

FT-FNG-002

**TECHNOLOGY FACT SHEETS
FOR EFFLUENT TREATMENT PLANTS
IN TEXTILE INDUSTRY**

SLUDGE DEWATERING

SERIES: SLUDGE TREATMENTS

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SLUDGE DEWATERING (FS-FNG-002)

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1.- INTRODUCTION

Dewatering is a physical process integrated in the sludge line of treatment plant. It is aimed at reducing the water content and therefore the sludge volume. In this way, its transportation costs to the final destination point is reduced. On the other hand, the dewatered sludge is easier to handle and the transport process is more convenient than in the case of a sludge with higher water content.

The dewatering technique chosen must be consistent with the amount and characteristics of sludges generated and with the biosolid final destination.

Water present in the sludge exists in four forms (see figure): free, colloidal, intercellular and capillary. Free water can be separated from sludge by gravity as it is not associated with solids. Chemical conditioning prior to the use of mechanical tools is required in order to remove colloidal and capillary water. For intercellular water removal, the structure containing it must be broken and this can be done through heat treatment.

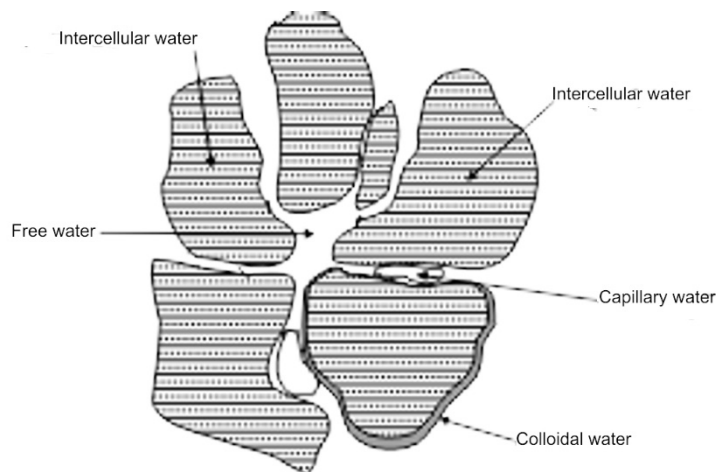


Figure 1.- Water presence within sludge.

Dewatering is often used before incinerating the sludges in order to increase their calorific value, and is also used before composting to reduce the amount of fluffing agents. If sludge goes to a landfill, dewatering is used so as to achieve the permissible moisture degree compatible with landfill sanitary conditions and structural characteristics.

2.- DEWATERING TECHNOLOGICAL TYPOLOGIES

There are two types of dewatering: natural and mechanical. The first type is formed by drying beds and the second one basically consists of: band filters, filter presses, vacuum filters and centrifuges. Mechanical dewatering is preceded by previous conditioning.

3.- SLUDGE CONDITIONING

Sludge conditioning is used to improve mechanical dewatering performance. There are basically two methods: chemical conditioning and thermal conditioning.

Chemical conditioning consists of the reagent addition to sludge so that solids flocculation and the release of some of the retained water are achieved.

The reagents used are of two types: mineral and organic. Among the former, there are ferric chloride (FeCl_3) and lime (CaO); and the latter include polyelectrolytes, which may be anionic or cationic.

Reagents of mineral type are more adaptable to sludge to be dewatered in filter presses or vacuum filters; for their part, organic reagents are best suited to sludges that will be dewatered through centrifuges or band filters.

Sludge chemical conditioning leads to an increase in sludge solids. For mineral reagents, an increase of 25% in solids can be achieved. Polyelectrolytes lead to a much lower increase of solids, however, they are more expensive than lime or ferric chloride.



In general, flocculation time should exceed 20 minutes. The following table lists the usual doses applied of different reagents.

Table 1.- Chemicals dosage commonly used in sludge conditioning prior to dewatering operation.

Chemical	Mixed sludge. Anaerobic digestion sludge	Aerobic digestion sludge	Subsequent dewatering type
Cl_3Fe	3-8%	8-15%	Press filter or vaccum filter
CaO	10-20%	20-35%	
Polyelectrolyte	0,2-0,5%	0,5-0,8%	Centrifuge or band filter

Thermal drying involves heating the sludge under pressure for a short time. It has a major application in the case of sludges from biological treatment.

4.- NATURAL DEWATERING: DRYING BEDS

Where there is enough space, the option of building drying beds shows very satisfactory investment and operating costs. On the other hand, their performance is comparable to that of the most efficient mechanical system. Little maintenance is required and can be carried out by unskilled labor force.

