Practical Paper

Dewatering of septic tank sludge in alternative sludge drying bed

Denise Vazquez Manfio, Adriano Luiz Tonetti and David Matta

ABSTRACT

In dewatering of septic tank sludge, the sludge drying bed is one of the main techniques used, but it demands a great deal of area and time for the removal of sludge cake. Modification of this system using permeable pavements and polymer can minimize such problems, facilitating the management of sludge when decentralized sanitation is used. Therefore, the objective of this study was to compare the dewatering of septic tank sludge using conventional sludge drying bed (CSDB) and a sludge drying bed with permeable pavement (SDBPP). At the same time of dewatering, the volume drained by the SDBPP was 37.4 ± 4.6% higher than that obtained in the CSDB. Therefore, a lower drying bed could be used. It was found that the use of synthetic polymer allowed dewatering to occur in less time, but did not interfere in the solids content of the sludge cake. The reuse of the pavement was proven possible, but required large volumes of water and mechanical equipment.

Key words | conditioning, drying bed, permeable pavement, septic tank, sludge

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INTRODUCTION

In Brazil, 22% of homes have septic tanks (IBGE 2012). These represent the main alternative for the sewage treatment in homes that do not have access to a sewerage system.

Sludge produced in these septic tanks have different destinations. In cities, they are transported to sewage treatment plants. However, in rural areas they are usually inappropriately disposed, being released directly into the soil or water bodies. This practice is also common in other developing countries.

The proper disposal of sludge requires removal of humidity. This operation is essential for reducing the mass and volume of the sludge. Sludge dewatering has the main advantages of reducing the transport cost to the place of final disposal; improving the management conditions; reducing the cost for disposal in landfills; and possibility of use in agriculture (Paixão Filho *et al.* 2014; Gabrielli *et al.* 2015; Metcalf & Eddy 2016; Tonetti *et al.* 2018).

Dewatering can be performed through natural or mechanized processes. In natural processes, evaporation and percolation are used for removing water from the sludge. The dewatering of sludge by sludge drying beds has this characteristic and is indicated for small and mid-sized communities. This technique can be applied in stabilized sludge, as found in septic tanks.

According to Metcalf & Eddy (2016), sludge drying beds offer several advantages compared with mechanized processes: simple in installation and operation; low sensitivity to the sludge quality; no energy demand; low cost; and low consumption of polymers. In addition, prolonged exposure to the sun may promote the removal of pathogenic organisms.

A conventional sludge drying bed (CSDB) is characterized by a tank with walls and concrete base. The bed must consist of a layer of sand and three layers of gravel and bricks, in which most of the water departs from the sludge by drainage lines adequately supported and covered with coarse gravel (NBR 12209 1992). Despite its simplicity, it requires long exposure time and large areas. Therefore,

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there is a need to maximize the process to improve efficiency. In addition, systems with smaller areas would occupy less space in rural areas and require less manual labor for their management.

The use of pavements with the capacity for draining water can be an alternative for sludge drying beds.

Permeable paving is a method of paving vehicle and pedestrian pathways that allows infiltration of water. The permeable pavement (Figure 1) reduces surface runoff and can trap suspended solids, therefore filtering pollutants from storm water.

Thus, the objective of our study was to compare the dewatering of sludge using conventional sludge drying beds and sludge drying beds composed of permeable pavement, and to evaluate the use of a synthetic polymer in the process.

MATERIAL AND METHODS

The study was conducted at the School of Civil Engineering, Architecture and Urbanism of the University of Campinas. The permeable pavements used were 0.06 m tall and cut into 0.10 m diameter with 0.8 kg mass (Figure 2).

For installing the sludge drying bed to bench scale, tubes of 0.10 m in diameter were used and the permeable pavement was fixed at the bottom inside of these tubes (Figure 3). Three different sludge drying beds were tested:

1. Conventional sludge drying bed (CSDB).
2. Sludge drying bed with permeable pavement (SDBPP).
3. Sludge drying bed composed of permeable pavement plus a layer of sand (SDBS).

The whole system was covered, protected from the sun and rain, and each was studied in quintuplicate.

The CSDB was built based on the Brazilian Guidelines (NBR 12209 1992). To the permeable pavement were added layers of 0.20 m of gravel and 0.15 m of sand (Figure 3). In that case, the permeable pavement was positioned at the base of the system and its only function was supporting the bed, preventing the drag of gravel and sand out of the set (Figure 2). It did not interfere in the draining capacity of the bed.

