The feasibility of electro-osmotic belt filter dewatering technology at pilot scale

H.G. Snyman,* P. Forssman, A. Kafaar*** and M. Smollen*****
*ERWAT Chair in Wastewater Management, University of Pretoria, Department of Chemical Engineering, (Water Utilisation Section), Pretoria 0001, South Africa
**Steinmuller Africa, P.O. Box 1537, Rivonia 2128, South Africa
***CSIR Environmentek, P.O. Box 320, Stellenbosch 7599, South Africa

Abstract Sewage sludge is typically dewatered using drying beds, belt filter presses or centrifuges. Mechanical dewatering of sludge is costly in terms of capital and running costs, especially the flocculent. In an attempt to address the need for more cost-effective dewatering technologies, electro-osmotic belt filtering was developed by Smollen and Kafaar in 1995. The mechanical equipment resembles a belt filter press but the belts are stainless steel, woven belts, which act as the electrodes. In this study, the feasibility of the technology was tested at pilot scale using waste activated-, anaerobically digested- and dissolved air flotation sludge. The parameters which were investigated includes the applied voltage, polyelectrolyte usage and sludge feed rate. Applied voltage of between 15 and 25 volts increased the dewatering significantly in the waste activated- and anaerobically digested sludge. Applying a voltage in dissolved air flotation sludge could not enhance the efficiency of dewatering, unless stored to de-air. The technology was found as sensitive to polyelectrolyte dosages as belt presses. The performance of the electro-osmotic belt filter was sensitive to feed rate, but performed well with non-thickened waste activated sludge (0.61% solids), resulting in cake solids above 20%.

Keywords Belt filter; dewatering; electro-osmosis; sewage sludge; wastewater sludge

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Introduction

The ultimate disposal of wastewater sludge (biosolids) continues to be one of the most difficult and expensive problems in the field of wastewater engineering (Tchobanoglous and Burton, 1991). Wastewater treatment plants operating on the activated sludge systems, generate two different sludge types; primary settled sludge and waste activated sludge. Generally the excess sludges are stabilised either by chemical treatment or by anaerobic digestion and then dewatered. Due to the low rainfall, high temperatures and availability of land many plants in South Africa still utilise drying beds for sludge dewatering. However, the rapid urbanisation and development close to the wastewater treatment works necessitates alternative dewatering technologies. The main method of mechanical sludge dewatering are vacuum filters, filter presses, belt presses, screw presses and centrifuges (Bradley *et al.*, 1992). Most of the mechanical dewatering technologies utilises polymers to condition the sludge before dewatering. These polymers can be extremely costly rendering mechanical dewatering uneconomical. There is therefore a need for alternative technologies, which use less polymer and other running and capital costs. Laboratory studies performed by Smollen and Kafaar (1995) have indicated that electro-osmotic belt filter dewatering could possibly be a more economical option for sludge dewatering. The technology was developed at the CSIR, South Africa which formed a formal alliance with Steinmuller (Africa) to develop the technology further.

The objective of this study was to determine the feasibility of electro-osmotic belt filter dewatering of wastewater sludges including waste activated-, anaerobically digested- and dissolved air flotation sludge at pilot scale.

Background

Before detailing the methods and results of this study, it is imperative that the differences between a traditional belt filter press and electro-osmotic belt filter dewatering be discussed.

Belt filter press

Belt filter presses are continuous-feed sludge dewatering devices that involve the application of chemical conditioning, gravity drainage, and mechanically applied pressure to dewater sludge. In most types of belt filter presses, conditioned sludge is first introduced on a gravity drainage section where it is allowed to thicken. In this section, a majority of the free water is removed from the sludge by gravity. On some units, this section is provided with a vacuum assist, which enhances drainage. Following gravity drainage, pressure is applied in a low-pressure section, where the sludge is squeezed between two opposing porous cloth belts (Tchobanoglous and Burton,1991). On some units, the low pressure section is followed by a high-pressure section, where the sludge is subjected to shearing forces as the belts pass through a series of rollers. The final dewatered sludge cake is removed from the belts by scraper blades.