The large occupied area, sensitivity to climatic conditions, the possible odor generation and the need to replace filter material are among their disadvantages.

Drying beds essentially consist of a draining medium on which sludge settle. Evaporation and filtration are the physical mechanisms that allow to reduce the amount of water of sludges in beds. The following figure shows a drying bed scheme.

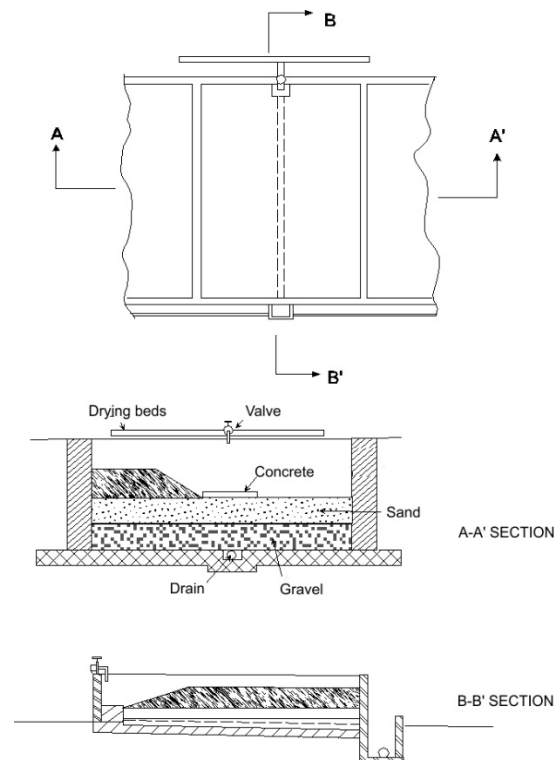


Figure 2.- Drying beds scheme.

As most of the sludge water permeates through the sand and gravel, an appropriate drainage pipe system must be designed. Drying beds are equipped with side drainage pipes (stoneware pipes with open joints, or perforated plastic pipes), mounted with minimum slopes of 1% and separated between 2,5-6 m. These pipelines should be placed properly and covered with coarse gravel or crushed stone.

The sand bed should be 200-300 mm thick, with some additional thickness so as to compensate the losses that may arise during cleaning operations. Beds with larger thicknesses slow down the drainage process. The sand should not have an uniformity coefficient above 4.0 and should have an effective grain size ranging from 0.3 to 0.75 mm.

On the other hand, sludges to be dewatered reach the beds via pipelines through which sludge should circulate at a speed exceeding 0,75 m/s.

The design parameters of drying beds are shown in the table below.

Table 2.- Design parameters for drying beds.

Gravel layer	10 - 20 mm	>0,15 m
Sand layer	$D_{10}=0,3-0,75$ mm $C_u < 4$	>0,20-0,30 m
Liquid sludge layer		<0,25-0.30 m
Head space		0,20 - 0,30 m
¹Annual use of each bed		<10 times (7-12)
¹Solids load		<120 kg SS/m ² ·year
¹Maximum Surface for each bed unit		<100 m ²
¹Drying level of each dried sludge cake		> 40%

¹Values for warm and wet climate

5.- MECHANICAL DEWATERING

Mechanical dewatering is typically composed of one of the following systems: vacuum filters, centrifuges, band filters or filter presses.

5.1.- Vacuum filters

In vacuum filtration, the force driving the liquid phase and causing movement through a porous medium is the atmospheric pressure due to vacuum application in the lower surface of the filter medium.

A vacuum filter (see figure below) consists of a cylindrical drum rotating around its axis and that is partly submerged in a tank filled with sludge. A porous cloth is placed on the drum allowing the passage of water.

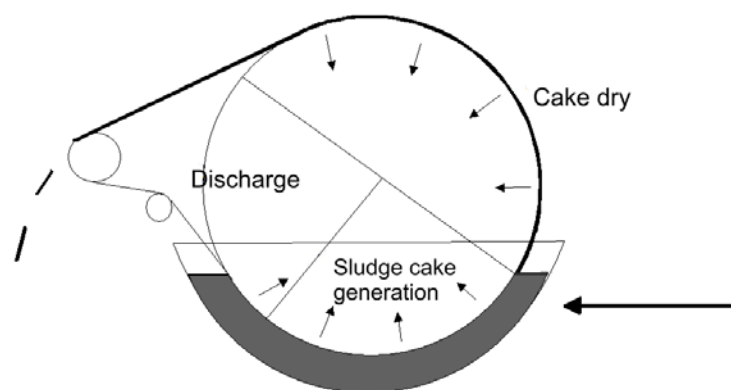


Figure 3.- Vacuum filter scheme.

