Laboratory studies on geotextiles tube dewatering by pressure filtration test in reduced model

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ABSTRACT: Geotextiles have been successfully used in porous media filtration and to retain in-suspension particles. Based on the efficiency of these materials, ease of construction, low cost and lower environmental impact, a dewatering technique using geotextile tubes and bags has been developed, with great merit when compared to the conventional techniques of residues dewatering and disposal. This paper presents an analysis of this technique when applied to sludge dewatering, through the employment of pressure filtration test. Tests with a sludge generated in Guanhães Water Treatment Plant Station were conducted during a research program concerning the dewatering behavior of sludge, focusing on the parameters of the geotextiles employed, the quality of the percolate obtained during the dewatering, the filtration, infiltration and dewatering efficiencies, as well as the characterization of the filter cake. The observed behaviour shows promising results for the dewatering of conditioning finer sediments with organics components.

1 INTRODUCTION

In Water Treatment Plants (WTP) untreated water becomes drinking water by processes that generate fine and cohesive residues (sludge). Great environmental impact could be associated to the release of these residues without previous treatment (Cordeiro & Campos 1999; Andreoli 2001).

Internationally, the dewatering technique using geotextile tubes are finding increasing acceptance with great merit when compared to the conventional disposal techniques for high water content materials (Fowler *et al* 2002; Moo-Young *et al* 2002a; Koerner & Koerner 2006). This technique allows strong reduction in the environmental impacts caused by the inadequate disposal of the sludge generated during the water treatment process.

Geotextile dewatering is the technique of solids retention using geotextiles as the filter medium. The efficiency of the system depends on the balance among the retention of solids and the maximum expulsion of liquid. It is important to note that the system hydraulic conductivity decreases during the dewatering process due to the filter cake formed by the retained particles, in a clogging phenomenon inherent to the in-suspension filtering. Cantré (2006) discusses the main parameters that influence the dewatering process as the sludge properties, the filling up pressure and the geotextile structure and properties.

There is some earlier research that estimated the geotextile dewatering system efficiency in terms of the pore characteristics filtration opening, water content and particle size distribution (Liao & Bhatia 2008, Muthukumaran & Ilamparuthi 2006). However, work to evaluate the behaviour of this dewatering process when applied to fine grained, highly compressible sludge, with great filtering resistance are still necessary (Cantrè 2006, Liao & Bhatia 2008).

Material generated in WTP has generally very small particles, resisting filtration and needing chemical conditioning (flocculation). This paper presents an analysis of the geotextile tubes and bags dewatering technique applied to WTP sludge, through the employment of pressure filtration tests conducted during a research program.

2 MATERIALS

2.1 *Sediments (sludge)*

The WTP sludge is characterized as a non-newtonian fluid with tixotropic behavior – it is a gel at rest and becomes a fluid under agitation, being difficult to sediment or float. (Silva & Isaac 2002). It is generally composed of organic and inorganic solid residues derived from untreated water, as alga, bacteria, virus, organic in-suspension particles, colloids, sand, clay and silt, with calcium, magnesium, iron, manganese and other chemical elements. Aluminum hydroxide and polymers are also frequently present due to the chemical products employed in the water treatment.

For the development of the research, samples of sludge were directly collected in the Water Treatment Plant of Guanhães (Minas Gerais - Brazil). Some parameters of the untreated sludge are presented in Table 1. Typical values of the Atterberg Limits for the conditioned sludge are LL of 397% and PL of 204%. The characteristic diameters are d_{50} of 0,001mm and d_{100} of 0,1 mm.