Electro-osmotic belt filter

The most prominent advantage the electro-osmotic process has over a filter press is the fact that it has the ability to remove the liquid, which is hard to remove using conventional methods. Figure 1 illustrates the various water fractions that are found in sludge (Smollen and Kafaar, 1995). Sludge particles are negatively charged. This charge is acquired by preferential adsorption of ions from the solution. The charge is countered by ions in solution which forms a liquid electric double layer. It consists of a strongly attracted layer (vicinal water) and a diffused layer (interstitial water layer). Mechanical dewatering removes bulk water and only part of the diffusion layer, while electro-osmosis dewatering extends its boundaries much further into the diffusion layer into the interstitial layer. In short, electro-osmotic dewatering is able to remove water which mechanical methods cannot.

Additional advantages could include:

- A significant reduction in polyelectrolyte use;
- The same energy requirements as filter presses;
- The process generates a filtrate and wash-water in the region of 200mg/l SS; and
- Due to the absence of force and pressure, the mechanical support would be significantly less than a filter press and the belts would last longer.

Visually, the electro-osmotic dewatering plant resembles that of a traditional dewatering belt filter press. The liquid sludge is conditioned with polyelectrolyte and dewatered by gravity. The sludge then passes between two stainless steel, woven, belts which act as the electrodes. The gap between the belt narrows to apply slight pressure to assist in the dewatering process. The sludge-cake can then be passed through a second and third stage depending on the requirements.

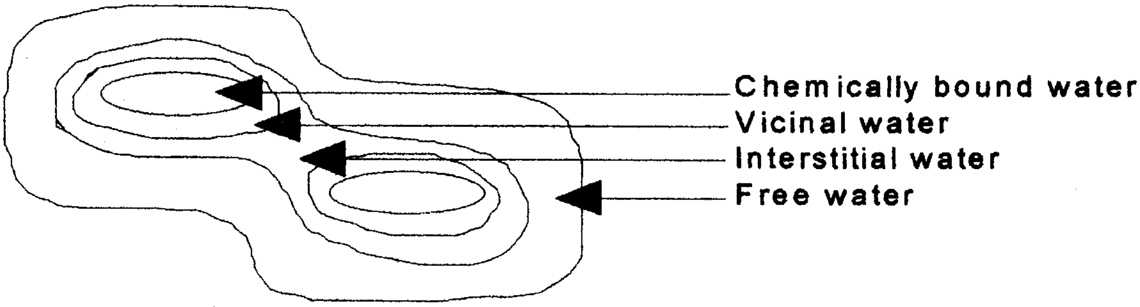

Figure 1 Water distribution in sludge floc (Smollen and Kafaar, 1995)

Materials and methods

Sewage sludge

Waste activated sludge, anaerobically digested sludge, dissolved air flotation sludges were withdrawn from the ERWAT Waterval water care works, South Africa. Primary sludge was obtained form the ERWAT Olifantsfontein water care works, South Africa.

Electro-osmotic belt filter pilot plant

Figure 2 illustrates one of three identical stages of the electro-osmotic belt filter. The sludge was conditioned with a stock solution of 0.1% ZETAC57 (NCP South Africa) polyelectrolyte and fed onto the gravity stage (not shown) of the belt filter. The gravity dewatering was increased by a plough system. The sludge then entered the first of three electro-osmotic stages operating at a current density of (100 A/m^2, with the belt width of 1 m with a 2 m contact area between the belts per stage. The small suction system was installed operating at –5 to –6 kPa to eliminate water accumulation on the belts. The system was also equipped with a belt washing system. The experimental work was all performed within belt speeds between 1.2 and 2.7 m/min. Typically, a belt speed of 1.5 m/min would carry a feed between 8 and 10 m^3/h.

Feasibility studies

The variables, applied voltage, polyelectrolyte dosage, sludge feed rate and cake thickness were tested on the three sludge types, separately. A single variable was tested at one time while all other variables were kept constant, unless otherwise stated. The voltage applied between the two belts on each stage were varied between 0 and 25 V to determine the optimum applied voltage for maximum cake solids. During these tests, the sludge feed rate, polyelectrolyte dosage and space between the belts were kept constant. The minimum polyelectrolyte dosages for a particular sludge type were determined using standard beaker tests and varied around this value on the electro-osmotic belt filter. Different sludge feed rates were investigated starting with a feed rate of 4 m^3/h up to 14 m^3/h. The cake thickness was varied by adjusting the gap between the belts between 6 and 12 mm.

Sample collection and analysis

The sludge feed samples were characterised by determining the DSVI, pH, moisture and ash contents (Standard methods). The percentage cake solids were also determined in the washwater feed, washwater filtrate, electro-osmotic belt filter filtrate and on the sludge after every stage on the electro-osmotic belt filter i.e. gravity-, first-, second- and third stage.

