AN INNOVATIVE APPLICATION FOR AN ESTABLISHED TECHNOLOGY TO IMPROVE SLUDGE DEWATERING

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ABSTRACT

This paper presents the results of full-scale waste water treatment plant (WWTP) sludge dewatering trials using a Bucher de-juicing press model HP2500 (Boehler et al., 2003). Besides digested sludge from the WWTP at Glarnerland Sludge from five other WWTP's was also dewatered. The investigations show that with hydraulic system tested dry solids (DS) contents of 32-41% (with a throughput of approximately 5 m^3 h^{-1}) could be reached. With extended cycle / batch time DS contents of up to 43.5% could be achieved. Dewatering trials with raw sludge (not putrefied) from two different WWTP's resulted in DS content of 35% and 41%. The dosage of coagulant aids, particle size distribution and volatile suspended solids (VSS) have a significant influence on the dewatering results. An economic efficiency calculation is presented with direct comparison to a centrifuge used at the WWTP. Return of investment is expected to be achieved within 3 years.

KEYWORDS

sewage sludge, sludge dewatering, sludge disposal, drainage technology

1 INTRODUCTION

Today in Europe biological waste water treatment is primarily carried out by the activated sludge process. Because of the physical-chemical processes involved in activated sludge waste water treatment, the sludge tends to accumulate heavy metals and low levels of organic compounds which are not readily biodegraded (e.g. pesticides, household chemicals, trace pollutants, etc.) and are present in the waste water. As a result of a detailed ecotoxicological risk evaluation (FAL, 2001) agricultural use of stabilised sewage sludge will be banned in Switzerland from 2005. Because disposal in landfills is already prohibited in Switzerland, sewage sludge has to be dewatered, dried, incinerated and the ash disposed of in landfills. In future 100% of the sewage sludge (200,000 mt DS/year) will be incinerated (BUWAL, 2001). Energy consumption calculations has shown there could be advantages in burning raw sludge, this has brought new discussions about burning non digested sludge. Sludge digestion is labor and cost-intensive and uses more than 60% of the total manpower of a waste water treatment plant (WWTP; Gujer, 1999).

A first step in the disposal of the resulting sludge (excess sludge + primary sludge) is a reduction of volume. An important partial step after digesting is the mechanical separation of sludge liquor from the solid.

The efficiency of drainage has a significant impact on the cost of subsequent sludge treatment and disposal. If incineration is the end of the treatment, the dewatered sludge must have minimum content of dried solid matter (>35% DS) in order to ensure an energy neutral incineration.

The efficiency of the sludge dewatering equipment has a significant impact on the overall cost of waste water treatment. The company Bucher Foodtech A.G. developed and patented (1964) an innovative hydraulic press system for de-juicing fruits and vegetables, this press system was used for full scale trials to dewater digested sludge and raw sludge from the Glarnerland WWTP (AVG) and other WWTP's. The research was financially supported by the Swiss Commission for Technology and Innovation (CTI).

2 MECHANICAL SLUDGE DEWATERING

2.1 OVERVIEW

Sewage sludge drainage is a common unit operation of solid-liquid separation. Drainage can take place by filtration or centrifugation. In order to operate efficiently, mechanical dewatering requires conditioning of the sewage sludge, flocculation increases the speed of dewatering.

Physical limits are set for the mechanical dewatering of sewage sludge and are determined by the size of the water fraction of a sludge suspension. The free water (or bulk water) fraction is not bound to sludge particles and can be separated by mechanical dewatering. The capillary interstitial water fraction, trapped in the crevices and interstitial spaces of the flock and organisms, the water bonded on surfaces and in cells, and the water of hydration, is bound water which mostly remains in the sludge filter cake after dewatering (Kopp, 2001; Vesilind, 2003).

The established mechanical de-watering technologies like belt presses (20-28%), decanting centrifuges (20-35%) and filter presses (28-*45%; * including aggregates, e.g. chalk) achieve DS contents indicated in the brackets (Jung et al., 1995).

