Sludge Dewatering Installations

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Abstract: *In this article, we aimed to present the theoretical concepts, from the specialized literature, related to the dewatering of sludge resulting from the wastewater treatment process, focusing on the dewatering facilities used in our country and around the world. Emphasis is placed on mechanical dewatering, but also on other sludge dewatering procedures.*

Keywords: *Wastewater sludge, dewatering, dewatering facilities*

1. Introduction

At the basis of all sludge treatment processes are two distinct technological processes, namely sludge stabilization through fermentation and sludge dewatering. Between these two main processes, various variants or combinations of procedures can occur, whose application is differentiated depending on local conditions, the amount and quality of sludge, the existence of lands for installing drying and storage facilities, or the intended use of the sludge, etc. Normally, at present, fresh sludge from urban wastewater treatment plants is preprocessed through anaerobic fermentation (to obtain biogas), followed by natural or artificial dewatering processes and finally its utilization in agriculture as fertilizer, but only if it complies bacteriologically. Dewatering is a physical (natural or mechanical) operation used to reduce the moisture content and volume of sludge. Its main objectives are [1]:

- Increase the dry substance content of the sludge by 3-40%;
- Reduce transportation costs due to volume reduction;
- Improve handling and transportation of sludge;
- Avoid odors;
- Increase calorific power by reducing humidity.

The main way to reduce the amount of sludge after treatment is to reduce the amount of water present in the sludge through thickening and dewatering. There is a limit to the amount of water that can be removed from the sludge by mechanical means and most dewatered sludge (for example, using belt press, filter press, centrifuge, etc.) have a dry substance content ranging from 15% to 40%. Any of the waste management alternatives also requires thermal drying of the waste [2,3].

2. Natural Dewatering

Drying beds for sludge ensure the dehydration of the sludge, allowing the liquid to drain both through gravity through a permeable medium on which the sludge is located and to evaporate in ambient conditions. Drying beds are uncomplicated in design and operation, as they simply involve spreading the sludge as a thin layer (up to 300 mm) on a porous bed of sand and gravel. The water is then allowed to drain through the bed and into a network of incorporated drainage pipes to allow for its collection (fig. 1). Further removal of water is ensured through evaporation from the surface of the sludge [2,3,4].

While most drying beds are uncovered, and therefore their performance is subject to local weather conditions, water evaporation rates can be increased by sheltering the layers in a glass structure (a greenhouse).

This modification is usually referred to as a solar drying bed and is used in warmer climates.

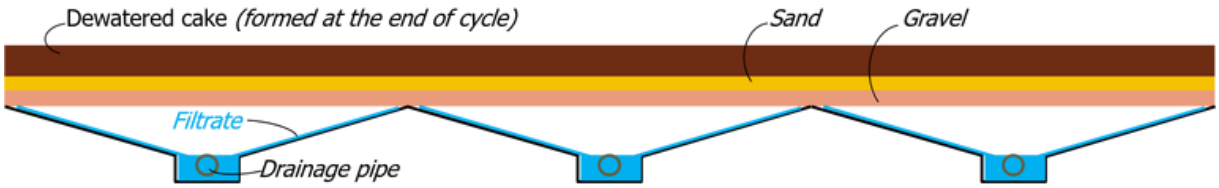

Fig. 1. Drying bed for sludge [4]

Sludge ponds, also known as lagoons, are located in natural depressions where the depth is greater than 2 meters, creating as much space for sludge as possible. Sludge is introduced into these ponds for fermentation, drying, or long-term storage. A lagoon contains a shallow, tight-bottomed reservoir to prevent the infiltration of sludge water into groundwater or other water bodies in the environment. The lagoon is filled with sludge and the solids are allowed to settle. During the drying/dehydration operational cycle, which is approximately a few months, water is lost through evaporation while the solids form a thick layer at the bottom of the lagoon, stabilized by anaerobic biological processes.

3. Mechanical Dehydration

According to the dehydration principle, there are three methods to do that [5]:

- Dehydration through vacuum filtering
- Dehydration through pressure filtering
- Dehydration through spinning

Artificial dehydration of sludge is performed through static procedures (vacuum filters, pressure filters) or dynamic procedures (centrifugation).