Table 1 – Parameters of the sludge

Parameters	Value	Parameters	Value
pH	7,28	Al (%)	0,18
DBO (mg/L)	132,33	Fe (%)	0,30
DQO (mg/L)	225,00	Mn (%)	0,02
Ni (%)	0,000038	Ca (%)	0,002
Zn (%)	0,000134	Al_2O_3 (%)	0,33
Pb (%)	0,000065	Fe_2O_3 (%)	0,43
Cd (%)	0,000007	Density (g/cm^3)	1,01

2.2 *Geotextiles*

Three woven geotextiles (GT1, GT2 and GT3) were used in this study. All the woven geotextiles are composed of polypropylene monofilaments. Some properties of these geotextiles are provided in Table 2.

Table 2 – Properties of geotextiles employed in this study.

Properties	GT1	GT2	GT3
Polymer type	Polypropylene	Polypropylene	Polypropylene
Mass per unit area (NBR 12568)	280 g/m²	358 g/m²	363g/m²
Grab tensile strength (NBR 12624)*	>= 55 kN/m	>= 70 kN/m	>= 80 kN/m
Characteristic permeability normal to the plane 0,05 mca (ENISO11058)*	10 x 10 $^{-3}$ m/s	10 x 10 $^{-3}$ m/s	10 x 10 $^{-3}$ m/s
Thickness (NBR 12569)	0,9mm	1,2mm	1,1mm

Note: *Values indicated by the manufacturer

3 APPARATUS

The developed equipment has as objective the simulation of field conditions of dewatering by geotextile tubes or bags in a WTP, to dewater the sludge produced in units of decantation and, in that way, to reduce its volume, allowing an appropriate disposal or subsequent use.

Figure 1 presents a view of the equipment employed in this research, which allows the bag to be filled up under an established pressure.

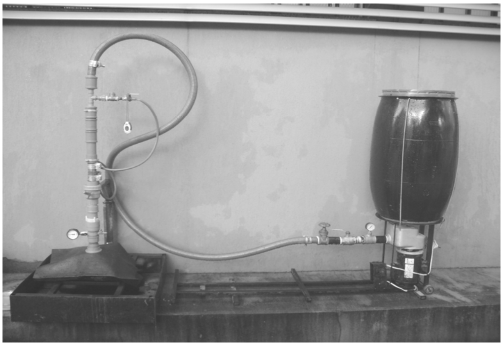

Figure 1 – Equipment for pressurized filling and dewatering.

4 TEST METHOD AND ANALYSES

To choose the polymer (type and quantity) to be added to the sludge, cone tests (Lawson 2006) were done considering the tested geotextiles.

Considering the ideal chemical conditioning defined by the cone tests, dewatering tests were conducted to evaluate the filtration and dewatering efficiency. Filling pressures between 0.2 and 0.4 kg/cm^2 were adopted and the sludge water content and the percolate turbidity were measured to evaluate the system performance.

The Filtration Efficiency, FE, can be estimated by the Moo-Young & Tucker (2002) proposition:

$$FE = \frac{TS_{initial} - TS_{final}}{TS_{initial}} \cdot 100\% \qquad (1)$$

where $TS_{initial}$ is the initial total solids and TS_{final} the final total solids, in mg/L.

The Dewatering Efficiency, DE, was defined as (Moo-Young *et al* 2002):

$$DE = \frac{PS_{final} - PS_{initial}}{PS_{initisl}} .100\% \qquad (2)$$

where $PS_{initial}$ is the initial percent of solids and PS_{final} is the final average percent of solids.

The initial and final water content could be analyzed by the Muthukumaran & Ilamparuthi (2006) proposition, which defines the Infiltration Efficiency, IE, as:

$$IE = \frac{w_i - w_f}{w_f} \cdot 100\% \tag{3}$$

where w_i is the initial sludge water content and w_f is the final water content. The infiltration term is not the ideal for the dewatering process, but the concept could be more representative.

Table 3 presents some results of the pressured filtration tests. Three tests were conducted for each geotextile type. Figure 2 shows the variation with time of the effluent turbidity for each group of geotextiles. Figure 3 presents the observed flow rate in these tests.