2.2 MATERIALS AND METHODS

2.2.1 HYDRAULIC PRESS SYSTEM HP2500 – CONFIGURATION AND FUNCTION

The Bucher HP2500 hydraulic de-juicing press used in these trials consists of a cylinder (total volume 2.5 m^3) equipped with a flexible drainage system and a piston (Figure 1). The main component of the system is the drainage system, which comprised 130 flexible drainage elements each element consists of a drainage core over which is fitted a filter sock (in the model HP2500 each drainage element is 1200mm long x 50mm∅). The filter sock is a strong, hard wearing filter cloth (similar to recessed-plate filter cloth) this holds back the solids of the sludge. Two filter cloths were initially trialled (Type M1 and Type V1), both exhibited very similar throughput. The drainage cores are provided with drainage channels (similar in appearance to the splines on a shaft) and lead the filtrate into collection chambers in the cylinder and piston and then to the collection tank.

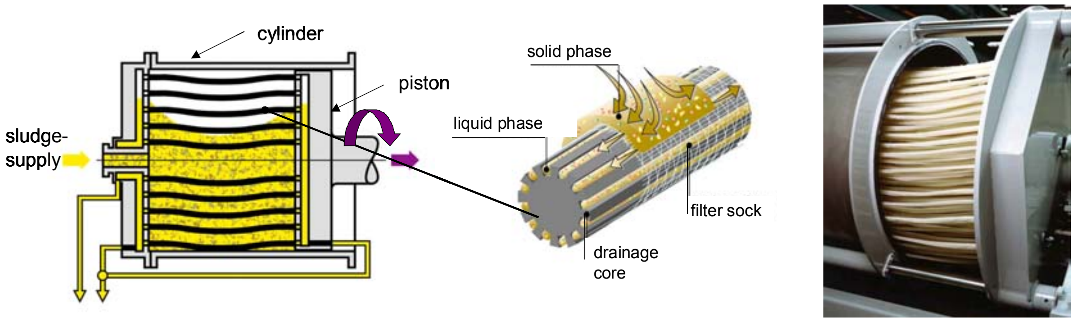

Figure 1: Hydraulic press system and functional principle of drainage elements, on the right side a opened cylinder with drainage elements

During a complete filtration batch / cycle, sludge is filled into the cylinder in several steps with a pump. Between each filling step pressure is gradually increased (up to 10 bar) as the piston reduces the basket volume and presses the liquid through the drainage elements into the filtrate collecting tank. A solid filter cake is developed with each filling step (e.g. 0.4 m^3 sludge is added at each step) throughout the first cycles. During the filling step the piston is drawn back, the drainage elements stretched and the filter cake broken into pieces. At the same time air flows back through the drainage elements to expand, clear and clean the filter socks. Due to the continuous rotation and compression of the cylinder new drainage paths are developed in the filter cake. In a single batch a total of 8 to 12 m^3 (depending on initial DS content of the sludge) sludge is processed in 30 to 40 compression steps. In order to achieve optimal DS contents, the last compression steps (about 10) occur without sludge being added. The principle procedure is shown in Figure 2.

The Bucher HP hydraulic press system is fully automated. Operating status, yield and performance values as well as alarms are continuously and automatically logged by an internal data acquisition system.

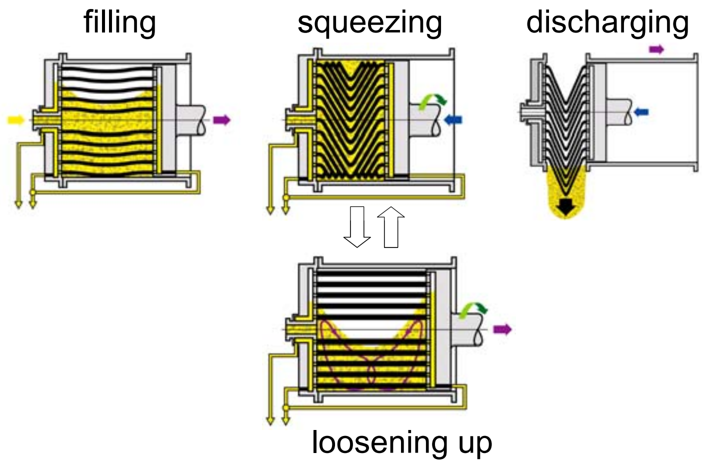

Figure 2: Principle procedure of sludge dewatering with the HP series hydraulic press system

2.2.2 FULL SCALE EXPERIMENTAL SET UP AT THE GLARNERLAND WWTP

Three machines were used during the sludge drainage trials at the Glarnerland WWTP's (Figure 3), an older belt press (ROEDIGER), a current generation decanter centrifuge (NOXON, typ DC 12 FC HS) and the Bucher type HP 2500 press. Dewatering trials on sludges from other sites were delivered to the Glarnerland WWTP by road tanker, the trials on these sludges were made only on the Bucher type HP2500 press.