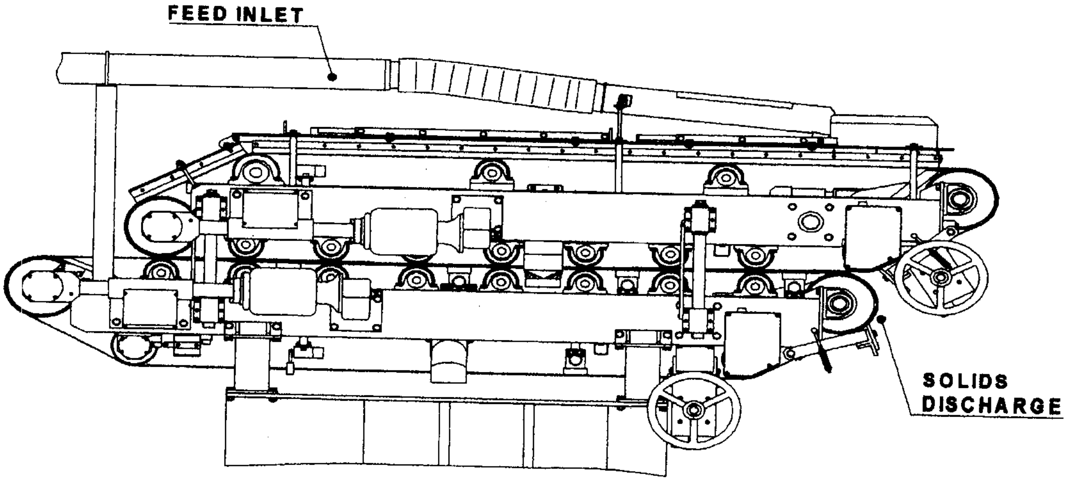

Figure 2 A schematic presentation of one of the three stages of the electro-osmotic belt filter pilot scale plant

Results and discussion

Anaerobically digested sludge

The anaerobically digested sludge used as feed had a solids content of between 1.3 and 2.0%, 35 to 40% ash, DSVI of 114 to 170 mg/l and a pH of 7.15 to 7.27. Waste activated and primary sludge was digested in mixed heated digesters and had an average sludge age of 39 days.

The influence of applied voltage. Figure 3 indicates the solids content of anaerobically digested sludge after each stage when operated at different applied voltages. The feed rate, polyelectrolyte dosing and feed concentration were kept constant at 9 m^3/h, 3 kg/ton (dry solids) and 1.9%, respectively. The applied voltage increased dewaterability significantly.

The influence of polyelectrolyte dosing. Laboratory tests indicated that the minimum polyelectrolyte requirement for the sludge was 5kg/ton (dry solids). Three different concentrations were tested i.e. 2, 4 and 5 kg/ton (dry solids) while the feed rate, voltage applied and feed concentration were kept constant at 6 m^3/h, 5 V, 15 V and 20 V and 1.5%, respectively.

Figure 4 indicates that the performance of the electro-osmotic belt filter is not as sensitive to polyelectrolyte dosages as traditional belt presses. In addition, similar results could be obtained even when the system was operated at dosages below the laboratory determined dosage of 5 kg/ton (dry solids).

The influence of feed rate. The influence of the feed rate onto the belts for anaerobically digested sludge is indicated in Figure 5. Five different feed rates were tested while the applied voltage, polyelectrolyte and feed concentration were kept constant at 5 V, 15 V and 20 V, 3.5 kg/ton (dry solids) and 1.8%, respectively. As expected, the maximum solids content decreased as the feed rate increased. The maximum solids concentration increased slightly between 10 and 14 m^3/h because of the sludge load pressing between the two belts

