Optimization of sludge dewatering process at Bensberg Municipal Wastewater Treatment Plant

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ABSTRACT
The main purpose of this research was to bolster the sludge dewatering process at Bensberg Municipal Wastewater Treatment Plant in the municipality of Bergisch Gladbach, Germany. The goal was to achieve an improved dried solids (DS) content with the materials and machinery used by the WWTP. Small and large-scale trials were carried in order to accomplish this goal. NALCO polyacrylamide based polymer was tested and the dosage was optimized in small scale trials; in the range of 7 to 8 ml polymer per 100 ml of digested sludge (7-8% V/V) the best capillary suction time values (CST) were obtained at 8.96 and 9.94 seconds respectively; however, when the previous dosage was tested in large-scale trials, DS improvements were not detected. The Kemicond process (treatment with sulphuric acid and hydrogen peroxide) was also tested. The best dewaterability results were obtained when the sludge's pH was decreased to 6 with H_2SO_4, followed by a treatment with 1 ml of H_2O_2. Nevertheless, this type of treatment is very aggressive, it requires special equipment and could be environmentally harmful in the long run. Other parameters were found to play a key role on the mechanical dewatering process, such as: time of press filling, compression time, age and type of filter membrane, the quality of sludge entering the press and the polymer-sludge mixing.

Key words: Dewatering, dried solids content, polyacrylamide, Kemicond.

Optimización del proceso de deshidratación de lodos, en la planta de tratamiento de aguas residuales municipales en Bensberg

RESUMEN.
El propósito principal de esta investigación fue impulsar el proceso deshidratación de lodos en Bensberg, que es una planta municipal de tratamiento de aguas residuales en el municipio de Bergisch Gladbach en Alemania. El objetivo era lograr un mejor contenido de sólidos secos (DS) de los materiales y maquinaria utilizada por la planta de tratamiento de aguas residuales. Las pruebas de pequeña y grande escala se llevaron a cabo para probar el polímero NALCO poliacrilamida. Después la dosis fue optimizada en las pruebas de pequeña escala en el rango del polímero de 7 a 8 ml por 100 ml de lodo digerido (7-8% V/V). Los mejores valores de tiempo de succión capilar (CST) fueron obtenidos en 8.96 y 9.94 segundos respectivamente; Sin embargo, cuando la dosis previa fue probada a grande escala, la mejora en el contenido de solidos secos no fue detectada.
El proceso Kemicond (el tratamiento con ácido sulfúrico y peróxido de hidrógeno) también se puso a prueba. Los mejores resultados se obtuvieron cuando el pH del lodo se redujo a 6 con H2SO4, siguiendo un tratamiento con 1 ml de H2O2. Sin embargo, este tipo de tratamiento es muy agresivo, se requiere equipo especial y pueden ser perjudiciales para el medio ambiente en el largo plazo. Se han encontrado otros parámetros para desempeñar un papel clave en el proceso la deshidratación mecánica, tales como: tiempo de llenado de la prensa, tiempo de compresión, la edad y el tipo de membrana de filtro, la calidad de los lodos en la prensa y el polímero de mezcla de lodos.

Palabras clave: Deshidratación, contenido de sólidos secos, poliacrilamida, Kemicond

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1. Introduction

Sludge is an unavoidable waste product originated from the treatment of municipal wastewater, it contains harmful substances which were removed from wastewater (Metcalf and Eddy, 2003) including organic matter, pathogens and chemical contaminants. Thus needs to be processed to reduce its environmental and health impacts for its later reuse or disposal.

The rising costs for sludge disposal on German facilities make it crucial to optimize processes focused on the reduction of volume and mass, such as the thickening and the mechanical dewatering process.

Annually, the sludge disposal costs at Bensberg WWTP oscillate around 1.5 million euros. It is necessary for the plant to optimize the dewatering process by optimizing the use of coagulants, adequate maintenance of the equipment, frequent monitoring, and use of the best available coagulants to obtain better-dried solids results.

There are several problems related to sludge treatment in the facility. A large variability within the performance of the filter press and a poor homogeneity of the sludge is observed. Total solid concentrations oscillate between 24-29% through mechanical dewatering with solid content variations within one day and at different points of the same press.

The main objective of this research was to define the main parameters that affect the overall dewaterability performance in terms of dried solids, and find possibilities to improve this process at Bensberg. The small scale trials focused mainly on the chemical dewatering through the use of polyacrylamide polymer as a dewatering aid and its dosage optimization. Furthermore, a relationship between the sludge dewatering capabilities, temperature, viscosity and pH were established. The full-scale trials were focused on the filter press performance and the use of different filter membrane materials.

One of the main materials used as chemical dewatering aids are organic polymers with two mechanisms for solid-liquid separation. The first one, is destabilization of colloidal systems by charge neutralization. Since sludge is found to be negatively charged (approximately -30 mV), cationic synthetic polymers are generally used to neutralize the sludge charge, flocculating the solid portion of the sludge and helping water release within the particles (Changa et al., 2002). The second mechanism is by inter-particle bridging. A polymer can adsorb on the surface of a colloidal particle as a result of chemical (e.g. chemical bonding due to charge) or physical forces (e.g. van der Waals force).

