake was notably drier than the rest.

The works using centrifuge dewatering was in the better performing area of the BFP results but it would be inappropriate to generalise on the basis of only one site.

Company B

Company B provided data from its annual return; consequently they were annual averages with no information about the number of observations or range of values (Figure 2). Some of the samples would have been taken when the cake was removed from site, but some others might have been taken from the dewatering machine. In the former case the cake might have been subject to wetting and drying from rain and sun.

As with Company A there is no discernable relationship between the size of the works [annual sludge production] and the dewaterability of the sludge. Thermal hydrolysis prior to MAD produced the most easily dewatered sludge - 33%DS off BFP.

One of the [conventional] MAD cake results is notably better than the rest at 30%DS. The company contact reports that this works has a high solids centrifuge. It is a conventional activated sludge plant with primary settlement. Septage accounts for about 10 - 25 % of the imports the remainder is a mixture of co-settled and activated; overall the ratio of primary : activated is perhaps 50:50. However the outstanding feature is that there is a long retention time in the digesters because the population served has not [yet] reached the design. There are two digesters sized for the ultimate design capacity which has not yet been met, consequently they are currently operating at mean retention times of 33-34 days, which far in excess of the norm for MAD (15-18 days).

However, in the absence of information about the type(s) of dewatering equipment and more information about the sludges it is really impossible to draw valid conclusions about

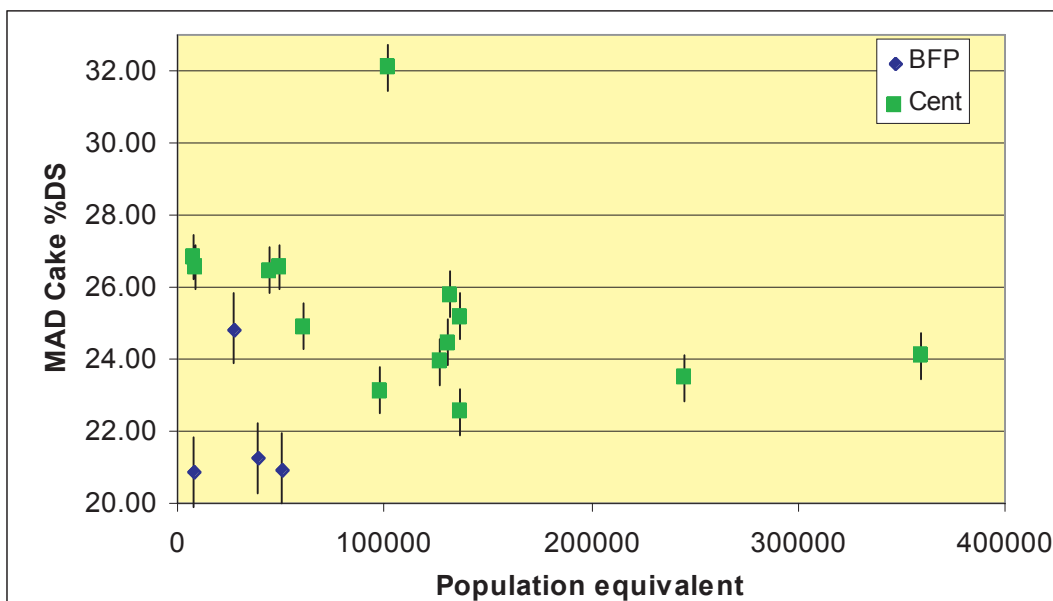


Figure 3: MAD dewatering performance in Company C (1 Jun- 31 Aug 2006; error bars ± 1 standard deviation)