The cylinder is partially immersed in a tank containing sludge to be dewatered; as this cylinder rotates, it is covered by sludge, then vacuum is performed inside the cylinder through external pumps and the water flows towards the cylinder center, from where it is removed.

Materials used as filter media are filter cloths or spiral wire meshes. The drum surface is covered with a porous medium, whose selection depends on the sludge dewatering characteristics. The drum surface is divided into circle



sectors. Each sector is separated from the adjacent one in the ends of the drum and connected to a rotary valve placed on the drum axis by means of a vacuum/drainage line. The rotary valve controls the different phases of the filtration cycle and leads the filtrate to the drum outside. As the drum rotates, the valve allows each sector to pass through each of the three phases of the process: cake formation, filtration-dewatering and cake discharge.

The dewatered sludge is finally collected on conveyor belts.

A major disadvantage of this type of filters is their high energy consumption ranging between 40 and 60 kW/t of SS.

The dryness obtained with a vacuum filter ranges between 20 and 25%.

5.2.- Centrifuges

The centrifugation process is widely used in the industry for the separation of different density liquids, sludge thickening or separation of solids. This process is also applicable to the sewage sludge dewatering and has been applied with varying levels of success.

5.2.1.- Fundamentals of thickening by centrifuges

The centrifuges are used to both dewater and to thicken sludges.

The separation process of sludge solid-liquid phase using thickening centrifuges is very similar to the one that takes place in the gravity thickening; the difference is that with the centrifuges, a centrifugal force being 500 to 3000 times greater than the gravity force is applied to the sludge, and it causes the suspended solids separation and concentration. The centrifugal force application on the sludge leads to the movement of the suspended solids, moving away from the centrifuge rotation axis.

The most commonly used centrifuges in the sludge dewatering are the horizontal axis ones. Their main elements are a cylindrical drum with truncated cone shape on an end and a spiral conveyor screw. They are equipped with a motor to produce the rotation of the drum, between 1600-2000 rpm (Qasim, 1994), and the screw, and the devices for the sludge and clarified liquid disposal.

The screw and drum rotate at a different speed. The sludge is fed into the unit continuously and the solids concentrate in the periphery. The spiral screw, that rotates at a slightly different speed, moves the accumulated sludge to the truncated cone end, where an additional solids concentration is carried out prior to discharge.

Depending on the progress of thickened sludge and clarified liquid (also called concentrate) within the centrifuge, two types of centrifuges can be distinguished:

- Centrifuges working via a current flow: the sludge and clarified liquid move in the same direction.
- Centrifuges working via a counter-current flow: the sludge and clarified liquid move in opposite directions (more common).

The concentrate contains low-density fine solids and recirculates to the plant treatment line. The sludge cake is discharged through a screw from the unit to a hopper or conveyor belt.

At present, there is a wide range of models in the market, whose characteristics vary according to the manufacturer, and the one that best suits the sludge conditions must be elected.



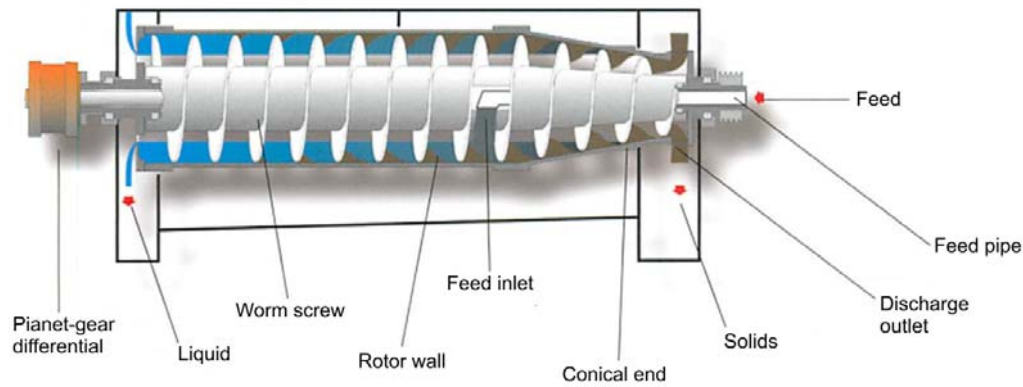


Figure 4.- Countercurrent operation centrifuge scheme (Alfa-Laval).