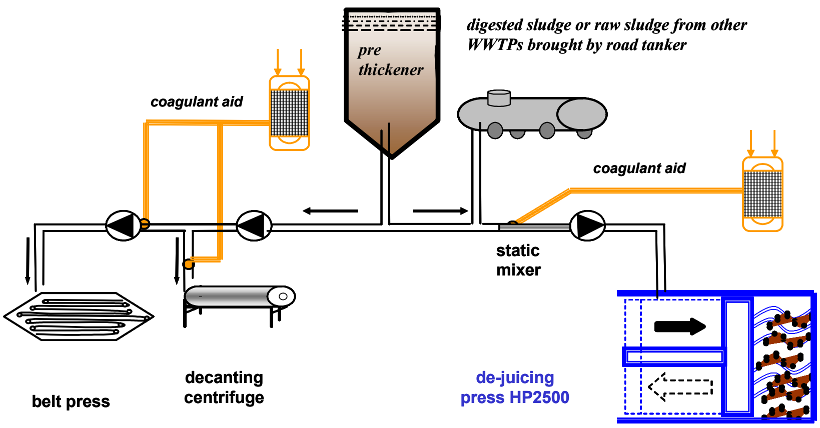

Figure 3: Experimental set up for full scale trials at the Glarnerland WWTP

2.2.3 DIGESTED AND RAW-SLUDGE USED IN TRIALS

Digested sludge was taken from the sludge pre-thickener of the Glarnerland WWTP, also digested sludge from another five WWTPs were dewatered. The trials with raw sludge (not digested) were carried out with sludge from the Glarnerland and Hombrechtikon WWTP's. The raw sludge used in the trials consists of a fraction of primary sludge and a fraction of excess biomass. The initial DS content of the sludge was in the range of 2 and 8% w/w.

2.2.4 ANALYTICAL METHODS – COAGULANT AID

Sludge samples were analysed for total solids (DS; 103°C, 24h) and ash content (volatile suspended solids (VSS); 550°C, 2h). Examinations of sludge particle size distribution were made with a MASTERSIZER X (Malvern Instruments Ltd., Malvern, U.K.). The sludge was conditioned using an organic polymer (CP31; FLONEX AG, Sissach, CH) as a coagulant aid. The coagulant aid was added as a 0.5%-solution (dilution with water) by a dosing pump (up to 8.5 m^3hr^{-1}) into the sludge line (∅ 100 mm, about 25 m long). To ensure good dispersion the polyelectrolyte was dosed against the direction of sludge flow and immediately before a static mixer and the sludge filling pump (rotary piston pump; $50m^3hr^{-1}$). Coagulation was complete within the sludge tube.

3 RESULTS AND DISCUSSIONS

3.1 DEWATERING EFFICIENCY AND THROUGHPUT OF HP2500

About 170 drainage trials were carried out at the Glarnerland WWTP with 1100 m^3 of digested and raw sludge. Figure 4 displays the results of the trials with digested sludge from 5 different plants, the differences in drainage behaviour with the different digested sludges is of interest.

With the Bucher HP2500 hydraulic press system a DS content in the range of 32 – 41% (circle) could be achieved. A throughput of approximately 150 kg dry solid per hour (about 5 m^3 with a DS content of approx. 3% of liquid sludge per hour) could be treated. Note that due to variations in DS of the various sludges the throughput is given as kg DS per hour to enable comparison. Up to 43.5% DS content could be achieved by extending the batch time but this gives a significant reduction in throughput.

The worse drainage results were with digested sludge from the Werdhoelzli/ZH WWTP (DS content within 25-26%). The drainage result for this mud slurry may be caused by a very high VSS of 53%. A recessed-plate filter press was operated in parallel on this sludge and showed the same poor dewatering.

