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Dewatering of the chemical sludge through drying bed modified by draining blocks

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Abstract: This article aims to study the sludge dewatering of sludge Water Treatment Plant (WTP) through drying bed modified by draining blocks using the polymer FO 4290 SH. It was carried out the design of the drying bed, statistical analysis and analysis of economic viability. The tests showed efficiencies of 93% in the amount of dry solids with 30 days of drying. The area of the drying bed was 968 m^2. Statistical analysis showed that the experiment is replicable in the 5% significance and viability analysis showed investment of US$ 225,330.32.

Keywords: Drainage blocks; dewatering; Polymers.

Introduction

Water treatment processes produce sludge that contains more than 95% of water present in its structure. According to Zhen et al. (2012), the sludge is composed of the combination of a liquid phase and a solid phase being necessary the knowledge of both phases for suitable disposal. The connection of the water to the solids is due to intermolecular forces of different types, classified in four categories: free water, interstitial water, vicinal water and hydration water, Sanin et al. (2011) representing 75%, 20%, 2% and 3% of the total sludge volume, respectively.

In the development of WTS (Water Treatment Station) dewatering technologies, most efforts have focused on the creation and improvement of solid-liquid separation processes (Oliveira and Rubio, 2012). To perform the dewatering of the sludge, chemical conditioning has become a prerequisite for the treatment of WTS sludge. The use of polymers to perform the sludge conditioning is an option to obtain better results in the solids content, with polyacrylamide polymers commonly used (Al-Hashmi et al., 2014).

The dewatering of the sludge can be by use of natural or mechanized systems for the removal of water. The mechanical dewatering can be through the use of centrifugation techniques, vacuum filtration and pressure filtration, since the natural dewatering systems can be through sludge ponds, sand drying beds or drainage blocks (Qi et al. .

Mechanical dewatering is a crucial step for the reduction of sludge volume; however, its operation is quite expensive (Bertanza et al., 2014). On the other hand, natural dewatering systems are less complex, easier to operate and do not require energy demand as mechanical dewatering systems require. The objective of this work is to study the quality of the process of natural dewatering of sludge in drying bed by draining blocks under pre-defined conditions.

Material and Methods

The study was carried out with WTS chemical sludge, located in Coqueiral, Aracruz, Espírito Santo, Brazil. The sludge was collected in the WTS float, being determined the total solids content, in (mg / L). With equations 01 and 02 it was possible to determine the mass of solids per test and the rate of application.

$$\text{Solid dry (kg)} = \frac{\text{Volume } (m^3) \times \text{Concentration } (g/m^3)}{1000 \ (g/Kg)} \qquad \text{Equation 01}$$

$$\text{Application Rate } (kgST/m^2) = \frac{\text{Solid dry (kg)}}{\text{Area } (m^2)} \qquad \text{Equation 02}$$

For the performance of each dewatering test, solution of 0.2% SH 4242 SH cation polymer was prepared and the dosage defined at 1.94 mg in./g.ST. The sludge conditioning followed the configuration shown in Figure 1.1. Using two buckets of 20 liters each, the polymer being added to the slurry and 03 inversions were performed.

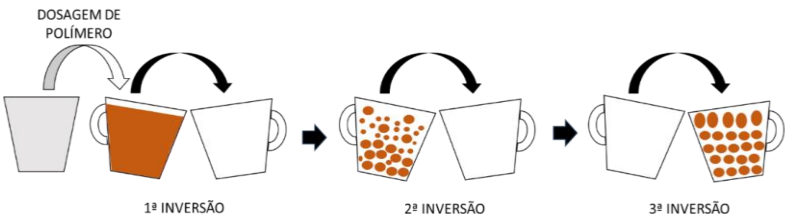

Figure 1.1 Experimental configuration

The method used for dewatering was the same as that used by Silva and Pohlmann (2014) adapted. The experimental apparatus consists of three fiber boxes, with dimensions of 30 x 61 x 45 cm with a capacity of 74.42 liters. At the bottom of each box, two interconnected panels (draining blocks) with the dimensions 30 x 30.5 x 5 were arranged forming a bed. For the accumulation of drainage water, three 50-liter reservoirs were used. In rainy seasons the prototype was covered with transparent acrylic tile at a height of 30 cm from the edge of the fiber box. The prototype of the dewatering system is shown in Figure 1.2.