5.2.2.- Utility and applicability

Advantages (Chamorro, 2014):

- Ongoing process.
- Very reliable process.
- Labor is not demanded continuously.
- Without direct environmental effects.

Disadvantages:

- High cost of implementation.
- High cost of maintenance.
- Sensitive to sand deposits.
- Servicing by qualified service personnel and specific workrooms.

5.2.3.- Design

The factors affecting the process are as follow:

A) Centrifuge design parameters:

- Flow factors.
- Current flow operation.
- Counterflow operation.
- Drum and screw geometry.
- Diameter.
- Length.
- Angle of the conical section, etc.
- Factors related to the sludge and polymer.
- Situation of the feeding points.
- Maximum rotational speed.

B) Operating parameters:

- Drum speed.
- Differential speed between the drum and the screw.
- Sludge feed factors.
 - o Hydraulic load.
 - o Solids load.
- Flocculant usage.

C) Sludge characteristics:

- Particle and floc size.
- Particle density.
- Viscosity.
- Temperature.
- SVI.
- Sludge age.



Of all these, the basic parameters for the process control would be:

- Feeding sludge concentration and flow (hydraulic and solids load).
- Polymer concentration.
- Differential speed between the drum and the screw.
- Thickened sludge concentration and flow.
- Clarified liquid concentration and flow.

The most important variables in the centrifuge operation are the hydraulic load and the solids load that feeds it. The former concerns the clarified liquid quality and the latter is related to the sludge dragging capacity within the centrifuge. An increase in the feeding flow will prejudice the solids recovery in the process and/or will involve greater polymer consumption. Any change in the solids load shall be accompanied by a change in the differential speed between the drum and the screw. The highest thickened sludge concentration is achieved with the minimum differential speed and a flow being in line with the sludge transport capacity.

Although it is not entirely necessary, the use of polymers is recommended for the optimization of the process. The use of polymers allows for increased hydraulic load in the centrifuge, as well as for higher yields in the thickened sludge concentration and in solids recovery. If the thickened sludge concentration normally obtained is between 3% and 6%, the polymer addition provides concentrations of 8%. The solids recovery increases from 85-90% to 90-95%.

The type of polymer to be used and its concentration will be dependent on the characteristics of the sludge to be thickened. It is advisable to test with different types before deciding on a specific one.

5.2.4.- Specific technical considerations

[Este apartado está en blanco de forma intencionada]

5.2.5.- Expected results

It is common the centrifuge yields to be quantified by the capture percentage, defined as follows:

$$Yield(\%) = \left[1 - \frac{Cr \cdot (Cc - Cs)}{Cs \cdot (Cc - Cr)} \right]$$

Where:

Cr = solids concentration in the clarified water resulting from the process (rejection or centred), mg/L, in %.

Cc = solids concentration in the cake, from the thickened sludge, mg/L, in %.

Cs = solids concentration in the fed sludge, mg/L, in %

Dewatered sludge typically attains a dryness ranging between 20 and 25%. At present, values of 30-35% are obtained and even of 40% (WEF, 1992), though at the expense of a large dose of polyelectrolyte (up to 5 kg/t MS).

The energy consumption ranges between 40 and 60 kW/t:SS. This process is comparable with vacuum filtration in terms of costs and performance.

Centrifuges are compact, closed (the escape of odors to the outside decreases in comparison with other options) and require little space. The noise generated by such equipment at 1 m varies between 80 and 90 dBA.

5.3.- Band filters

A band filter basically consists of a conveyor belt on which the sludge is placed, and of a covering belt. Sludge is located between both belts, that are permeable. This set goes through a series of rollers positioned to achieve the



sludge compression. In some models, vacuum is performed in some course area in order to increase the water extraction.

A band filter scheme is shown in the following figure.