For this work, cationic Nalco polyacrylamide was used as a sludge conditioning agent. This compound is very effective due to its high molecular weight (3 to 15 million number-average MW), high solubility, and the presence of several polar groups in the molecular chain which habilitate it to form bridges among particles and agglomerate particles into big flocs by neutralizing charges.

Furthermore, for small scale trials the Kemicond procedure was tested prior to dewatering digested or undigested sludge. It operates at low pH values. In the first step, antifoam is used to prevent the development of excessive lather. Secondly, sulphuric acid (H_2SO_4) is added, usually until a pH equal to 4 is reached. However, for this work higher pH values worked better. Finally, after incorporating the acid, CO_2 and hydrogen sulphide H_2S are released. The principle works with the addition of acid since the gel-like inorganic matter holding water is dissolved, and chemically bounded water is released. (Nikolic, A., Karlsson, I. K. 2005, p.4).

As part of the full scale trials, different types of filter membranes were tested to determine which would have the best dried solids results. Table 1 shows technical data for the different types of membranes used.

The membranes tested were composed of a plastic monofilament with different thickness and permeability, their effect on final dried solid content was tested and will be further discussed.

Table 1. Filter membranes: technical data.

Membrane	Material	Weight (g/m^2)	Thickness (μm)	Permeability L/dm^2/min/200Pa
Marsyntex®	Monofilament	285	420	300
Clear Edge®	Polyamide Monofilament	350	530	400
Sefar®	PP Monofilament	250	390	156

2. Methodology

2.2. General Analytical Procedures.

2.2.1. Total solids (TS)

TS percentage was determined gravimetrically based on the loss of volatiles and free water. A sample of 15 g of sludge was placed into a ceramic glass and heated in an oven at 105 ºC until mass remained constant, which was within a period of 20 to 24 hours.

The estimation of the total solids content as percent (%) was estimated according to Equation 1.

$$TS\% = \frac{W_d - W_p}{W_s} \times 100 \qquad (1)$$

Where TS is the total solids content of the unknown or control sample (%); Wd is the total weight of the unknown or control including the weighing dish, after drying (g); Wp is the tare weight of the weighing dish (g); Ws is the weight of the unknown or control, before drying (g) (Holstege, 2010).

2.2.2. Viscosity

A digital R model Selecta STS Rotational viscometer ® was used to measure dynamic viscosity, 500 ml samples were used. The speed normally established for the sludge is 60 to 100 RMP, after rotation during one minute, the viscosity and temperature lectures were taken in cP and in ºC respectively.

2.2.3. Capillary Suction Time

The capillary suction time (CST) test involves measuring the time to move a volume of filtrate over a specified distance as a result of the capillary suction pressure of dry filter paper measured in seconds. The CST test provides information regarding the ease of separating the water portion from the solids portion of sludge. (Aarne, 1988).

A HeGo Biotec® capillary suction timer was used for the tests; 4 mL of sludge were taken with a plastic bulb and poured into the CST device.

2.3. Small Scale Trials

2.3.1. Relationship between temperature and viscosity

A sample of sludge from the anaerobic digester was taken; the relationship between temperature and viscosity of the sludge was constructed with temperatures of 23, 31, 40, 50 and 60ºC. The first measurement corresponds to the temperature in the environment and higher temperatures were achieved by heating the sludge in a mixing and heating plate.

2.3.2. Relationship between capillary suction time and viscosity with and without polymer dosage

Nalco polyacrylamide in concentrations of 6 kilograms of active substance per kilogram of dried solids was used. A relationship between the viscosity and the capillary suction time was built in order to obtain information about one of the sludge's rheological properties and its dewatering capabilities. A mixed sludge sample was taken from anaerobic digesters. First, the sludge's behavior was tested without polymer dosage and its CST and viscosity values were obtained at temperatures of 10, 20, 30, 40, 50 and 60 ºC.

2.3.3. Relationship between T and CST and Viscosity with polymer dosage.

Further experiments were made for the digested sludge on the rheological and dewaterability parameters with polymer dosage. NALCO polyacrylamide polymer was fixed to a dosage of 36 ml for 500 ml of a mixed sample of two anaerobic digesters. This dosage was taken from the full scale value used at the time with a relationship of 1 m^3 of polymer (with 1% concentration) for a volume of 16 m^3 of sludge.

2.3.4. Relationship between polymer dosage and sludge parameters

Samples from the post thickener were used since the sludge from this process had been partially conditioned with a small dose of polymer, and the objective of this trial was to see if there is any relationship between the polymer and the sludge's characteristics. The sample was divided in seven samples of 500 ml each. Polymer dosages between 33 and 37 ml were tested on each sample. Viscosity, temperature, pH and capillary suction time were also measured.

2.3.5. Polymer dosage optimization

Seven samples of 100 ml of digested sludge were taken from digester 1. Doses of 0, 3, 4, 5, 6, 7, and 8 ml of the polymer were added to each flask and were immediately mixed with a magnetic mixer for 10 seconds, and the capillary suction time (CST) was measured according to 2.2.3.