The SDBPP solely consisted of permeable pavement. In the SDBS a layer of sand of 0.01 m was also evaluated (Figure 3).

In all situations, there was a vertical empty space of 0.75 m at the top of each tube (Figure 3).

Infiltration rate

For each bed a test to determine the infiltration rate ($m^3\ m^{-2}\ day^{-1}$) was conducted. To do so, water was introduced through the upper part of the beds, keeping the water column height constant over time. The water volume leaving the bottom of the structure was then measured every 5 seconds.

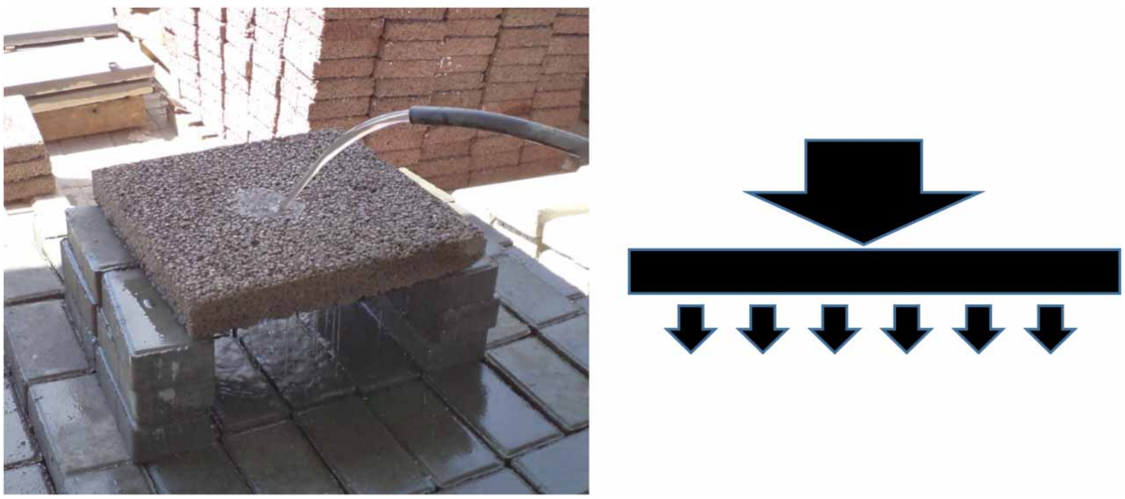

Figure 1 | Permeable pavement used in the project and image showing the infiltration in the pavement.

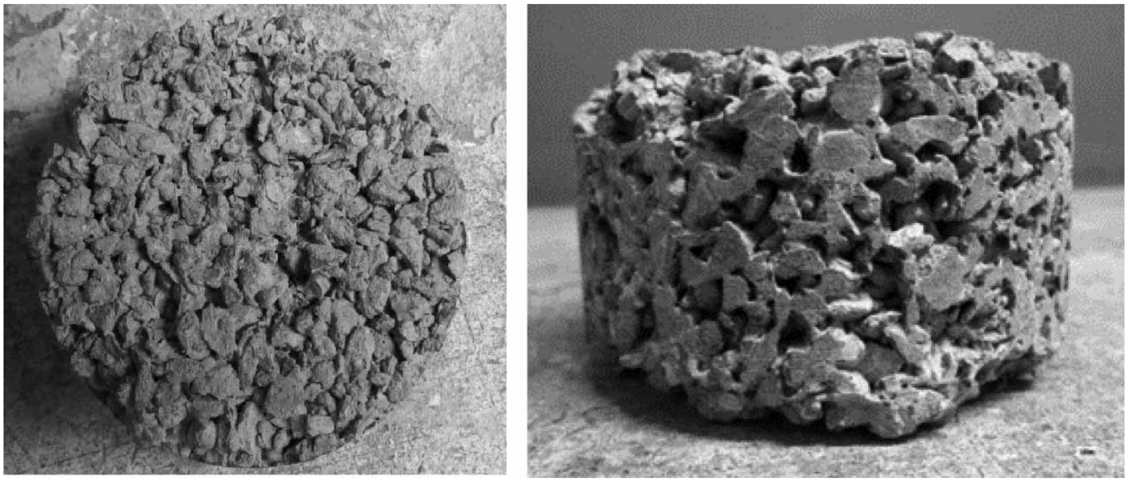

Figure 2 | Permeable pavement used in the project.