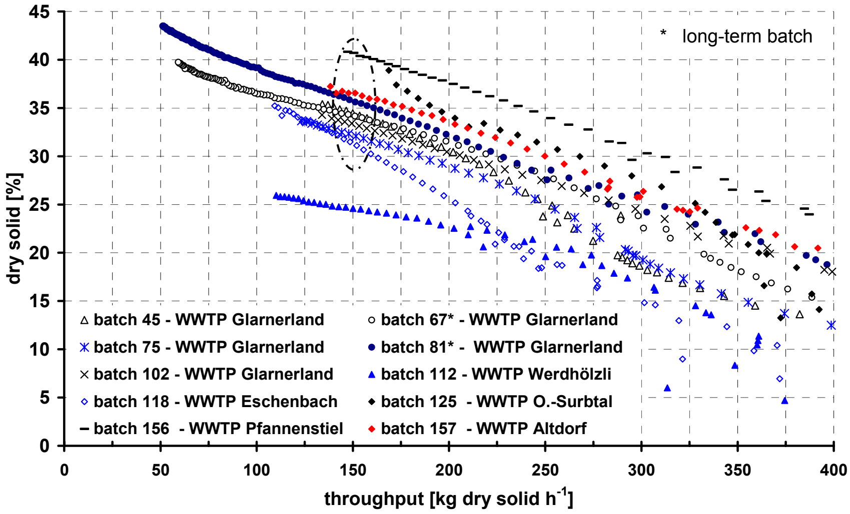

Figure 4: Dewatering trials with sludge from different WWTP's in the investigation period

Figure 5 shows de-waterability of raw sludge with the Bucher HP2500 hydraulic press system. The drainage of raw sludge from the Glarnerland WWTP resulted in an average DS content of 35% and a DS content of 41 % from the Hombrechtikon WWTP.

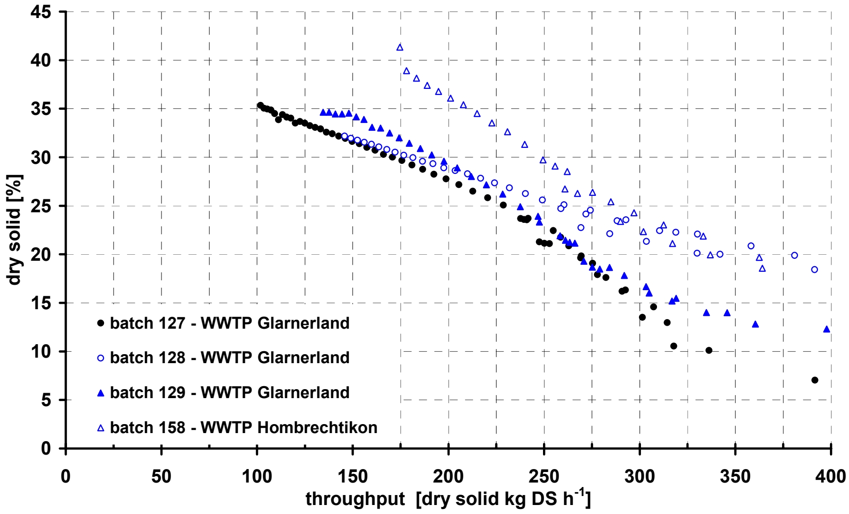

Figure 5: Dewatering trials with raw sludge from two different WWTP's

3.2 IMPACT OF PRESSURE

The pressure of the Bucher HP2500 may be varied to accommodate variations in the drainability of the feed sludge and to prevent clogging of the filter socks. The pressing pressure at the beginning of the batch is low and increased continuously after a predetermined DS concentration. Trials were made with different end compression phases to determine the influence of pressure. Limiting the pressure to 5 bar at the end of the batch reduces the DS by about 1.5% to 3% compared with operating to 10 bar (Figure 6).