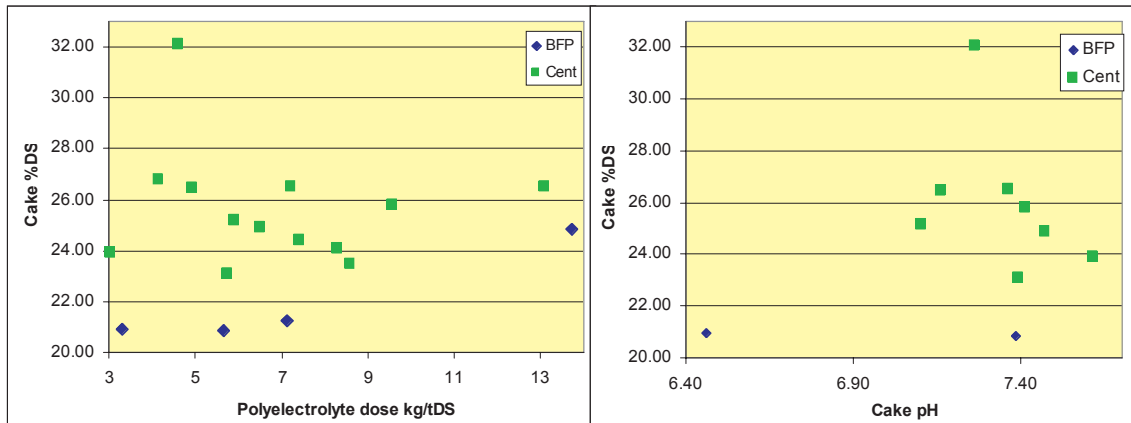


Figure 4: Company C - MAD cake %DS in relation to polyelectrolyte dose (left) and sludge pH (right)

the dewatering performance and whether there is a relationship with the type of cake.

Company C

Company C provided more detailed information about its dewatering than the other companies. Samples were taken between 1 June and 31 August 2006. For the MAD works an average of 80 samples was taken per works (minimum 40; maximum 92). Figure 3 supports the impression from Company A and Company B that centrifuges produced drier cake than BFP. Is there a suggestion of a weak negative correlation with works size? Company C reported the point in the process from which samples were collected; some samples were taken from outside storage and some from the dewatering machine or from inside storage; sampling location did not appear to have influenced the results significantly despite the prolonged hot dry weather during this sampling campaign.

The data from centrifuges in Figure 4 appear to confirm the understanding that the optimum polyelectrolyte dose, whatever it might be, is specific to the particular sludge. With reference to the contractual dispute that inspired this paper, it is notable that average polyelectrolyte dosing exceeded 6kg/tDS at 9 sites. Across all of the centrifuge works, polyelectrolyte dose is not correlated with cake dry solids. For BFP there might be a relationship between

polyelectrolyte dose and cake %DS, but since there are only 4 data points (representing 265 samples) it is not possible to draw a reliable conclusion.

Figure 4 (right) does not reveal any relationship between cake %DS and sludge pH. There are fewer data on this graph because the pH was not reported for all works.

Company C reported the nature of the sludges fed to the MAD at each of the sludge treatment centres (Figure 5). There does not appear to be any relationship between the mix of sludges fed to the digesters and the dewatering performance.

According to the Process Scientist responsible for the centrifuge site producing 32%DS average (range 27.25 to 31.77) there is nothing especially remarkable about the works to explain this performance, but it has been averaging around 30%DS for 5 years. The same model of centrifuge and type of polyelectrolyte are used at some other works. The digesters are working well but not outstandingly better than other works and there is no trade discharge that would explain the performance. The only distinguishing feature of this works is that calcite deposits in the centrate lines, rather than struvite, not that this explains why the works' dewatering performance should be so much better than the rest.

Company C also provided performance data about raw sludge dewatering. As expected, cake %DS was greater