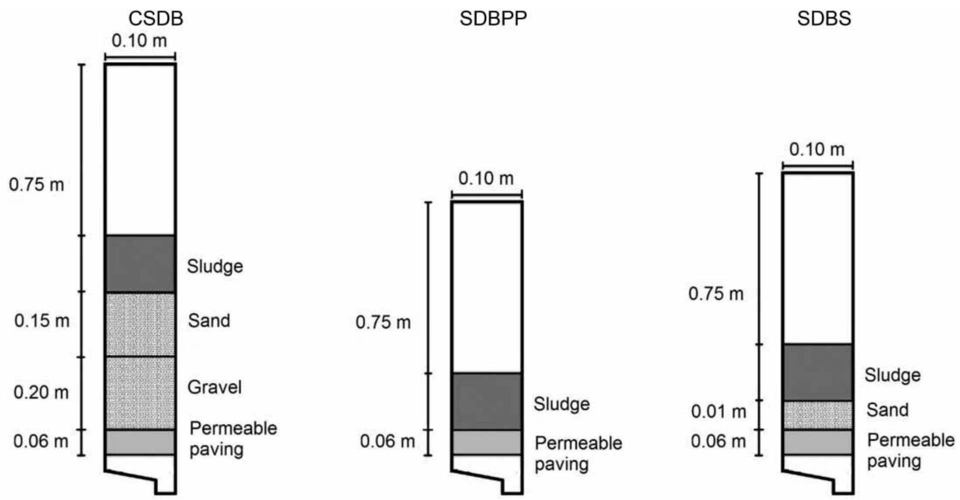

Figure 3 | Conventional sludge drying bed (CSDB), sludge drying bed with permeable pavement (SDBPP) and sludge drying bed composed of permeable pavement plus a layer of sand (SDBS).

After the tests in which the sludge was applied to the surface of the beds, this infiltration test was repeated. However, a cleaning of the filters with a high-pressure machine (1,300 psi) was conducted before the execution of this test. This action aimed to remove residual sludge particles in the beds, seeking to restore the initial infiltration rate.

Sludge

The sludge used was from septic tanks in Campinas (São Paulo, Brazil). The sludge characterization was based on *Standard Methods for the Examination of Water and Wastewater* (APHA *et al.* 2010).

The determination of optimal dosage of polymer (Superfloc® 8394, Kemira) was performed through the Capillary Suction Time (VESILIND 1988; WPCFM 1988; APHA *et al.* 2010; Metcalf & Eddy 2016). In that case, a dosage of 0.20 gL^{-1} of polymer was found for the sludge adopted in the research.

Dewatering evaluation

Dewatering evaluation consisted of the disposition of 2.0 L of sludge in the three types of sludge drying beds (Figure 3).

Table 1 | Comparison between average data found in the literature and in this research

Parameters	Philippi et al. (1999)	Withers et al. (2011)	Moussavi et al. (2010)	This study
TS ($mg.L^{-1}$)	1,083	–	1,070	77,634
VS ($mg.L^{-1}$)	673	–	–	35,164
pH	6.6	7.3	7.3	7.0
Alkalinity ($mg\ CaCO_3.L^{-1}$)	–	6,085	480	2,300

TS, Total solids; VS, Total volatile solids.

Immediately after the application of this sludge volume, the timing of collection of the water that was percolated by the drying beds was initiated.

For quality evaluation of the percolated liquid, all the liquid leaving the drying beds was collected and stored. Next, the concentration of total solids (TS) was evaluated. The sludge cake on the surface of the beds was also evaluated by the concentration of TS.

These tests involving the application of the sludge and collection of the drained liquid were repeated three times. In this study, these repetitions were named series I, II and III, shown later in the results in Table 2.

Statistical comparison among the infiltration rate in the permeable pavements before and after application of sludge was performed using analysis of variance (ANOVA) and the post hoc Tukey's test. A p value of <0.05 was considered statistically significant.