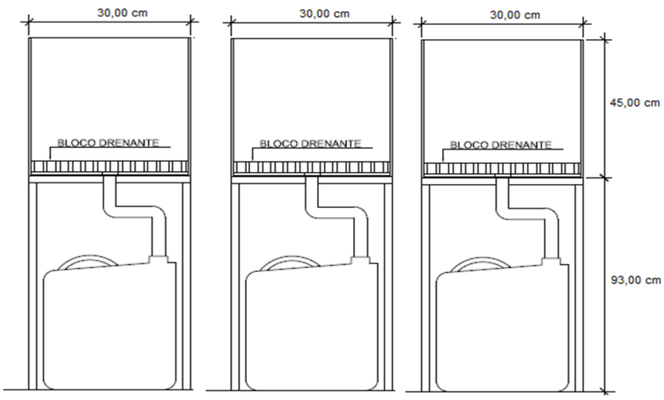

Figura 1.2 Experimental Apparatus

The tests were carried out in triplicate and analysed: total solids, drained volume, ambient temperature, relative humidity, drying time, parameters for drained water and dry sludge characterization according to ABNT NBR 10.004. The percentage of total solids was statistically treated using PAST software version 2.17c. For cost analysis, the experimental data from the tests were used. Regarding precipitation data measurements, these were carried out through the monitoring carried out by the Capixaba Research Institute for Technical

Assistance and Rural Extension (INCAPER) referring to the agro meteorological database of a station located at Aracruz's headquarters at the coordinates Longitude: -40.276 and Latitude : -19.82.

Results and Discussion

The quantification of total solids was adopted, since the measurement of total suspended solids did not present significant difference at the 5% level of significance. Table 1.1 shows the conditions used in the tests and in Figure 1.3 the behavior of free water drainage and height variation in the 1st, 2nd and 3rd tests.

Table 1.1 Conditions for Dewatering Sludge

Test	Period	Application Rate ($KgST/m^2$)	Sludge Height (cm)	ST (mg/L)	Precipitation (mm)	TAT	HAT
1º	15/03/17 – 14/04/17	4,30	15	$2,87.10^4$	48,07	29,05	67,65
2º	16/04/17 – 25/05/17	7,68	25	$3,07.10^4$	29,77	23,41	72,29
3º	26/05/17 – 25/06/17	3,50	10	$3,50.10^4$	10,26	25,22	72,12

TAT: Average Temperature Test (ºC), HAT: Average Humidity Test (%)