2.3.6. Optimization of polymer dosage for digested sludge and thickened sludge.

Another test was carried considering the best range of polymer dose from trial 2.3.4. For these tests, a digested sludge sample and a thickened sludge sample were used, and CST was measured according to 2.2.3.

2.3.7. Optimization of polymer dosage for digested sludge.

A last trial was carried for the sludge dosage optimization, using a 3 liter mixed sample from digester 1 and 2. Then, this sample was distributed in six smaller samples of 500 ml each one with a polymer dose of 25.5, 30, 32.5, 35, 37.5, and 40, were tested (corresponding to the dosage of 5, 6, 6.5, 7, 7.5 and 8 ml per 100 ml of digested sludge). CST, temperature and viscosity were measured and related to the polymer dosage.

2.3.8. Kemicond Tests

Samples of 500 ml of digested sludge were used. The pH of the sludge was measured. Then, it was stirred with a magnetic mixer. Ten drops of anti-foamer were added. Measurements were taken at different pH values, from 7 until 5. Then the sludge was divided into five smaller samples of 100 ml to test concentrations of 1,2,3,4 and 5 ml of hydrogen peroxide (H_2O_2), the samples were stirred at 25 rpm, and left to react for 45 minutes.

After the sludge was treated, its dewaterability capabilities were tested on an Erlenmeyer vacuum flask. The sludge was dewatered through vacuum from 1 to 5 minutes, depending on the sample and on its dewatering capabilities. Then the sludge's dried solids were measured according to 2.2.1.

The pH was lowered with sulphuric acid (H_2SO_4, 2 molar), different dosages of hydrogen peroxide (H_2O_2) were tested. The volume of filtrate was also measured and pH was raised with the addition of NaOH, and pH near 4, 5, 6 and 7 were tested for the different H_2O_2 concentrations.

2.3. Full scale trials.

The full scale trials were conducted in the plant's filter press. Dewatering time, membrane filters and total solids content were studied.

2.4.1. Filter press performance.

The performance of the filter press was tested and the filtered cake dried solids content were measured. Many factors can affect the press' performance, for instance, the filter membrane material used, shown in Table 1, membranes are composed of different monomers and their permeability and thickness can also differ. Another factor is the pressure; at different points of the press, different pressures might be achieved, and also pressure can be variable within the length of the press. Also, the distribution of the sludge in the height of the filter membrane can vary, it was important to take the samples in different parts of the press.

Samples were taken from 3 different points from each press. There are two filter presses operating in Bergisch Gladbach WWTP, each press consists of 72 plates. Samples, were taken at the beginning of the press (plate number12), at the middle of the press (plate number 34) and at the end of it (plate number 62). Also, for each plate, three samples were taken, above, below and middle of the plate.

2.4.2. Dried Solid filter press 1.

Approximately 50 cm x 20 cm, samples were taken from the same spots as the previous trials, this larger sample was pulverized and a mixed for the dried solids measurement.

2.4.3. Filter membranes.

The filtering membranes were replaced (mainly Marsyntex ®) for new ones, (Clear Edge ®) on filter press 1 and Sefar ® on filter press 2), and the sludge's total solids were tested according to 2.2.1. to evaluate their filtering capabilities.

2.4.4. Filter Press Hydraulic Parameters.

In both, filter press 1 and 2. The time of filling was modified, this is the mass of sludge fed into the filter press per second. Different ranges were tested starting from 500 seconds to 1200 seconds, on 100 seconds intervals. The lower and higher ranges were set due to recommendations by the manufacturer, but the filling time that actually gives the best results had never been tested in the plant. Likewise, the hydraulic compression time was tested in the range of 1500 and 3000 seconds, and 100 seconds intervals.

3. Results and Discussion

Different relationships were constructed to observe weather the sludge's dewatering capability, measured through capillary suction time, was dependent on temperature, viscosity and polymer dosage.

3.1. Small Scale Trials

3.1.1. Relationship between temperature and viscosity

Figure 1 shows an expected inverse relationship between the sludge's temperature and its viscosity. At ambient temperature (23° C) a viscosity of 816 mPs was registered, when the temperature was raised to 60ºC, the viscosity decreased almost ten times to 76 mPs. Temperature has a high effect on the sludge's viscosity, one of the sludge's rheological properties. Additionally, temperature and viscosity relationships with the sludge's capability for dewatering were also related to capillary suction time values.