- The main advantages of artificial dehydration processes are [6, 7]:
- Short process duration
- Small area required for equipment

Lack of influence of inhibitors on dehydration processes.
The disadvantages include [6, 7]:

- Preconditioning of sludge
- No influence on pathogenic potential
- Limitation of incineration application due to increased mineral content of sludge, in case of conditioning with mineral salts
- Low fertilizing value of dehydrated sludge.

3.1. Press Filter

The press filter is a piece of equipment used for dewatering sludge from various wastewater treatment processes (e.g. industrial wastewater treatment plants, household wastewater treatment plants, etc.). Using this equipment, we can obtain a cake-like, highly-dried sludge with a high solid content.

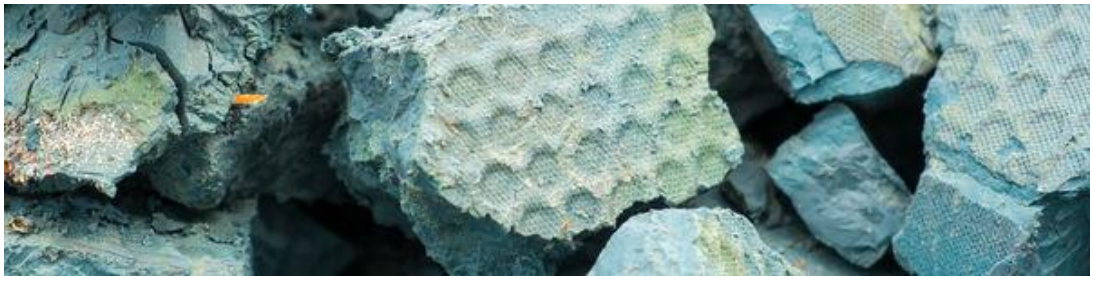

Fig. 2. The cake produced by the press filter, which has chunks of dehydrated sludge solids with an imprint of the filter cell membrane [8]

The pressure filter is the most efficient solid/liquid separation system and the most widely used filtering system in various industrial applications [8, 9]. According to [9], the pressure filter operates

by slowly filling the spaces between the plates with sludge before applying 7-20 bar pressures for 1-2 hours. Water is forced out of the sludge under the applied pressure, and the filtrate is returned to the influent of the treatment plant. Air is then washed through the system for 5-15 minutes to remove most of the residual water from the cake formed in the depressions. The filter cake can also be washed at this point to remove contaminants. The plates are then separated and the solid filter cake, 25-40 mm thick, is allowed to fall. The complete operating cycle of filling, filtering, emptying, and washing the press can take up to five hours.
Advantages [9]:

- High productivity: due to fine filtration under high pressure,
- High capacity: are designed to ensure maximum capacity for utilisers,
- Safe functioning: press filters are designed variable alternatives for user's safety,

3.2. Belt press filter

A belt filter press (BFP) ensures sludge dewatering by pressing the sludge to force water to pass through a permeable medium. The process produces a cake (the dehydrated product) with a dry solid (DS) content of 30% or more in the case of primary sludge. Modern belt presses are based on a combination of chemical conditioning, gravity drainage and mechanical pressure in a continuous feeding system for sludge dewatering. The sludge is squeezed between tensioned spiral belts and a series of decreasing diameter rolls (to increase pressure) to remove moisture and create a dehydrated sludge cake. A BFP combines sequential drainage and mechanical pressure to remove water. The equipment normally includes 2-3 recirculation belts (figure 3), with two belts combining at one point to compress the sludge and squeeze out the water. Conditioned sludge is first transported along a gravity drainage section of one of the porous belts, as in the case of a gravity belt thickener. It then undergoes pressure as it is passed between two recirculation belts, forming a deposition area at the entrance, which moves over a roll. This squeezing action of the two belts in this pressure area releases more water. Many belt filter press technologies contain a second pressure area that comprises a series of rolls through which the two belts with solid sludges are retained between them. The rolls in this high-pressure area apply the stretching of the belts, exerting both shearing and compressive forces on the sludge, which releases even more water.