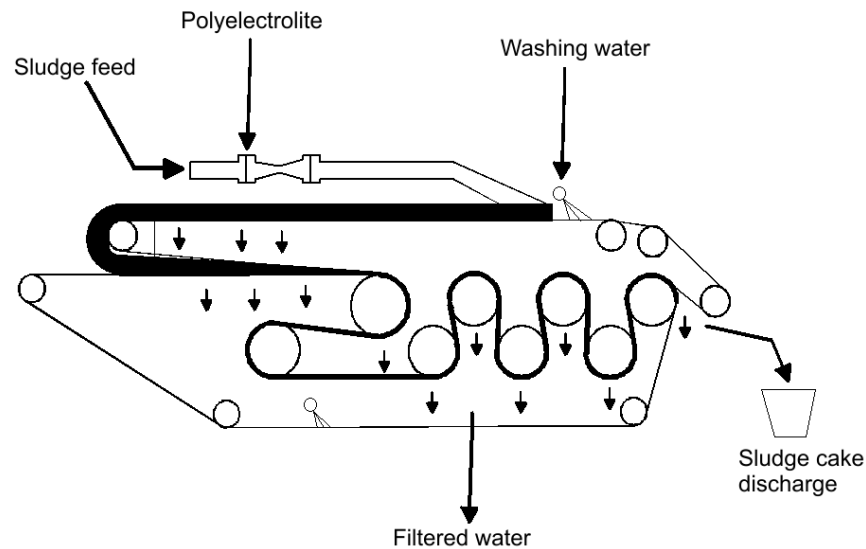


Figure 5.- Band filter scheme.

In a band filter, after the conditioning, the sludge settles at the beginning of the belt in an area where water extraction is carried out by gravity, just draining it through the belt. As this process progresses, the covering belt moves closer and closer to the sludge and enters into the pressing area. Finally, it enters an area in which the roller position is such that a strong compression in the belt pivot points occurs.

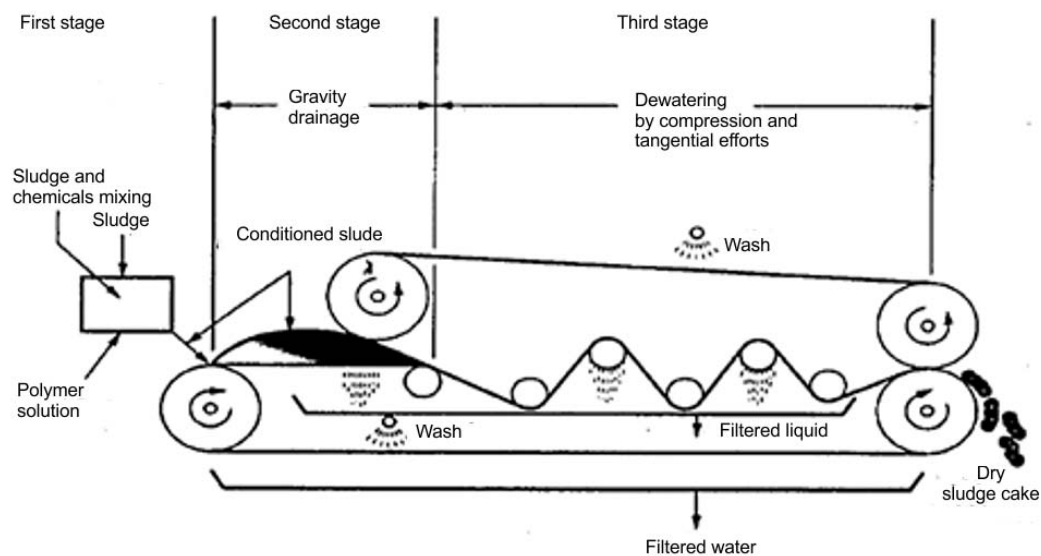


Figure 6.-Phenomena produced in filter press dewatering.

The dryness of the digested mixed sludge cake varies between 20 and 25%. The yield obtained depends on many variables, such as the sludge characteristics, conditioning type, roller configuration and belt speed.

Energy consumption ranges between 30 and 40 kWh/t MS.

Advantages (Chamorro, 2014):

- Ongoing process.
- Low energy consumption.
- Auxiliary installations are not needed.
- Ease of maintenance work.



Disadvantages:

- High cost of implementation.
- High cost of maintenance (regular cloth replacement).
- Labor is demanded continuously.
- Water consumption for cleaning the cloths.
- Environmental effects: aerosols.
- Need for security protocols.

5.4.- Press filters

In a filter press, dewatering is carried out by forcing the disposal of water present in the sludge by means of high pressure application.

The filter press allows for high solid concentrations in the cake, for a very clarified filtrate (high solid collections). Their disadvantages are the mechanical complexity, high costs for reagents, high labor costs and the limited lifetime of filter cloths.

This filter press consists of a series of rectangular plates facing each other and positioned vertically on a frame with a fixed end and another mobile end; a filter cloth is adjusted or hangs over each plate. The remaining space between two plates, in its central hollow part, is the thickness that the resulting cake will obtain. This thickness may vary between 15-30 mm. Plates remain together with enough strength to adhere hermetically so they are able to withstand the pressure applied during the filtration process. In order for the plates to keep together, hydraulic presses or mechanically driven screws are used.