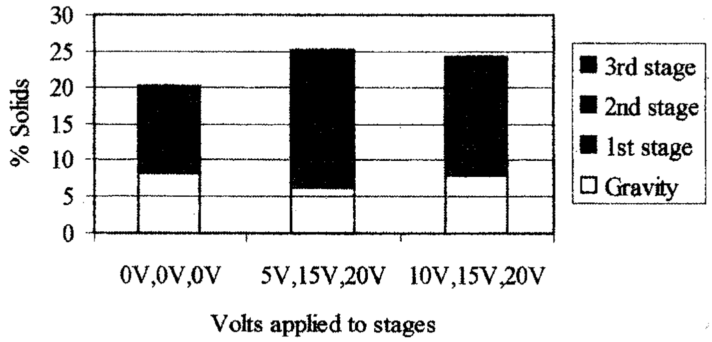

Figure 3 The influence of applied voltage on anaerobically digested sludge

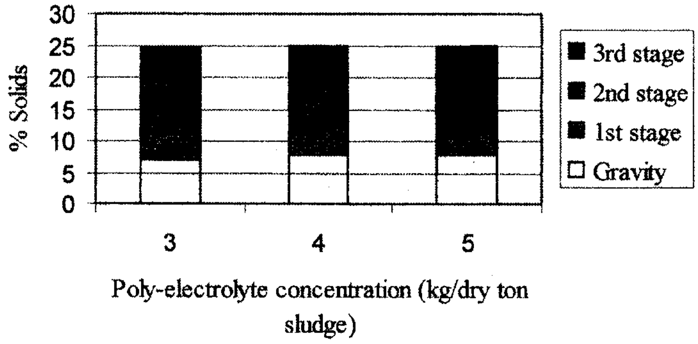

Figure 4 Influence of polyelectrolyte dosing on the electro-osmotic dewatering of anaerobically digested sludge

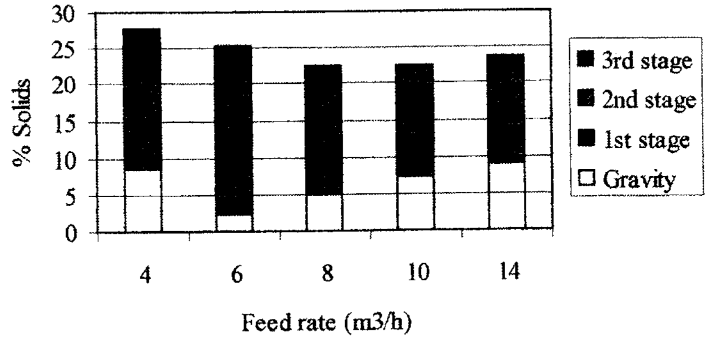

Figure 5 Influence of the feed rate on the electro-osmotic dewatering of anaerobically digested sludge

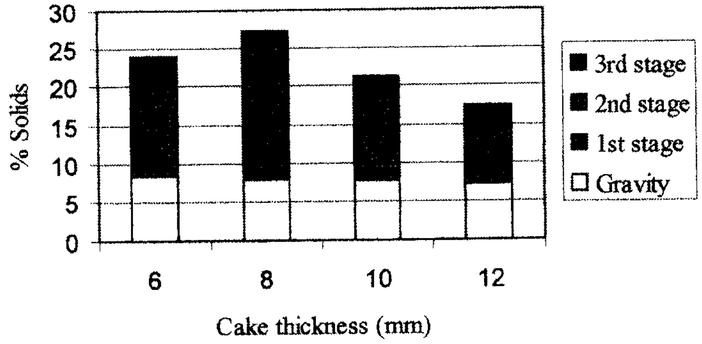

Figure 6 Influence of the space between belts on the electro-osmotic dewatering of anaerobically digested sludge

acting the same as a belt press. The high feed rates did not effect the quality of the wash-water or the filtrate which remained in the region of 0.05% solids.

Influence of the space between belts. The system can be operated to narrow the gap between the belts to enhance dewatering through the application of some pressure. The space between the belts were varied between 6 and 12 mm while the feed concentration, feed rate, polyelectrolyte dosage and applied voltage were kept constant at 1.8%, 6 m^3/h, 3.8 kg/ton (dry solids) and 5 V, 15 V and 20 V, respectively. The results indicate that the optimum space is 8 mm. However, the second stage on the 6 mm space test did not perform as well as what was normally observed. Despite this, the observed trend in Figure 6, where 8 mm space was optimal, is typical. The quality of the wash-water and the filtrate was significantly lower at 6 and 8 mm space between the belts. The wash-water quality decreased from 0.04% at 10 mm to 0.4% at 6 mm and the filtrate from 0.06% at 10 mm to 0.17% at 6 mm.