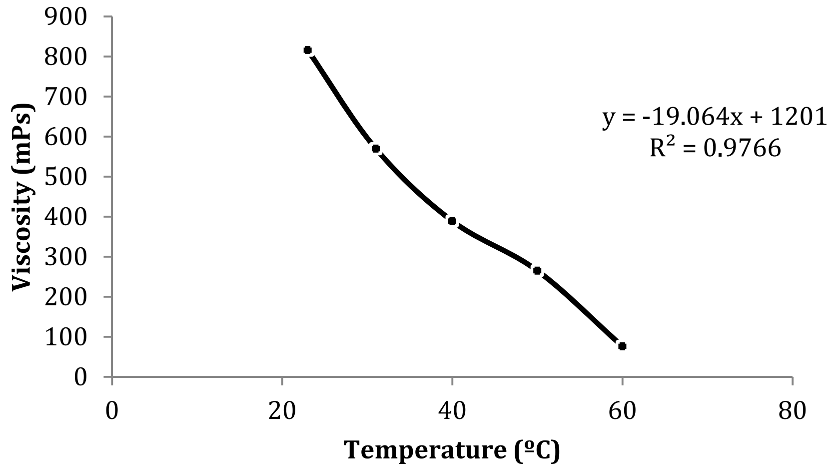

Figure 1. Sludge Temperature vs Viscosity

3.1.2. Relationship between capillary suction time and viscosity with and without polymer dosage.

From Figure 2, it can be observed that capillary suction time is affected by temperature and viscosity. The CST values on the digested sludge without polymer dosage vary from 214 seconds at temperatures around 10ºC to 503 seconds for the highest temperature tested (60ºC).

There is a direct relationship between capillary suction time and temperature which is represented by the following Equation 2:

$$CST = 7T + 112 \quad (2)$$

The relationship between viscosity and temperature is given by Equation 3:

$$Viscosity = -5T + 430 \quad (3)$$

Combining equations 2 and 3, a relationship between CST and viscosity can be obtained in Equation 4.

$$CST = -\frac{7}{5} Viscosity + 714 \quad (4)$$

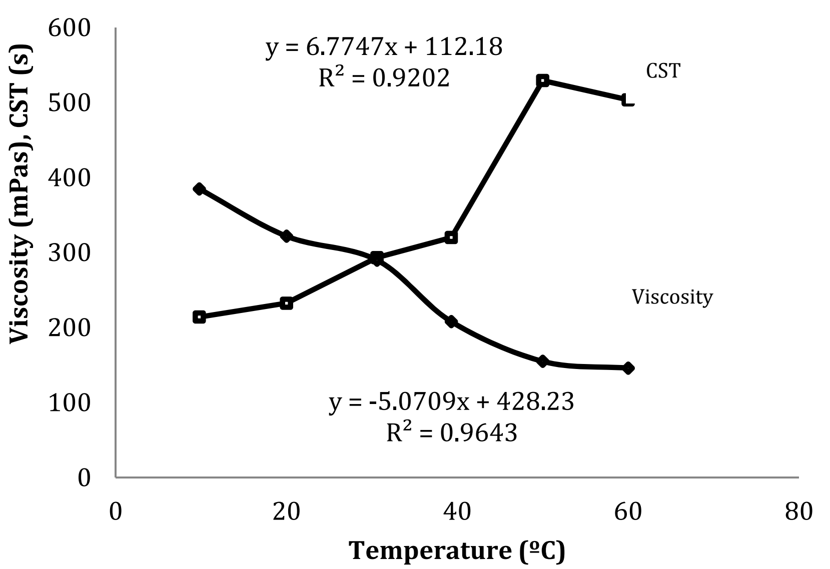

Figure 2. Relationship between T, CST and Viscosity without polymer

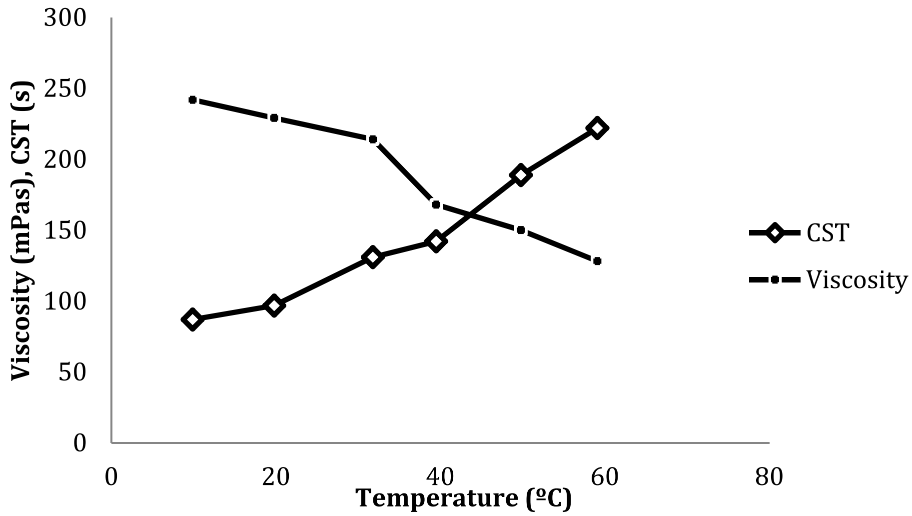

Figure 3. Relationship between T and CST and Viscosity with polymer dosage.

These relationships only give a rough idea of how temperature influence sludge's rheological properties measured as viscosity, and its capability to separate from water, measured as capillary suction time. The capillary suction time relationship states that at higher temperature values, the CST is higher, meaning that the water separates from the sludge at a much lower pace, and at lower temperatures the CST values decreased.