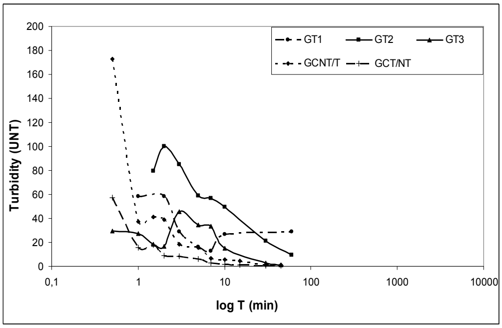

Figure 2 – Effluent turbidity during filtration.

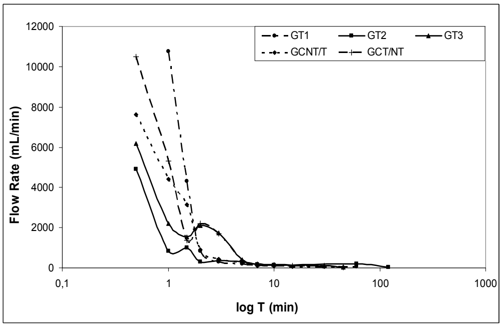

Figure 3 – Flow rate measured during filtration tests.

5 DISCUSSION AND CONCLUSION

To define the conditioning conditions, a careful polymer selection is very important to improve the flocculation and to get the best dewatering and water content reduction.

The initial water content of the sludge samples tested in the pressure filtration equipment was highly variable but the relative reduction between initial and final water content is in a narrow range of values as shown in Table 3. The high value of the Coefficient of Variation observed in DE analysis is due to the different initial conditions of the sludge samples.

The Filtration Efficiency remains between 95 and 99% in all the tests. As illustrated in Figure 2, after 10 minutes an important reduction of the total solids (in-suspension + dissolved solids) of the percolate could be observed. The filter cake formation responsible for particle retention implies a significant decrease of the flow rate, as shown in Figure 3.

The pH of the percolate in the test does not present a significant variation, remaining close to the natural sludge condition, which means it is possible to reinsert the percolate into the conventional treatment system. This insertion could be an interesting theme of future research.

The main difference between the geotextiles studied is the tensile strength. The structure of these products is almost the same and does not present significant differences in the filtering behavior for the tested sludge. Therefore, in this case, the tested products could be employed successfully to dewater the WTP conditioned sludge, the choice being due to the expected mechanical features (tube diameter, for instance).

One of the conclusions of this work is that the proposed dewatering technique can be a promising method to improve the environmental quality and destination of the water treatment residues. It is important to remember that the conditioning process could be destroyed under pressure and it is necessary to carry out the work under an acceptable range of pressures.

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Table 3 – Results of the pressured filtration tests.

Geotextiles		pH filtrate	Initial Water content (%)	Final Water content (%)	FE (%)	DE (%)	IE (%)
GT1	GT1_A	8.09	4799.78	898.12	-	390.91	81.28
	GT1_B	7.52	16495.80	1677.99	95.10	832.41	89.82
	GT1_C	7.80	2850.52	1317.20	99.30	108.26	52.79
	Sample mean				97.20	443.86	74.63
	Sample coefficient of variation (C.V.)				3.06	82.23	25.98
GT2	GT2_A	7.49	6224.93	1888.89	98.52	218.08	69.65
	GT2_B	7.61	5420.54	1563.50	97.74	231.91	71.15
	GT2_C	7.55	4499.64	1299.77	97.33	228.57	71.11
	Sample mean				97.86	226.19	70.63
	Sample coefficient of variation (C.V.)				0.62	3.19	1,20
GT3	GT3_A	7.22	11627.34	2069.39	-	440.74	82.20
	GT3_B	7.72	3531.23	1726.04	99.13	98.90	51.12
	GT3_C	7.33	4877.45	1822.36	99.16	158.69	62.63
	Sample mean				99.14	232.77	65.31
	Sample coefficient of variation (C.V.)				0.02	78.43	24,05