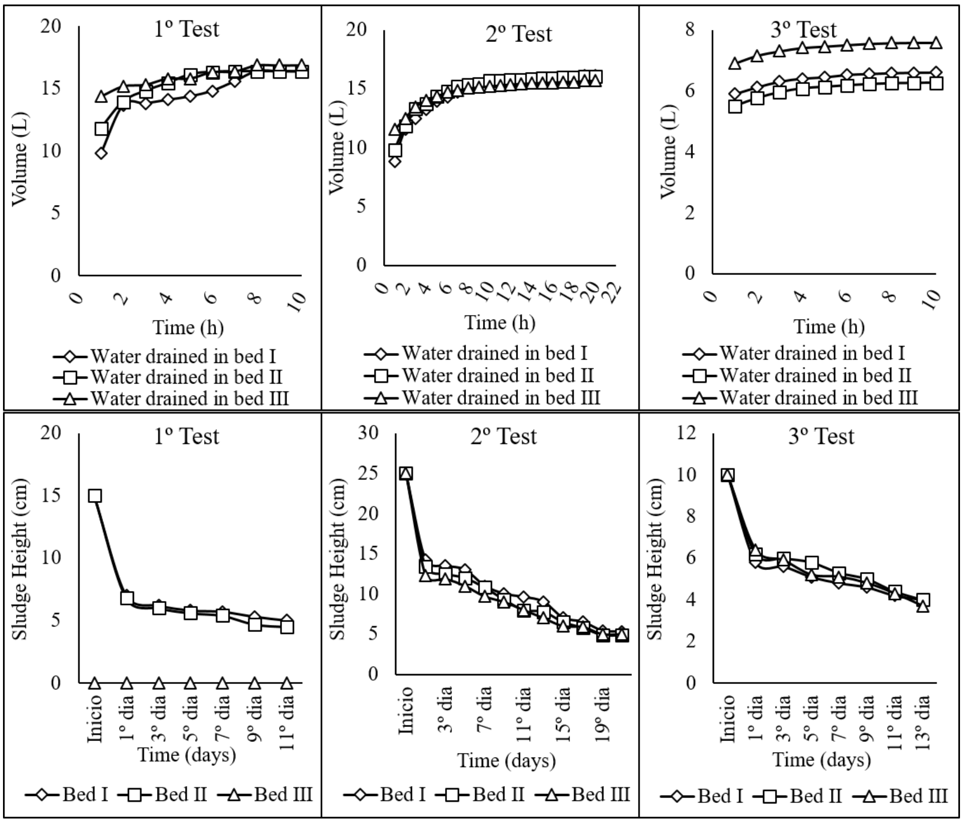

Figura 1.3 – Free water drainage and sludge height variation in dewatering

As indicated, the three beds drained practically the same volume of water in each test, lasting 10 hours for the 1st and 3rd tests and 20 hours for the 2nd test. From this period it was verified that the beds did not drain free water, beginning to dry, that is to say when drainage stops influencing and evaporation becomes the dominant phenomenon. As indicated, the three beds drained practically the same volume of water in each test, lasting 10 hours for the 1st and 3rd tests and 20 hours for the 2nd test. From this period it was verified that the beds did not drain free water, beginning to dry, that is to say when drainage stops to influence and evaporation becomes the dominant phenomenon. According to van Haandel and Marais (1999) the free water present in the sludge makes up about 70% and can be separated from the solids only by gravitational force. In relation to the first test, beds I, II and III drained at the end of 10 hours, 58% for beds I and II and 60% for bed III, which represents a reduction in volume of water drained by the volume of (28 liters) the concentration of 2.87% of total solids.

In the second test, a 20-hour period was observed for all free water to be drained, with 35% for beds I and II and 34% for bed III, which represents a reduction in volume of water drained by volume of water. (47 liters) the concentration of 3.08% of total solids. Finally, in the third test, it was verified that the beds I, II and III drained at the end of the 10 hours, 36%, 35% and 42% respectively, representing a reduction in volume of water drained by the initial mud volume (19 Liters) the concentration of 3.50% of total solids.

Grover (1979) points out that the normal water withdrawal cycle for the natural drainage system varies from 24 to 72 hours, depending on the type of sludge, plant conditions and the desired concentration of total solids. After this drainage period, additional dewatering may occur due to evaporation, however, the rate of evaporation may vary depending on the weather conditions and whether the drying units are outdoors or covered. In conventional drying beds, not only evaporation must occur from the water attached to the sludge, but the phenomena of capillary action of the sand with the water thus increasing the drying time. In the case of drying beds modified by drainage blocks, as there is the presence of a false floor, this phenomenon is not found and the water evaporates only from the sludge.

As for the reduction of sludge height, in the 1st test, after the 10th day of drying, the height of the sludge was reduced by 66%, 67% and 70% for beds I, II and III, respectively. In the 2nd test the drying process occurred more slowly, but the reduction of the sludge height was expressive, after the 20th day of drying the height was reduced by 78% for bed I and 80% for bed II and III. It was observed in specific in the second test, the appearance of two different layers in the drying bed, a lower wet layer (with almost constant humidity and close to 85%) and a dry top layer exposed to the direct influence of solar radiation, presented Total solids content higher than the lower layers. In this way, the layer of sludge in direct contact with the atmosphere tends to act as a barrier that prevents the penetration of the solar radiation and consequently the reduction of evaporation rates in the layer of the inferior sludge. As for the dewatering of the 3rd test was observed after the 13th day of drying the height of the sludge was reduced by 60% for beds I and II and 63% for bed III. The average behavior of the solids content is shown in Figure 1.4.

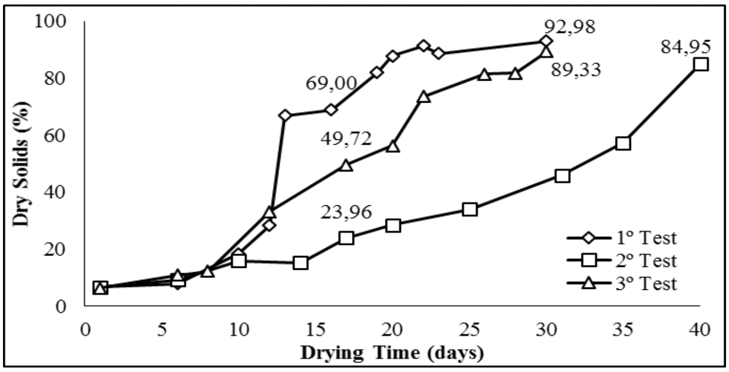

Figure 1.4 Average solids content of sludge

The analysis of the 1st test shows that with 16 days of drying, the sludge presented total solids content close to 70% and in 30 days approximately 93%. Drying of the 2nd test did not show similar behavior to the 1st test. With 17 days of drying the total solids content reached approximately 24% and at 40 days it reached 85%, lower than the efficiencies obtained in the 1st test. The 3rd test presented with 17 days of drying 49% total solids content and with 30 days 89%. The main reasons for the slight difference of the 1st and 3rd tests are related to the average temperatures and relative humidity of the air have provided better conditions for the 1st test, besides the application rate to be differentiated.

Oerke and Fabisiak (2001) in a study carried out at the Williams Reuse Water Treatment Station in Monaco identified that with the use of modified drainage block drying beds the load capacity increased three to four times compared to beds And that after the sludge dewatering, total solids concentrations on the order of 45% were obtained over a period of 5 to 10 days of drying.