3.1.3. Relationship between T and CST and Viscosity with polymer dosage.

The CST values were significantly decreased with polymer dosage (Figure 3). The sludge's viscosity was affected by the polymer, a less viscous sludge is obtained, improving dewatering capability. The flocs were immediately formed after the polymer addition. However, the purpose of this experiment was to observe if the relationship between CST and the other parameters were affected by the polymer.

According to Figure 2 and Figure 3, the behavior between temperature, CST and viscosity are independent from the polymer dosage.

3.1.4. Relationship between polymer dosage and sludge parameters

Figure 4 displays the behavior of the variables with polymer dosage. There is no effect on pH values, but polymer dosage has high effect on viscosity and little effect on the other variables. The best CST results were obtained at polymer dosage values of 33.5 mL and 36 mL per 500 mL of sludge , with CST values of 7.2 and 9.3 respectively, which is equivalent to 1 m^3 per 16 m^3 of sludge that are fed into the filter press each day.

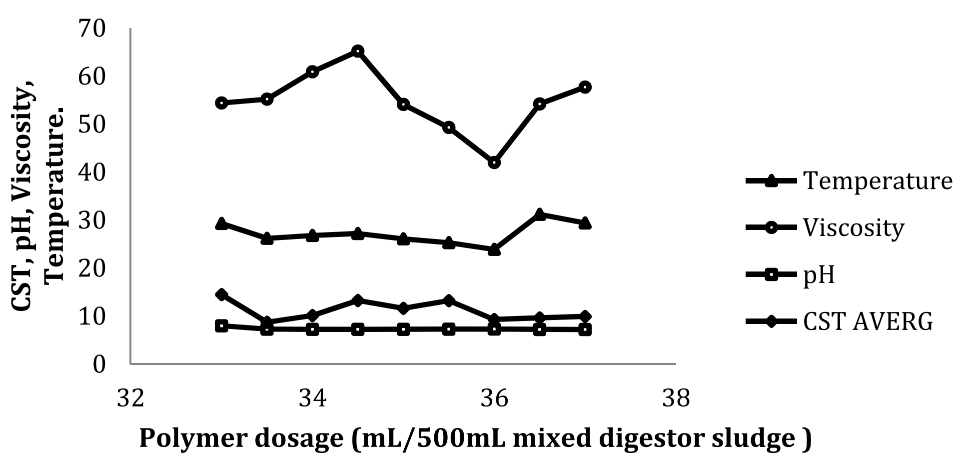

Figure 4. Relationship between polymer dosage and sludge parameters

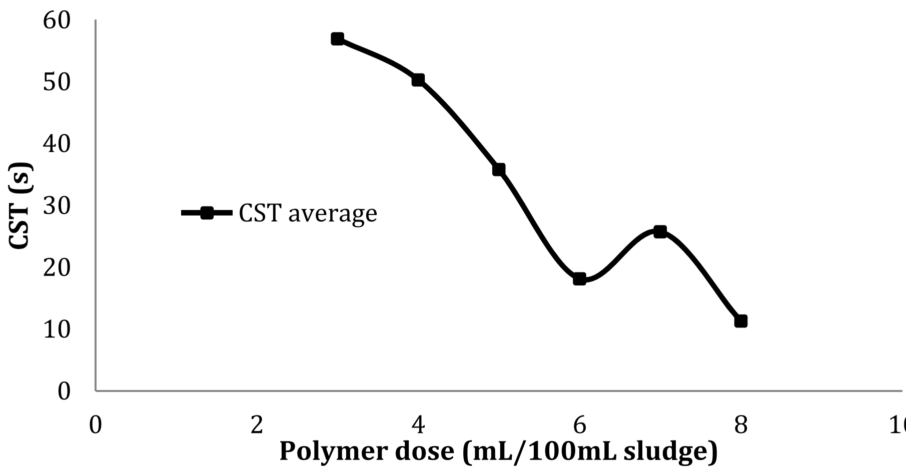

Figure 5. Polymer dosage and CST relationship

3.1.5. Polymer dosage optimization

Figure 5 shows that polymer dosages, between 56 to 30 seconds, below five ml give poor CST results,. In the range from 6 to 8, the CST results were improved (18 and 11 seconds respectively).

3.1.6. Optimization of polymer dosage for digested sludge and thickened sludge

The texture of the thickened sludge is very different from that of the digested sludge, some flocs could be already observed from this sample and also a slight separation of water could be observed. The results from this trial are presented on Figure 6, in where (PT) is the post thickener sample and (SD) sample from the digester. Both samples followed the same behavior; but the post thickener sample is slightly better. Dewaterability average was 3 seconds faster than those of the digested sludge. Therefore, the thickening process has a positive effect on the sludge's water separation.

The sludge had improved dewaterability due to the previous conditioning. The best CST result was obtained at a polymer dosage of 7.5 ml per 100 ml of thickened sludge, with a CST value of 8.8 seconds. The extreme values of 6 and 8.5 showed higher CST between 15 and 16 seconds for thickened sludge.