Waste activated sludge

The waste activated sludge used as feed had a solids content of between 0.5 and 0.7%, 26 to 33% ash, DSVI of 110 to 151 mg/l and a pH of 7.1 to 7.28. The biological nutrient removal plant was typically operated at a sludge age of 7–9 days.

The influence of applied voltage. Figure 7 indicates the solids content of the dewatered waste activated sludge after each stage when operated at different applied voltages. The feed rate, polyelectrolyte dosing and feed concentration were kept constant at 9 m^3/h, 5.8 kg/ton (dry solids) and 0.7%, respectively. In these experiments the voltages were kept the same at all the stages. For example, in Figure 7, the 10 volt bar refers to 10 volts applied to the first, second and third stages. Similar to the anaerobically digested sludge, the applied voltage increased dewaterability significantly, with an increase in dewatering efficiency as the voltage is increased.

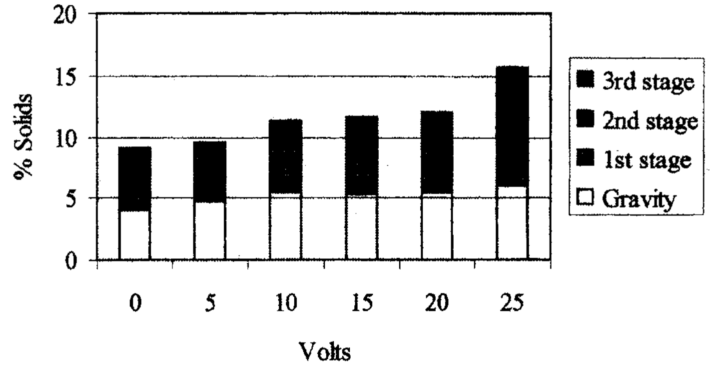

Figure 7 Influence of the applied voltage on the electro-osmotic dewatering of waste activated sludge

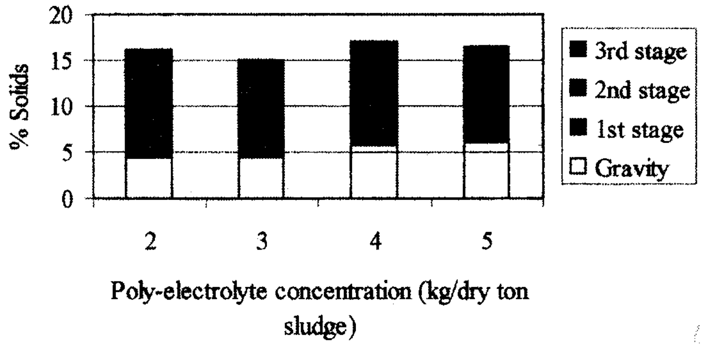

Figure 8 Influence of polyelectrolyte dosing on the electro-osmotic dewatering of waste activated sludge

The influence of polyelectrolyte dosing. Laboratory tests indicated that the minimum polyelectrolyte requirement for the sludge was 3.5 kg/ton (dry solids). Four different concentrations were tested i.e. 2, 3, 4 and 5 kg/ton (dry solids) while the feed rate, voltage applied and feed concentration were kept constant at 6 m^3/h, 5 V, 15 V and 20 V and 1.5%, respectively.

Figure 8 indicates that the performance of the electro-osmotic belt filter is not as sensitive to polyelectrolyte dosages as traditional belt presses. The increased polyelectrolyte concentrations did, however, increase the efficiency of the gravity dewatering stage. As was the case with the anaerobically digested sludge, similar results could be obtained even when the system was operated at dosages below the laboratory determined dosage of 3.5 kg/ton (dry solids). This would have tremendous cost benefits on a full-scale plant.

The influence of feed rate. The influence of the feed rate onto the belts for waste activated sludge is indicated in Figure 9. Seven different feed rates were tested while the applied voltage, polyelectrolyte and feed concentration were kept constant at 5 V, 15 V and 20 V, 3.8 kg/ton (dry solids) and 0.61%, respectively. Again, a similar trend was found when comparing the results to the anaerobically digested sludge results i.e. the solids content decreased as the feed rate increased. However, the solids loading was not sufficient to press against the belts to increase the solids concentration at high feed rates, since the feed concentration was only 0.61% dry solids. The effect of the amount of water in the sludge can also be seen in the performance of the first stage. In the anaerobically digested sludge tests, the first stage typically contributed more to the maximum solids concentration than was observed in the waste activated sludge. However, the results prove another benefit to electro-osmotic belt filter dewatering. At low feed rates, the dewatering compared favourably with belt presses which are normally operated with pre-thickened sludge. The electro-osmotic belt filter could generate sludge of over 20% solids without any pre-thickening.