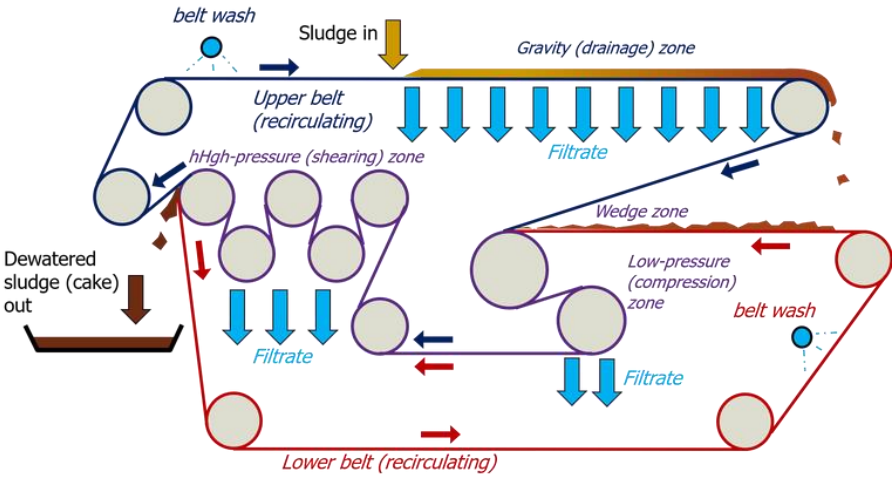

Fig. 3. Example of arranging the belts and rolls for a belt filter press, double belt system [3]

Advantages [10]:

- The personnel requirements are low, especially if the equipment is large enough to process solids in a single shift;
- Maintenance is relatively simple and is usually provided by the sewage treatment plant maintenance team;
- Belt replacement is the main reason for increasing maintenance costs;

- Belt presses can be started and stopped quickly compared to centrifuges, which require up to an hour to increase speed;
- The noise produced is lower compared to centrifuges.

Disadvantages [10]:

- Odors can be a problem, but can be controlled with good ventilation systems and chemicals such as potassium permanganate;
- Belt presses require more operator attention if the feed solids vary in concentration or organic matter;
- Waste water solids must be screened to minimize the risk of belt damage;
- Washing the belt at the end of each shift or more frequently can consume a lot of time and require large amounts of water.

3.3. Press filter with screw

A screw press (SP) (Figure 4) provides sludge dewatering by transporting it along the interior of a permeable cylinder. It relies on a slow-rotating Archimedes screw (~5 RPM) in a cylindrical screen (also referred to as a drum or basket). It is typically inclined by ~20° from horizontal to assist in draining the water into the basin. The screen typically has a nominal opening value under 0.5 mm and is based on mesh wire or occasionally perforated metal. Screens are less susceptible to clogging than the filtering media used for other thickening and dewatering processes. As a result, spray cleaning is applied only intermittently for approximately 2-4% of the operating time. As with all thickening and dewatering processes, the solids (or cake) content of the product depends on the quality of the feed sludge. The solids, cake content has been shown to be inversely proportional to the volatile solids (VS) in the feed sludge [1, 2, 11].

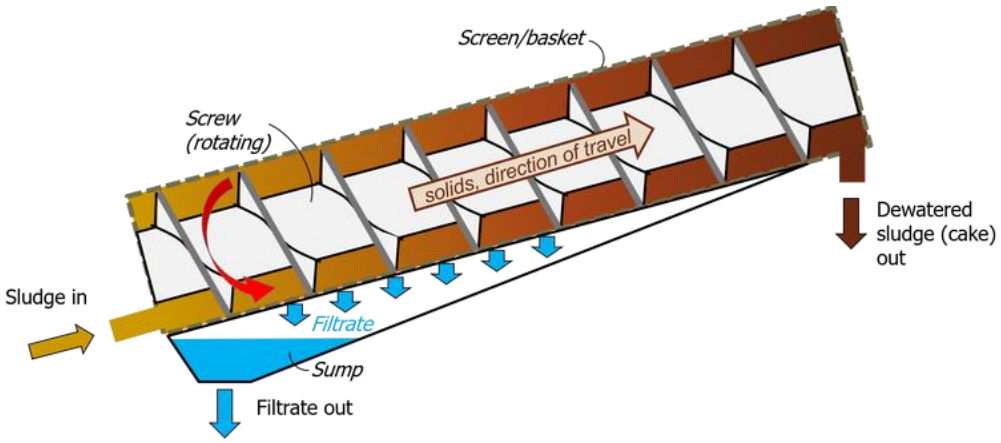

Fig. 4. Press with screw [11]

3.4. Rotary Press

A rotary press (RP) is a dewatering technology that removes water by passing sludge through a narrow, rotating, parallel-flow channel with porous walls. The rotary press provides dewatering using a cylindrical vessel that houses two circular screens that rotate slowly (< 2 rpm) and are positioned together. The sludge enters the channel formed between the two screens and follows a circular path around the channel at a low applied pressure (0.1-0.5 bar) (figure 5). The combination of the applied pressure, generated by creating a restriction at the outlet, and shear forces generated by the rotational action and moving solids encourage filtrate to pass through the two screens as the sludge moves around the channel [2,3,11].