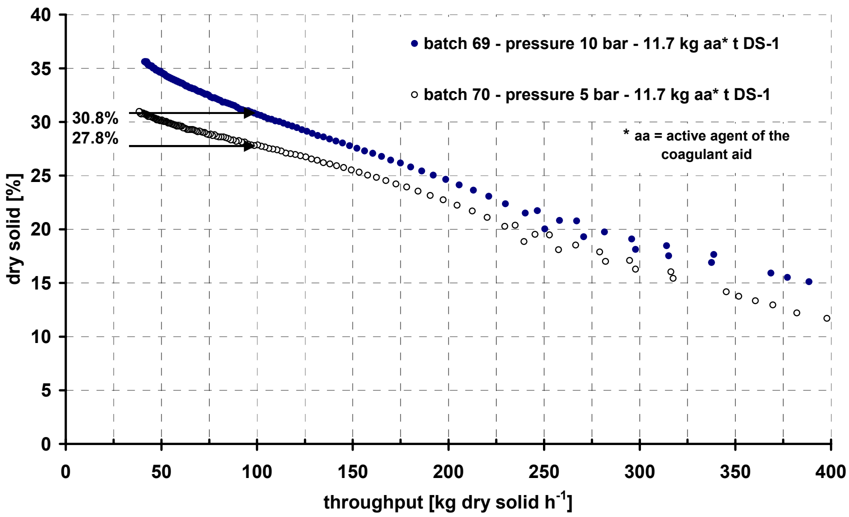

Figure 6: Trials with different compression phases at end of batch

3.3 IMPACT OF COAGULANT AID

The addition of cationic organic polymers as a coagulant aid leads to a significant improvement in the de-waterability and thus has a large influence on the drainage performance of mechanical sludge dewatering, this is known as "Filter Cake Permeability". During flake formation two reactions occur simultaneously;

a) Coagulation by compensation of the electrostatic forces

and

b) Flocculation.

With the coagulation the electrostatic repelling forces are destabilized and the separated particles can move closer together, so the free water fraction can better run from the sludge matrix. During the flocculation bridges are formed between the sludge particles by adsorbed polymers, resulting in the formation of macro flakes.

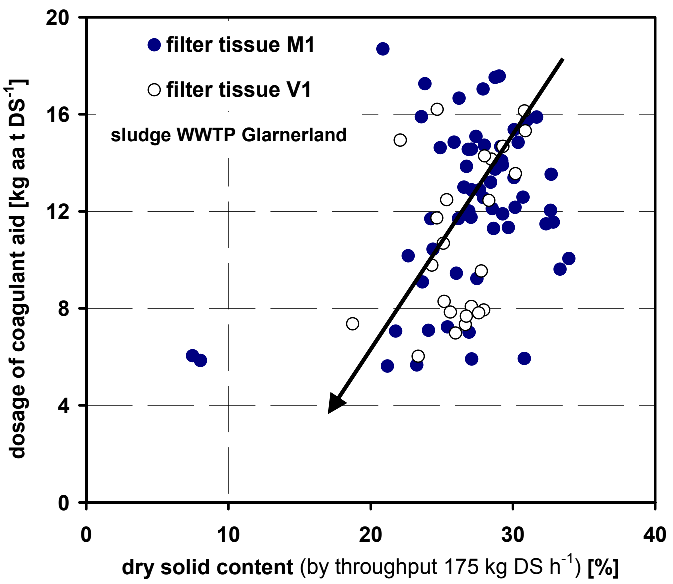

Figure 7: DS content achieved with different dosage of coagulant aid

The dosage of coagulant aid is also necessary in the Bucher HP2500 hydraulic press system (≥10 kg coagulant aid per metric tonne DS). Increasing the coagulant dosage resulted better drainage results (Figure 7). The arrow marks the trend.

Figure 8 shows four de-watering trials with digested sludge of uniform quality. The 4 dewatering operations show the significant influence coagulant aid dosage has on achievable DS content and throughput. With increasing dosing quantity the achievable DS content rises.