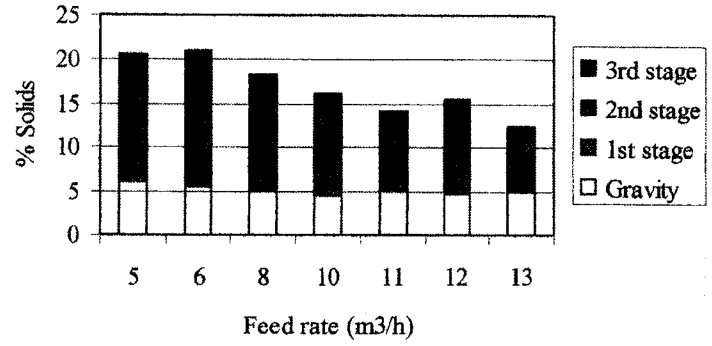

Figure 9 Influence of the feed rate on the electro-osmotic dewatering of waste activated sludge

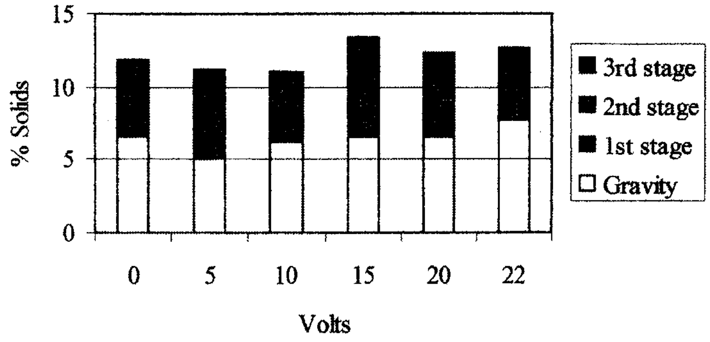

Figure 10 Influence of the applied voltage on the electro-osmotic dewatering of dissolved air flotation sludge

Influence of the space between belts. This aspect could not be evaluated due to the low solids content in the feed sludge.

Dissolved air flotation sludge

The dissolved air flotation sludge had the same characteristics as the waste activated sludge except that it has been thickened to 3.2% which was used as the feed to the electro-osmotic belt filter. Figure 10 indicates the solids content of the dewatered dissolved air flotation sludge after each stage when operated at different applied voltages. The feed rate, polyelectrolyte dosing and feed concentration were kept constant at 8 m^3/h, 2.2 kg/ton (dry solids) and 3.2%, respectively. In these experiments the voltages were kept the same on all the stages as explained in the waste activated sludge tests.

The applied voltage had little effect to enhance the dewatering of dissolved air flotation sludge and could only achieve a maximum of 13% solids. It is known that air is a poor conductor of electricity, and the air in the sludge is possibly the reason for the electro-osmotic belt filter's poor performance. When storing the dissolved air flotation sludge in an anaerobic environment for a few days, the dewatering efficiency was enhanced to 19% solids. The tests on the polyelectrolyte dosage, feed rate and cake thickness could not be performed due to the dissolved air flotation units being decommissioned.

Conclusions

The feasibility of electro-osmotic belt filter dewatering of wastewater sludges including waste activated-, anaerobically digested- and dissolved air flotation sludges was determined at pilot scale. The parameters investigated included the applied voltage, polyelectrolyte usage and sludge feed rate. Applied voltage of between 15 and 25 V increased the dewatering significantly in the waste activated- and anaerobically digested sludge. Applying a voltage in dissolved air flotation sludge could not enhance the efficiency of dewatering, unless stored to de-air. The technology was found less sensitive to polyelectrolyte dosages than belt presses. Polyelectrolyte dosages below the minimum laboratory determined values, still produces satisfactory cake solids, which translates in significant running cost saving. The performance of the electro-osmotic belt filter was sensitive to feed rate, but performed well with un-thickened waste activated sludge (0.61% solids), resulting in cake solids above 20%. This means that the waste activated sludge does not have to be pre-thickened as is the case with most belt presses, indicating a cost saving potential. The results obtained in this study proved the potential of electro-osmotic dewatering as an alternative technology to dewater excess sewage sludge.

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