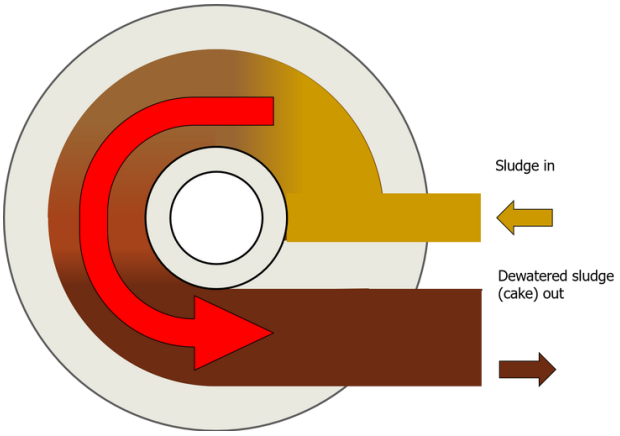

Fig. 5. Sludge flow through the rotary press [11]

3.5. Solid Bowl Centrifuge

According to [12], centrifugation is a phase separation process of particles with different specific weight (solid-liquid). Under the centrifugal force, the solid, heavy phase deposits on the interior walls of the rotating drum, where it is constantly scraped by the conical screw inside, which also directs the scraped material towards the conical end at the discharge opening. The liquid phase, separated by gravitational flow, is sent to the liquid discharge opening located opposite the solid material discharge opening. According to [2,3], compact concentrates with a higher solid material content: 22-25% DS are obtained through centrifugation. If the sludge has a high content of inorganic solid matter, the DS concentration can reach 33-35%. These types of equipment can be grouped into three categories, with specific application domains [2,3,11]:

- conical rotor centrifuges, which produce good dewatering and clear centrate, but are not suitable for fine solids;
- cylindrical rotor centrifuges, which generally produce clear centrate;
- cylindro-conical rotor centrifuges, which produce well-dewatered cakes and clear centrate.

The solid bowl centrifuge, according to [11], can be used to produce a relatively dry cake from separated solids and is flexible enough to handle a wide fluctuation in feed material and still achieve excellent clarification and dewatering performance. The centrifuge (figure 6) consists of a solid bowl, which rotates and contains the process. A screw conveyor, contained in the bowl, rotates at a slightly different speed from that of the bowl.

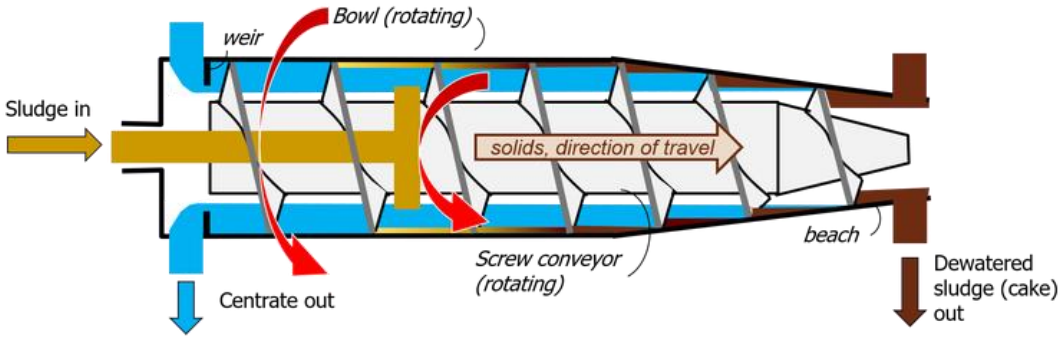

Fig. 6. Dehydration centrifuge with a strong bowl, countercurrent operation [11]