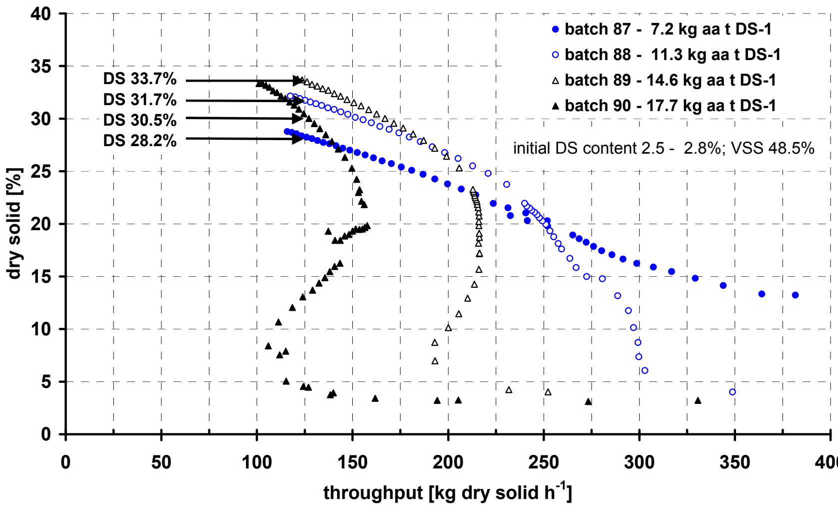

Figure 8: Impact of coagulant on de-waterability of digested sludge

Of note is the reduced dewatering speed at the beginning of the trials if dosage of coagulant is increasing. This is probably due to surplus flocculant increasing the viscosity of the filtrate and/or mycels of flocculant or a gel formed on the filter sock. With further processing this effect is reversible.

3.4 IMPACT OF VOLATILE SUSPENDED SOLID AND PARTICLE SIZE DISTRIBUTION OF SLUDGE

It is well-known from the literature that volatile solids content has a significant influence on drainage. During this investigation it was confirmed that a higher DS contents can be achieved with a lower less volatile solids content. The arrow marks the trend in Figure 9.

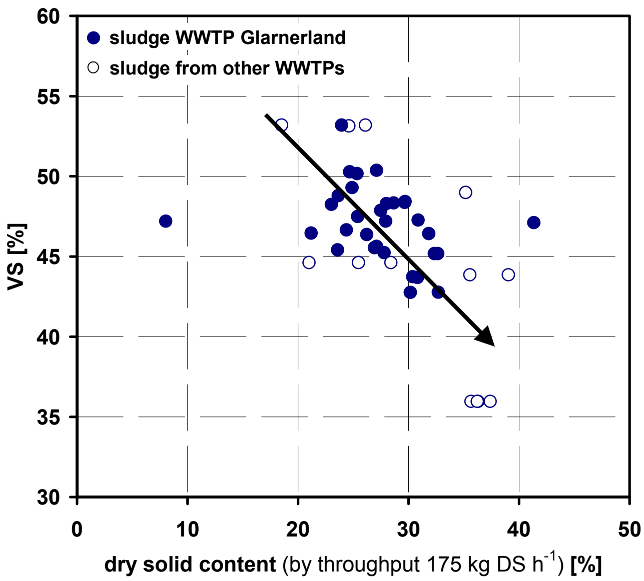

Figure 9: DS content achieved with different volatile suspended solids

Average particle size of sludge from Glarnerland WWTP used in these trials is significantly finer and has a smaller size variation compared to sludge samples from other WWTP's. A smaller average particle size is expected to correlate with increased water detention, due to higher specific surface area. Further, a smaller size distribution causes a relatively high amount of capillary water (Kopp, 2002). It can therefore be stated that the sludge from the Glarnerland WWTP tested in our trials has unfavourable dewatering characteristics (confirmed also by the performance of the conventional dewatering devices at this WWTP). Due to the homogeneity of the particle distribution found in the sludge tested, the performance of the dewatering process described here cannot be correlated directly with particle distribution (see Figure 10).