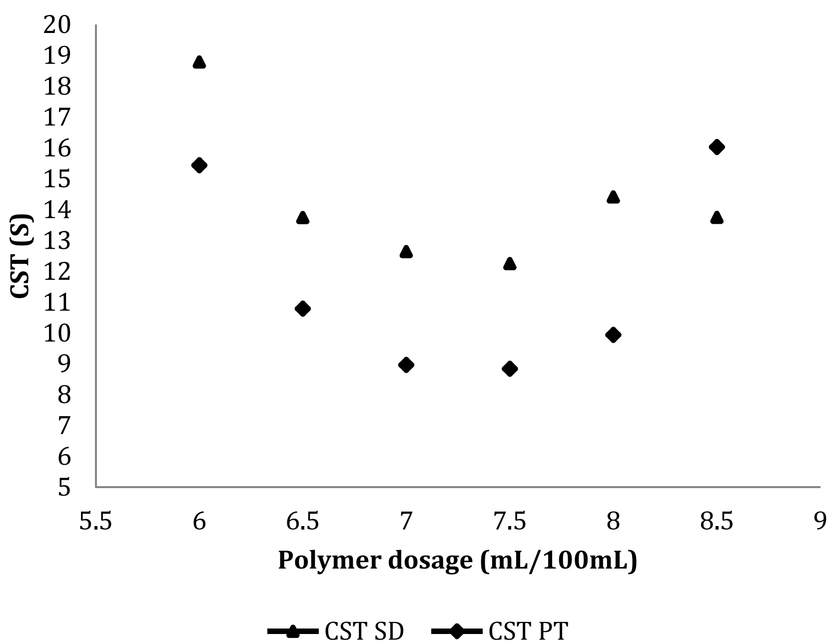

Figure 6. Optimal polymer dosage

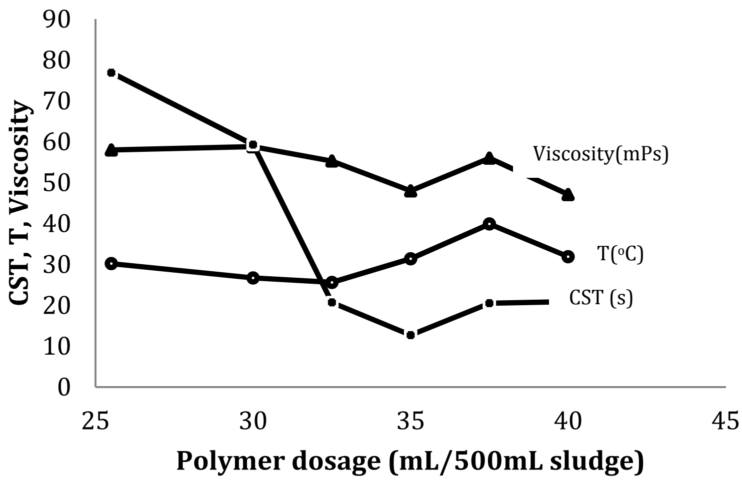

Figure 7. Relationship between polymer dosage and sludge parameters

3.1.7. Optimization of polymer dosage for digested sludge.

The best polymer dosage was at 35 ml per 500 ml of sludge (Figure 7), this corresponds to a value of 1,12 m^3 per 16 m^3 of sludge in full scale. This is actually the current polymer configuration that is used at Bensberg. However, chemical dosages must be periodically evaluated due to changes in sludge characteristics, also a line CST sensor would be required when sludge CST values are high, then polymer dosage can be automatically adjusted.

3.1.8. Kemicond Tests

Figure 8, shows that the percentage of dried solids is directly dependent on the hydrogen peroxide added to the sludge. A dried solid concentration as high as 17.57 % was achieved with this treatment alone (pH=4 and 4mL of H_2O_2) , using only digested sludge, without post thickening or any polymer addition. The vacuum dewatering might not be as effective as the mechanical dewatering used in full scale, therefore the results obtained through this trials are not comparable with press filter dried solids results. The dewaterability can be significantly increased with this method, however it could be improved with a polymer conditioning step.

Furthermore, there was not a clear relationship between the pH value and the dried solids percentage. This may indicate that the NaOH treatment could serve only to produce a less acid sludge, but it does not affect its dewatering capability.

Figure 9 displays the filtrate results. The filtration volume was also affected by the addition of higher concentrations of H_2O_2. The filtration was very quick, within less than one minute the sludge was completely dewatered with concentrations between 2 and 4ml. The highest filtrate was obtained with an addition of 3 mL of H_2O_2 with a filtrate volume of 52.5 ml.