The filter press surface may be up to 400 m², and the plate surface of 2 m². They can be made up of more than 100 plates.

During operation, the sludge, chemically conditioned, is pumped to the space between the plates, and a variable pressure between 690 and 1550 KN/m² is applied and held for 1-3 hours, forcing the liquid through the filter cloth and the plate outlets. Following, plates separate and the sludge cake is extracted. The filtrate is typically recirculated to the plant head.

The operating phases of a filter press are as follow (Gallardo, A., 1998):

- Filling with a duration of 15 to 20 minutes.
- Filtering with a duration ranging between 1 and 3 hours depending on the sludge type.
- Discharge with a duration of 30 minutes.
- Washing with a duration of 30 minutes each 2 or 3 filtrates.

Filter presses have several operational and maintenance problems that vary from difficulties in the reagent feeding and sludge conditioning systems to decommissioning periods to carry out excessively long maintenance works.

Aspects to be considered in the facility design of filter presses include:

- Proper ventilation of the dewatering facility (adopting between 6 and 12 changes of air per hour is recommended, depending on the ambient temperature);
- Washing systems at high pressure;
- In cases where lime is used, provision of a washing system by acid circulation in order to remove any lime deposit that may form;
- To have a sludge grinder before the conditioning tank;
- To include a sludge cake crushing system after the filter press (especially if dewatered sludge incineration is desired);
- Equipment to facilitate the extraction and maintenance of plates.



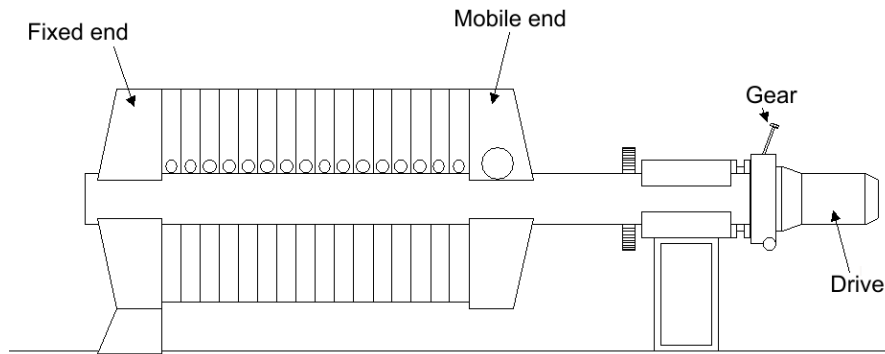


Figure 7.- Press filter scheme.

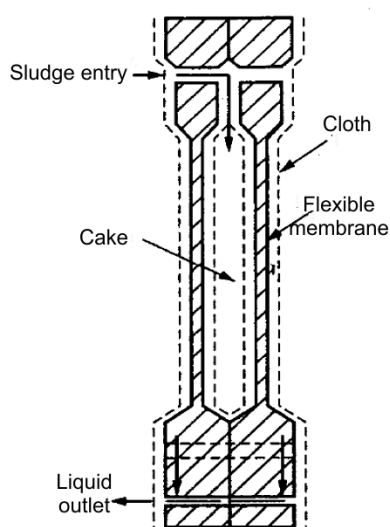
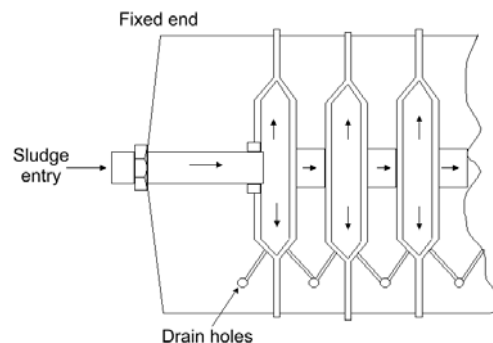


Figure 8.- Press filter cells scheme and filtering cloth arrangement view.

Filter presses work discontinuously, as opposed to dewatering methods considered so far that did so continuously.

The main advantage of filter presses is their capacity to attain dryness over 35%. The energy costs equal those of vacuum filtration and are adaptable to different sludge types. On the contrary, they have a very high investment cost, need a great deal of reagents in the conditioning phase and generate high operating costs.

Energy consumption ranges between 40 and 60 kWh/t MS.