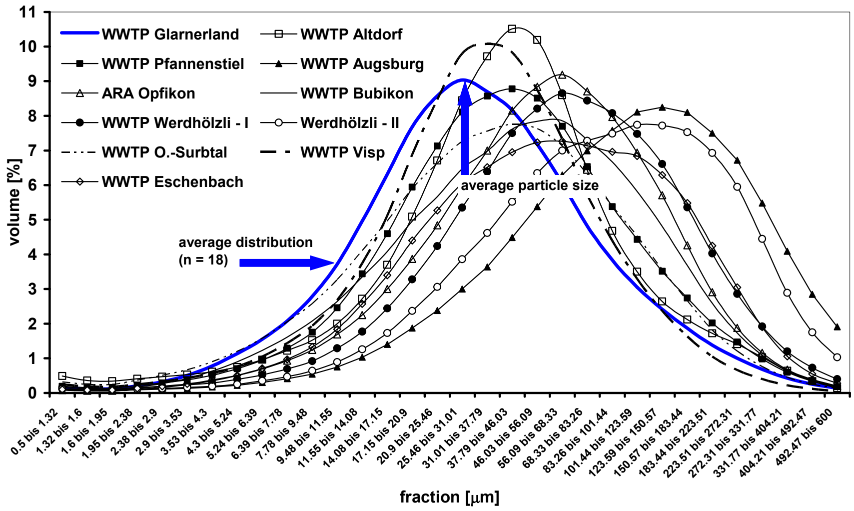

Figure 10: Particle size distribution of different digested sludge

3.5 COSTS OF SLUDGE DE-WATERING WITH BUCHER HP-SYSTEM

The economic efficiency of using a Bucher HP Press has been calculated in direct comparison with the new decanter/centrifuge at the Glarnerland WWTP. Investment cost, maintenance costs, operating expenses (personal costs, sludge conditioning etc.) and costs for the disposal (transport + incineration) were considered.

To guarantee a throughput of 8~10m^3/hr for the Glarnerland WWTP a Bucher HP5000 fruit press is required.

Based on an average increase of 3% DS using the Bucher HP-System compared with the installed decanter/centrifuge and a real disposal cost of cost of €145/t wet sludge the payback for period of the additional capital cost of the Bucher HP-System press over the capital cost of the decanter/centrifuge is 3 years.

If the disposal costs increase (for example, due to lack of incineration capacity) the economic efficiency of the press improves (figure 11) rapidly.

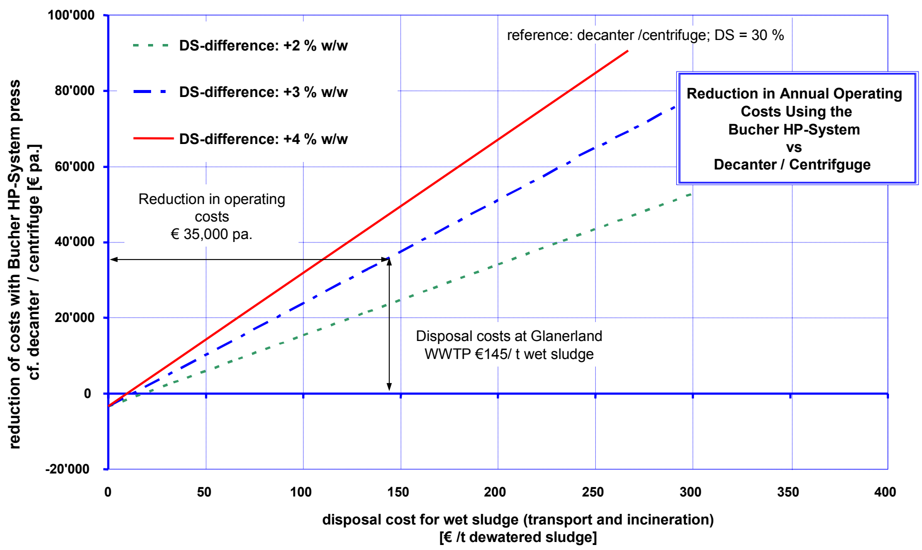

Figure 11: Economic efficiency calculation between Bucher HP-System Press and decanter/ centrifuge

4 CONCLUSIONS

The investigations using the Bucher HP2500 hydraulic press system at the Glarnerland WWTP shows that using a technology established in one field but used for a totally different application can open a new domain. In this case well established technology from the fruit processing industry can fulfil the needs of ecological processing.

In comparison to other established mechanical dewatering technologies the innovative application of the Bucher HP2500 hydraulic press system (originally designed for fruit and vegetable de-juicing) achieved higher DS content on waste water sludges and can be automatically operated without supervision under the practical conditions of a WWTP. The economics show that this alternative technology can compete with conventional systems. Further optimisation (drainage system, hydraulics, size….) will increase the efficiency and the economics of the system in relation to other technologies.

The planned commercial adoption of this technology by a number of WWTP's will give the opportunity to show whether this hydraulic system will, in the long term become established in the field of sewage sludge treatment.

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