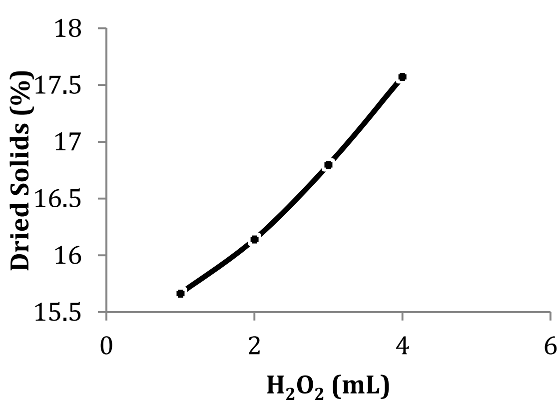

Figure 8. Dried solids percentage for sludge treated with KEMICOND pH =4

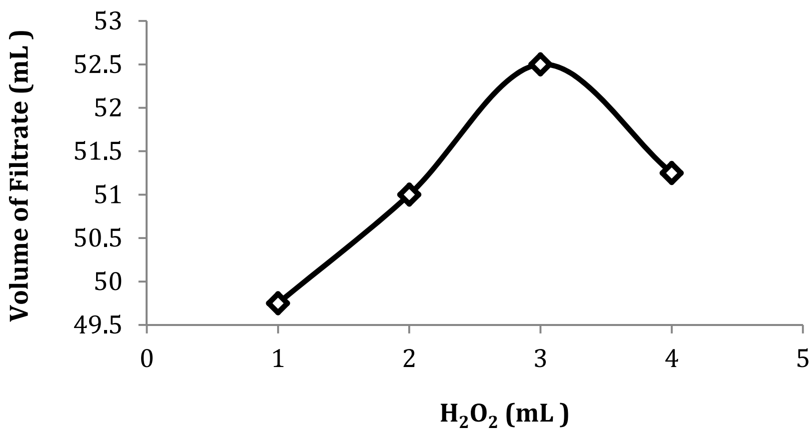

Figure 9. Volume of filtrate of sludge treated with Kemicod, pH=4, at different H_2O_2 dosages

This sludge conditioning is very aggressive, so it might require special equipment. In addition, large quantities of sulfuric acid and hydrogen peroxide would be required for the amount of sludge treated. An average of 50 L of H_2SO_4 and 30 L of H_2O_2 would be required per 1 m^3 of digested sludge, an average of 112m^3 of sludge is treated per day at the plant. This would represent a need for H_2O_2 of 1200 m^3 per year and 2000 m^3 of H_2SO_4 per year.

3.2. Full scale

3.2.1. Filter press performance.

The summary of the results for filter press 1 are described in Table 2.

Table 2. Average dried solids content for filter press 1.

%Total Solids Press 1				
	Under	Middle	Upper	Average
Plate 12	25.91	26.18	28.38	26.82
Plate 34	28.88	22.70	27.55	26.38
Plate 62	24.90	24.47	28.86	26.08
Average	26.56	24.45	28.26	

A higher solid concentration is observed in the upper part of the plate (28.26%), lower dried solids are achieved from samples taken from the middle part of it (24.45%). DS values are very similar along the length of the filter press, achieving the lowest DS for plate 62 and the highest DS for Plate 12. In average, the distribution of DS is even or less homogeneous along the filter press.

The results from filter press 2 are displayed in Table 3.

Table 3. Average dried solids content for filter press 2.

%Dried Solids Pres 2				
	Under	Middle	Upper	**Average**
Plate 12	26.10	25.62	27.87	26.53
Plate 34	28.60	27.24	28.00	27.95
Plate 62	26.40	25.95	27.06	26.47
Average	27.03	26.27	27.64	

The behavior from both presses is not very different, since they are fed with the same sludge. Other parameters might influence their behavior, such as the membranes usage, and other hydraulic parameters results will be later analyzed.

3.2.2. Dried Solid filter press 1.

Average results from this trials are shown in Table 4.

Table 4. Dried solids filter press 1 with larger sample

	Plate number			Average
	P10	**P34**	**P62**	
Upper	25.82	28.66	26.92	27.13
Middle	25.95	25.12	30.24	27.10
Under	28.64	27.91	25.52	27.36
Average	26.80	27.23	25.52	26.52

When larger samples are taken, there are smaller differences between the dried solids results at different spots. Therefore, it is better to take a mixed sample for more reliable total solids analysis. The dried solids values are similar between the different points of the filter press, and this type of sampling is more reliable than the first one were bigger fluctuations are observed from one point of the press to another, and from different points within the plate.

Sludge fed into the press comes from the post thickening process in which some polymer has already been added. However, sometimes a poor mixture of polymer occurred in this process since sludge is continuously fed into the filter press and there is not enough time for it to be homogeneously mixed with chemicals. This has also a negative impact on the final dried solids results. Even though, the same sludge is fed into both presses there is a slight difference between the performance from Filter Press 1 and Filter Press 2. Filter press 2 has better dried solids results. Additionally, this press was easier to handle in comparison to press 1. The filtered cake was easier to detach from the filter membrane, and a more compact cake was obtained. Filter press 1 was very difficult to handle, the filtered cake was strongly attached to the membrane, and more time was spent by opperators to clean the press. Also a thicker cake was formed, and the dried solid content was regularly lower than that on filter press 2.

3.2.3. Filter membranes.

Some of the advantages that were immediately observed after the membranes were changed are the following:

- The filtered cake was easily detached.
- There was a more uniform elutriation on the entire filter cake.
- Less time spent emptying the filter press after each cycle.
- Less sludge residue was observed on the membrane.