In practice, flocculated sludge is introduced into the centrifuge drum through an injection pipe. The drum has a high rotation speed (3500 rpm), the particles move towards its sides, in the clarification area. The particles are then pushed through an Archimedes screw towards the conical end of the drum, in the drying area, by the rotation of the sludge. The clarified liquid, called 'centrate', is discharged at the other end of the drum through an overflow. The decanter centrifuge will often produce better results than other dewatering equipment when secondary or biological sludge are present in the material to be processed. The main reason for this is that decanter centrifuges do

not use filtering media for separation and dewatering, which can often become blocked by biological sludge.
Advantages [13,14]:

- Centrifuges can provide lower overall operating and maintenance costs than conventional belt press filters;
- Centrifuges require a small operating space;
- Centrifuges are continuous operation equipment that can be incorporated into any technological process;
- Operators have low exposure to pathogens, aerosols, hydrogen sulfide, or other odors;
- Centrifuges are easy to clean;
- They increase the quality of the technology in the system they are incorporated into;
- Major maintenance components can be easily removed and replaced. Repairs are usually carried out by the manufacturer.

Disadvantages [13,14]:

- Centrifuges have high energy consumption and are quite noisy;
- Experience in using the equipment is necessary for optimizing performance;
- Special structural considerations must be taken into account;
- Replacement parts are expensive internal parts and are subject to abrasive wear;
- Start-up and shut-down can take an hour. The centrifuge is gradually brought up to maximum speed and slowed down for cleaning before shutdown.

3.6. Mechanical dehydration on vacuum filters

This is the most widely used process currently for artificial water drainage. The construction form of vacuum filters can be different (disc, hopper or drum), drum vacuum filters (figure 7) being the most commonly used for dewatering sludge from wastewater treatment.

Fig. 7. Vacuum – rotary drum filter [6]

According to [6], dehydrating sludge on vacuum filters has the advantages of continuous operation (unlike press filters) and high filtration capacity. There is also a flexible construction configuration (available discharge options, drum cells, construction materials, design - open or closed filter, airtight), which provides the possibility of adapting to process needs. Among the disadvantages, relatively rapid degradation of filter cloths, relatively high cake moisture (70-80%) and higher energy consumption than press filters can be mentioned.

4. Other Sludge Dewatering Processes

4.1. Electro-Dewatering

The Electro-Dewatering (EDW) technology removes water from sludge based on the principle of electro-osmosis.
According to source [15], electro-osmotic dewatering (EOD) is a technique that removes water by placing a colloidal material between two electrodes. This is based on the electrostatic effects of the double electric layer that forms at the water particle interface of the colloidal material. An EDW

device consists of a narrow horizontal channel through which the sludge is fed. A direct electric field is placed over the channel, with the anode at the top and the cathode and a filter cloth at the base. The cathode on which the filter cloth is placed is porous to allow water to pass through it [3,16]. The application of an electric field causes the water to be extracted from the sludge under the influence of the electro-osmotic force. No additional mechanical force is required: the water removal rate depends on the charge on the particle surface and the applied voltage. Through this method, a cake of up to 50% dry solids (DS) has been obtained, with a reduction in sludge volume of up to 75% at sludge loading rates of 75-150 kg DS/(m2.h) per m2 dewatering surface.

4.2. Liquid Sludge Treatment through Dewatering Technology

The dewatering technology mainly consists of a sludge treatment technique that, through progressive water removal, allows for their drying and therefore water removal. The process is carried out with "GTX Tube" structures made of composite materials: geogrids and geotextile-consolidated membranes, such as the filter system. The designed system minimizes the possibility of particles transported in the drainage water to leak out. The "GTX Tube" performs a simple and efficient technological dehydration, meaning that, being gradually filled with the treated sludge, an activity that takes place continuously through the pumping station to compensate for the loss of water that is removed, it gives at the end of the process a solid used as a dry material [17]. Therefore, it can be easily removed, disposed of or alternatively reused, for example to shape slopes, etc.

Fig. 8. GTX Tube System [17]

5. Conclusions

Comparing data obtained from mechanically dewatering sludge on the four types of equipment, the following conclusions can be drawn:

- Centrifuge or vacuum-filter dewatering produces sludge cakes with comparable moisture content;
- Belt filter press dewatering produces sludge cakes with lower moisture content;
- Dewatering of primary fermented sludge is more efficient than dewatering the fermented sludge resulting from the mixture of primary sludge and excess.

It is very important to treat the sludge resulting from wastewater treatment, but it is even more important to find the most efficient method both from an environmental and economic point of view.

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