Advantages (Chamorro, 2014):

- High dryness.
- Ideal with chemical stabilization process (lime).
- Medium operational costs.
- Easy to operate.

Disadvantages:

- High cost of implementation.
- Batch process.
- They require a buffer tank.
- Regular presence of personnel (discharge).
- Need for protocols (cloths).
- High reagent consumption (lime, iron salts or aluminum).

5.5.- Comparison of mechanical dewatering systems

The following table provides an overview of the characteristics of mechanical filtration systems mentioned.

Table 3.- Mechanical processes features summary

Process	Cake dryness, %	Energy consumption kW/t-SS	Performance	Investment cost
Vaccum filter	15-25	40-60	18-22 kg SS/m ² ·h	Medium
Centrifuge	20-25	60-80	-	Medium
Band filter	27-33	30-40	Variable	High
Press filter	40-45	40-60	3-4 kg SS/m ² ·h	Very high

It can be appreciated that the use of filter presses provides the highest dryness but at the expense of a very high investment cost, even though the energy consumption is comparatively at the intermediate area.

If the cake dryness is not a conditioning factor, more alternatives may be used. Note the low energy consumption of band filters although their initial cost is higher than vacuum filters and centrifuges.

6.- THERMAL DRYING

This system enables the extraction of embedded water from sludges thanks to its evaporation. Thermal drying may be by direct or indirect drying.

In the first case, hot gases are used and come into contact with the sludge to be dewatered, obtaining up to 90% dryness.

In the indirect thermal drying, the heating medium is a dryer wall, similar to a heat exchanger, giving dryness lower than that by the previous method, of 60-70%.



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ANNEX 1

REQUIRED SURFACE ESTIMATION

Reference brand PIERALISI Surface requirements



Decantador centrifugo Giant III

Decantador centrifugo Giant II L

Modelo	Longitud total [mm]	Anchura total [mm]	Altura total [mm]	Peso [kg]
BABY 1	1.660	825	1.095	500
BABY 2	1.860	825	1.095	550
BABY 3	2.060	825	1.095	650
FP600/M	2.470	1.040	1.425	1.360
FP600 RS/M	2.770	1.040	1.425	1.510
FP600 RS/M	3.070	1.040	1.425	1.660
JUMBO 12RS/M	3.205	1.475	1.685	2.600
JUMBO 2	3.615	1.475	1.685	2.950
JUMBO 3	4.025	1.475	1.685	3.350
JUMBO 4	4.435	1.475	1.685	3.700
HERCULES 470/2	3.490	1.580	1.725	2.950
HERCULES 470/3	3.900	1.580	1.725	3.350
HERCULES 470/4	4.310	1.580	1.725	3.700
MAMMOTH 570/2	4.370	1.920	1.970	5.540
MAMMOTH 570/3	5.050	1.920	1.970	6.500
GIANT 2	5.050	2.215	2.220	9.000
GIANT 3	5.510	2.215	2.220	9.900
GIANT II L	6.530	2.400	1.500	10.000
GIANT III	5.300	3.000	1.750	11.200

ANNEX 2

GRAPHICAL DESCRIPTION OF UNIT PROCESSES



Figure 1. Positive displacement pumps for sludge conveying.



Figure 2 Compact equipment for polyelectrolite preparation in sludge conditioning.



Figure 3. General view of a dewatering centrifuge.



Figure 4. General view of drying beds.



Figure 5. General view of a covered drying beds area.



Figure 6. Vaccum filter dewatering.



Figure 7. Vacuum filter for dewatering
(Técnicas de Filtración, S.A. TEFISA).



Figure 8. General view of a thickening centrifuge.

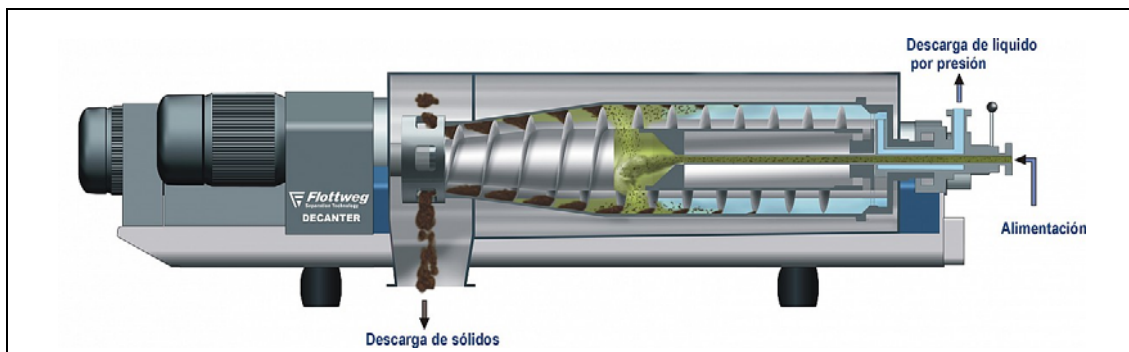


Figure 9. Thickening centrifuge scheme.