3.2.4. Filter Press Hydraulic Parameters.

The best Hydraulic results were observed at 900 seconds of filling time, compression time of 2100, using a Clear Edge Membrane. Table 5 shows the best dried solid values obtained for these trials.

Table 5. Dried Solids Values.

Dried solids load (%)	Dried solids entrance (%)	Cake dried solids (%)	Active substance dose kg/kg active substance	Viscosity Pa□s	Temperature (ºC)
3.45	3.62	30.57	7.88	210.3	27.86

3.2.4. Disposal cost reduction achievements

The plant's current production of dried solid mass of sludge is 1,800 tons, which is 25% of dried solids. This means that the plant needed to dispose a total of 7200 tones of sludge at 48€ per ton, leading to a total disposal cost of 346,000 euros in 2011. Figure 9 shows the savings per unit percent of improvement on sludge dried solids. The sludge was concentrated up to 30%, which means that if we consider only the mass of sludge to be disposed, the plant will be saving 58 000 euros annually.

4. Conclusions

The polymer dosage tested in the small scale cannot be interpolated to the full scale, or a wider range should be tested in order to see a difference when higher volumes of sludge are being conditioned. In general, the polymer dosage used at the plant, was the right dosage, and higher or lower dosages did not have influence on improving the dried solids content.

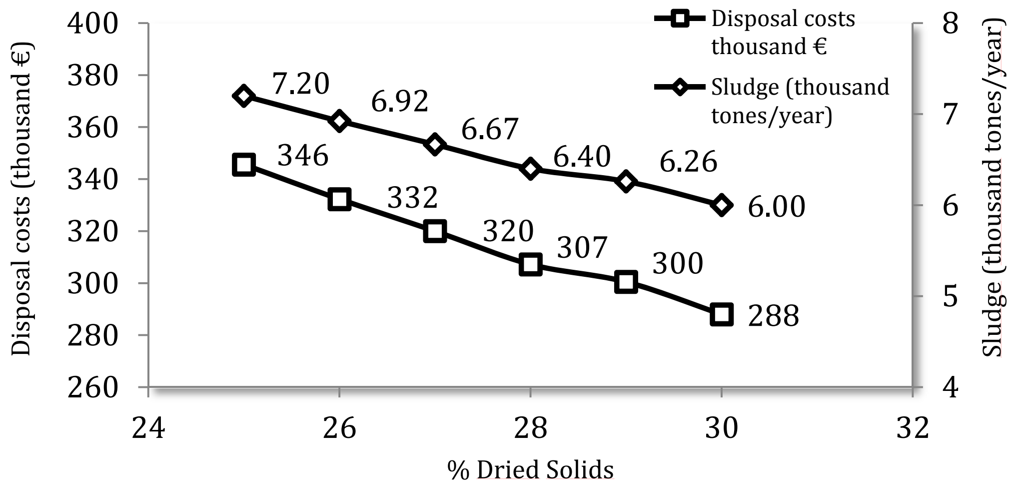

Figure 9. Disposal cost reduction achievements**.**

Dewatering polyacrylamide based polymer has an acceptable performance as dewatering aid. It improves drastically the solid liquid separation from the sludge, facilitating thickening and mechanical dewatering. However, further studies should be carried to test different dewatering aids, such as natural flocculants, especially when the sludge is disposed for agricultural purposes and for future restrictions on the disposal of sludge with non-degradable compounds. Although many natural polymers are still being developed and tested, there are chitosan based polymers already available in the market which could be tested by the plant in a small scale, and it can also be incorporated into the water treatment process for flocculation in order to produce more biodegradable sludge. This natural polymers are cheaper than synthetic polymers, iron or aluminum salts, so they could help not only to produce environmentally safe sludge but it could also help save costs on the dewatering and flocculation process since a big part of costs are designated to costly chemicals.

The plants' laboratory tests include the measurement of the filtered cake total solids from Filter Press 1 and 2. However, the sample is taken at a single point of the press, and the sampled plate is always different. This kind of sampling might not give reliable results so a larger and more thoroughly sampling procedure should be applied in order to have an effective monitoring of dewaterability yields since in practice it was observed that sometimes there could be great variability on the sludge's dried solids results, not only between one plate and another but within the plate itself, so this could be taken into account to improve analytical procedures in the facility.

The parameters that play a key role for improving sludge dewatering are the use of polyacrylamide polymer, since it leads to an immediate water release from the sludge particles. Also, hydraulic parameters such as press filling time and compression time play an important role on the sludge's final dried solids composition, and in the overall process efficiency. As the press filling time increases, a larger amount of sludge can be treated and the overall compression time decreases, making the whole process more efficient using less energy for compression. Also, at a right combination of both press filling time, which is at 900 seconds and compression time at 2100 seconds, a drier sludge cake is obtained with a dried solid concentration of 30%. The dewatering process was optimized at Bensberg Wastewater Treatment Plant for economical purposes, reflected on the WWTP annual disposal savings. However, there is still much to do in order to make the process sustainable, since it uses non-biodegradable substances and spends much energy. Alternatives should be sought in the future for water treatment facilities, to make their sludge less harmful for the environment and make the overall process more resourceful, and less energy consuming.

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