The reason for the efficiency of the 2nd test was lower and the drying time higher, can be attributed to the average temperature during the test was smaller, the average relative humidity was higher among the tests performed. Although the precipitation rate was lower than the 1st test, the precipitations during the 2nd test were more distributed.

According to Bennamoun (2012), in general, the increase in temperature and low precipitation rates may lead to an increase in the drying rate. The drying operation depends on the climatic conditions and when the sludge heights are high the drying time can be relatively long making the number of applications in the drying bed difficult. Van Haandel and Lettinga (1994) point out that, in general, the appearance of cracks during sludge drying promotes an increase in the evaporation, which are possibly responsible for the rapidity and complete development of the drying process, being more evident in the 1st And 3rd trials. Moisture and mechanical properties have a relationship that leads to the following concept: as the percentage of water decreases, the sludge becomes pastier and below a 75% percentage loses the characteristics of a fluid and becomes a semi Solid Below 65% the sludge becomes a hard solid and below 40% this solid breaks into granules. When the water percentage becomes even lower around 15%, the solid tends to disintegrate into a fine powder. In Figure 1.5 the appearance of the sludge is presented at the end of each test performed.

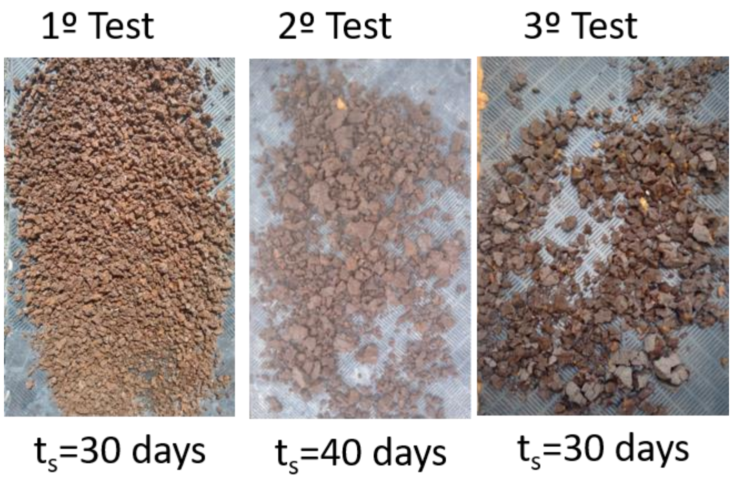

Figure 1.5 Appearance of the sludge at the end of each test

The characterization of the sample of drained water was performed, being that the values of Escherichia Coli, Total Coliforms and aluminum were above the legal limits in the drained volume. Uggetti et al. (2009) points out the recirculation of the volume drained to WTS as a solution. Regarding the characterization of dry sludge, this was classified as Non-Hazardous - Non-Inert Class IIA (Abnt, 2004). With the classification obtained from the sludge, it can be inferred that the chemical sludge drained through the use of draining blocks presents potential to be used in agriculture as an input. However, studies should be carried out to identify the fractions to be used, the form of application and whether there is a need to perform some type of treatment before its use. Sludge drying data in terms of total solids were treated statistically and homogeneity of the variance was determined in 0.9999 for the 1st test, 0.9853 for the 2nd test and 0.9999 for the 3rd test, demonstrating that each treatment contributed in equal form for the sum of the squares. From the analysis of significance, it was verified that there is no significant difference in the drying of beds I, II and III in each test, and it can be admitted that the treatments have the same effect at the level of significance of 5% for the parameter total solids content. The estimated area of the drying bed was 968 m^2, consisting of two rows of 8 beds in parallel, with reference to sludge application up to 15 cm in height, volume of treated water of 807.321,60 m^3/year, average ST 0,0314 kg/m^3; WTS flow 32 l/s; Discharge of the float every 5 days for 15 minutes, sludge density 982 kg/m^3. The cost analysis considered US $ 4.87 per kg of FO 4290 SH polymer, US$ 50.00 for the allocation of 1 ton of sludge and US$ 229.00 for the construction of 1 m^2 of drainage block drying bed with cover In polypropylene, obtaining investment in the order of US $ 221,672.00 for construction of the drying bed and annual operating cost of the system in the amount of US $ 12,438.28.

Conclusion

In the case of WTS sludge dewatering performance, through the use of drying beds modified by draining blocks, the results indicated that the dewatering was very efficient reaching total solids contents in the order of 93%. Comparing the results of drainage blocks with theoretical drying results in sand beds, it is possible to indicate that in drainage block beds drying is faster, which favors shorter dewatering and drying cycles, increasing the Bed, thus guaranteeing a greater number of applications per year.

It is concluded that the drainage block modified drying bed is efficient for the dewatering and drying of sludge, being a solution for the waste management systems of WTS.

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