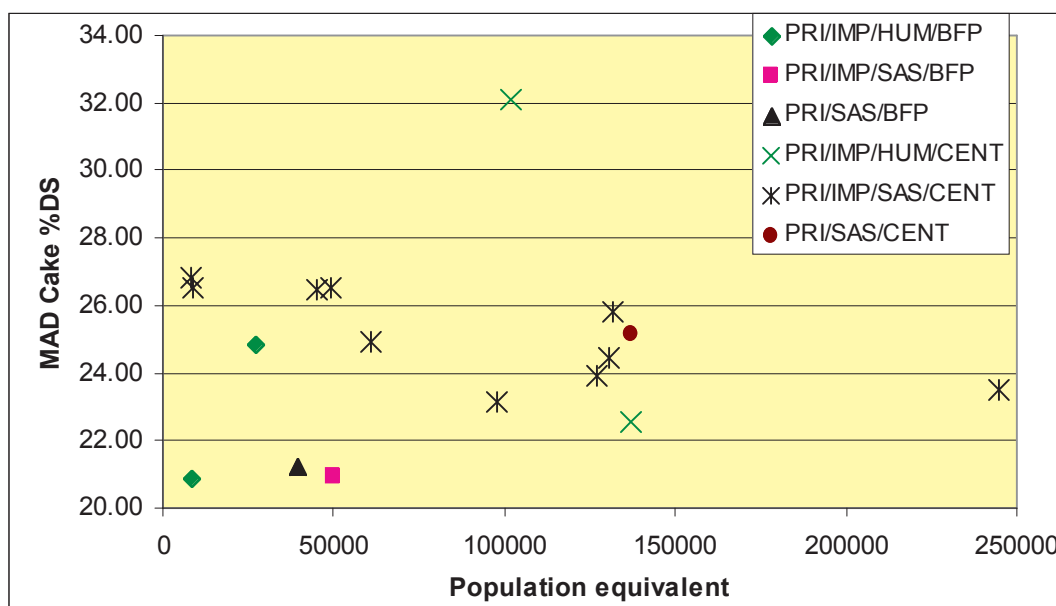


Figure 5: Company C cake %DS in relation to MAD feed sludge type and population equivalent

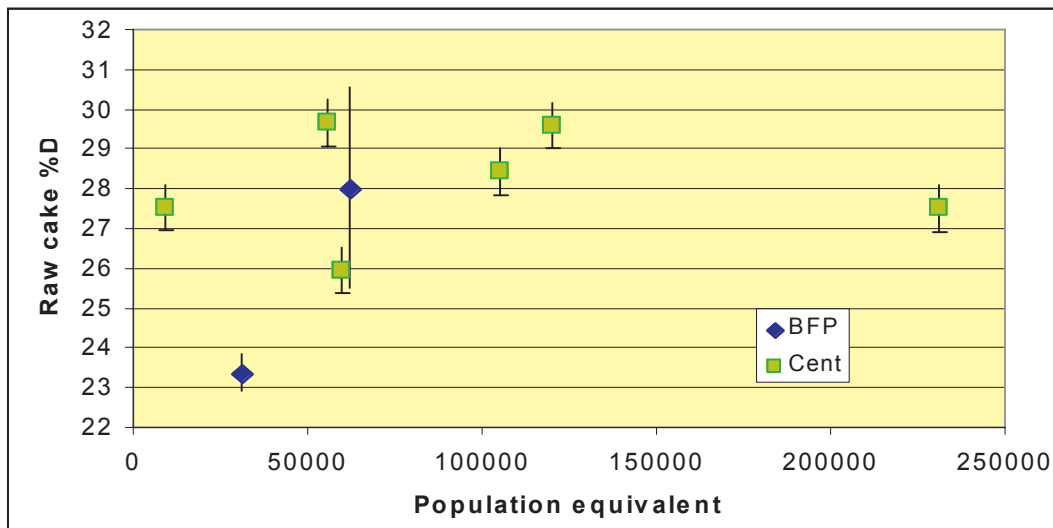


Figure 6: Raw sludge dewatering from Company C (error bars = ± 1 std dev)

than for MAD sludge. Centrifuges produced drier cakes than BFP, but there were only 2 data points for BFP so it would be inappropriate to generalise.

Company C has some of the best dewatering performance reported. 7 MAD sites had average cake dry solids in excess of 25%, all of these were centrifuge sites, but only 2 had a minimum figure for cake dry solids greater than 25%. Even for this company a 95thile of 25%DS would be exceptional.

CONCLUSIONS

At the time of writing this paper the majority of members of the Water UK biosolids network had still to provide data but the data that have been provided show that dewatering performance is very individual. There are many factors that contribute to good dewatering. As with other performance indicators, personnel appear to be a key factor. None of the companies reported that there was any form of automation of the conditioner dosing based on feedback or feed-forward. Centrifuges achieved drier cakes than BFP, but there is the caution around cake-odour associated with high solids centrifuges. Greater solids destruction (resulting in smaller %VS) is associated with drier cakes.

Regarding the contractual dispute that inspired this paper, even today it would be unreasonable to expect, and cavalier to guarantee, a 95thile performance of 25%DS for MAD sludge except where the feed to the MAD had been pre-treated to increase volatile solids destruction substantially. It would also be unreasonable to expect, and cavalier to guarantee, a polyelectrolyte dose not exceeding 6 kg/tDS.

Dewatering remains a crucially important operational activity with a decisive effect on operating costs. Technology that can continuously optimise the conditioner dosing from real-time data will be very worthwhile as will improvements in upstream process that present a more dewaterable feed to the dewatering equipment.

ACKNOWLEDGEMENTS

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