<https://www.flottweg.com/es/la-gama-de-productos/centrifugas/>



Figure 10. General appearance of a centrifuge (Alfa-Laval).

<http://local.alfalaval.com/es-es/key-industries/wastewater-treatment/carteraproductos/pages/default.aspx>

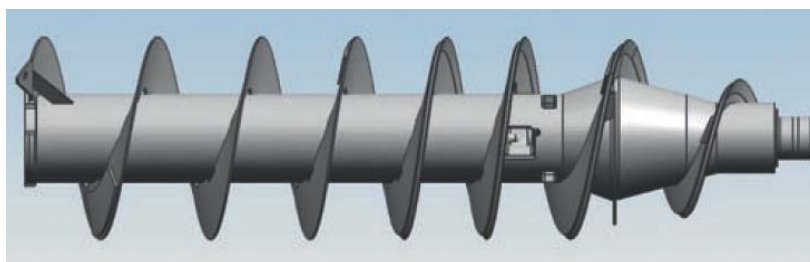


Figure 11. Worm screw detail from a centrifuge (Alfa-Laval).

<http://local.alfalaval.com/es-es/key-industries/wastewater-treatment/carteraproductos/pages/default.aspx>



Figure 12. General view of a dewatering centrifuge.



Figure 13. General view of a centrifuge for dewatering.



Figure 14. General view of three band filters



Figure 15. Sludge over filtering cloth on a band filter prior to entering compression stage.



Figure 16. General view of the feeding área of a band filter.



Figure 17. Band filter cloth washing by ejectors.



Figure 18. Band filter dewatered sludge outlet.



Figure 19. Lateral view of a band filter.



Figure 20. Band filter dewatered sludge outlet.



Figure 21. General view of a press filter.

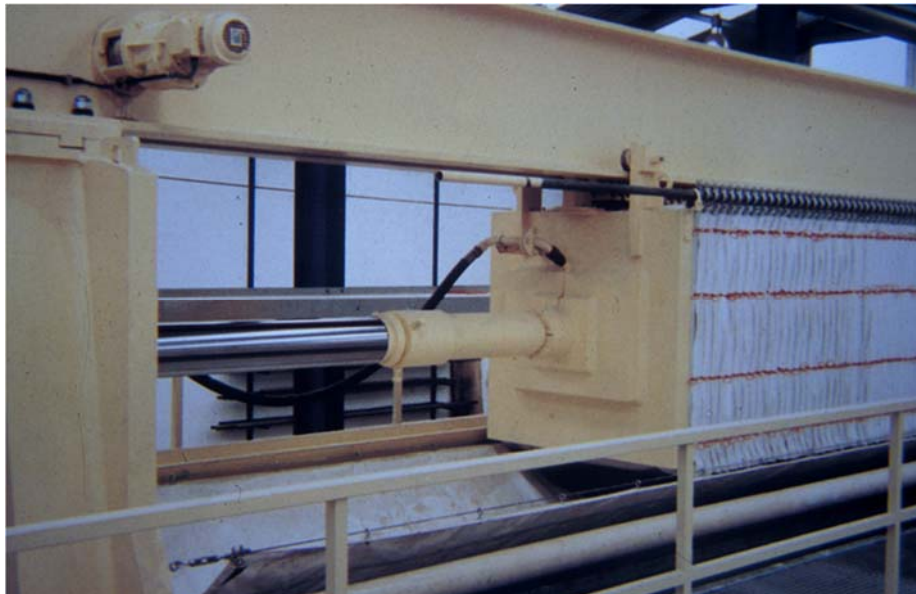


Figure 22. General view of a press filter. Detail of a filter plate.



Figure 23. General view of a press filter in operation (Santiago de Compostela).



Figure 24. Filtered water after each filter cell in a press filter.



Figure 25. Final appearance of dewatered sludge cake in a press filter.



Figure 26. Final appearance of dewatered sludge cake in a press filter.



Figure 27. Small press filter.