RESULTS AND DISCUSSION

Before the application of sludge, the infiltration rate of all beds was determined with the use of drinking water. The average found for the SDBPP was 2,521.0 $m^3\ m^{-2}\ day^{-1}$. This average reached 115.7 $m^3\ m^{-2}\ day^{-1}$ for the CSDB and 400.4 $m^3\ m^{-2}\ day^{-1}$ for the SDBS.

These data demonstrate that permeable pavement allows a significant increase in the infiltration rate. The infiltration rate was more than 20 times higher than the value obtained for the CSDB. Therefore, a drying bed with a much smaller area could be built.

The adoption of a small layer of sand over the surface (0.01 m) led to a decrease in the infiltration rate. Even so, the value obtained was superior to the value found for the CSDB. The purpose of using this sand layer would be to hinder the clogging of drainage pores of the permeable pavement. Thereby, the coarse material in the sludge

Table 2 | Results of the sewage sludge dewatering in the tree systems with and without synthetic polymer

		SDBPP		SDBS		CSDB	
Series	Duration (days)	TS sludge cake (%)	Volume dewatered (mL)	TS sludge cake (%)	Volume dewatered (mL)	TS sludge cake (%)	Volume dewatered (mL)
Without synthetic polymer							
I	35	19.60	540	22.08	578	28.24	561
II	39	27.77	665	29.67	675	32.79	492
III	28	24.87	628	28.24	609	28.72	587
Average	–	24.08	611	26.67	621	29.92	547
Standard deviation	–	4.14	64	4.03	49	2.50	49
With synthetic polymer							
I	4	24.12	1,484	26.45	1,413	29.80	1,232
II	8	25.03	1,411	26.2	1,377	27.53	1,145
III	5	23.27	1,481	24.73	1,513	28.43	1,265
Average	–	23.95	1,464	25.19	1,434	28.59	1,214
Standard deviation	–	0.88	41	0.93	70	1.14	61

would be retained in the sand, which could be removed by a simple scraping.

Sludge characteristics

The sludge used in the survey had a TS concentration of 7.8%, higher than that traditionally found in the literature (Table 1). Possibly, this result appears due to the long operation period of the septic tank without the removal of sludge (7 years).

From these TS, 47 ± 10% consisted of volatile solids. According to Metcalf & Eddy (2016), Amuda *et al.* (2008) and Andreoli (2009), this volatile portion is a good indication of the organic fraction of solids and its digestion level. Moussavi *et al.* (2010) correlated the values of total volatile solids in septic tank sludge and obtained the value of 57%, classifying the sludge as stabilized. In Brazil, for agricultural use, the sewage sludge is considered stable if the relation between volatile solids and TS is below 70% (CONAMA 2006).

Sludge dewatering in the systems

After applying sludge on the surface of the beds, with and without the use of polymer, the CSDB had a significantly lower percolated liquid volume than the one found in the other two beds (Figure 4). Therefore, the beneficial effect of using SDBPP can be verified. That is, an SDBPP could be significantly smaller than the CSDB. On average, after the second day of percolated liquid collection, the volume drained by the SDBPP was 37.4 ± 4.6% higher than that obtained in the CSDB. Therefore, from this point of view, a smaller drying bed could be used.

As expected, the sludge dewatered at a sharper rate when the polymer was added (Figure 4). This behavior can be justified by the polymer interaction with the sludge particles, which occurs almost immediately after its application (WPCFM 1988). Because of this rapid infiltration, smaller periods of dewatering could be used (Table 2), which would imply a greater quantity of drying cycles in real-scale beds or smaller areas of sludge drying beds.

When applying the sludge without the addition of polymer in SDBPP and SDBS, the percentage percolated throughout 30 hours was 48.6%. That is, from 2,000 mL of applied sludge, there was an output of 972 mL of percolated liquid. This percentage percolated over 30 hours and reached only 30.1% in the CSDB. Therefore, it is again demonstrated that the use of permeable pavement can make the drying bed smaller.

For the sludge that received polymer, in the first 3 hours the SDBPP, the SDBS and the CSDB dewatered, on average, 69.0, 48.7 and 18.5% of the total volume of applied sludge, respectively (Figure 4). However, if a total of 24 hours is taken into account, the difference between the volume collected in the three situations (SDBPP, SDBS and CSDB) is very low: 73.5, 70.0 and 60.0%, respectively. That is, when using polymer, the type of drying bed will not interfere with the dewatering.

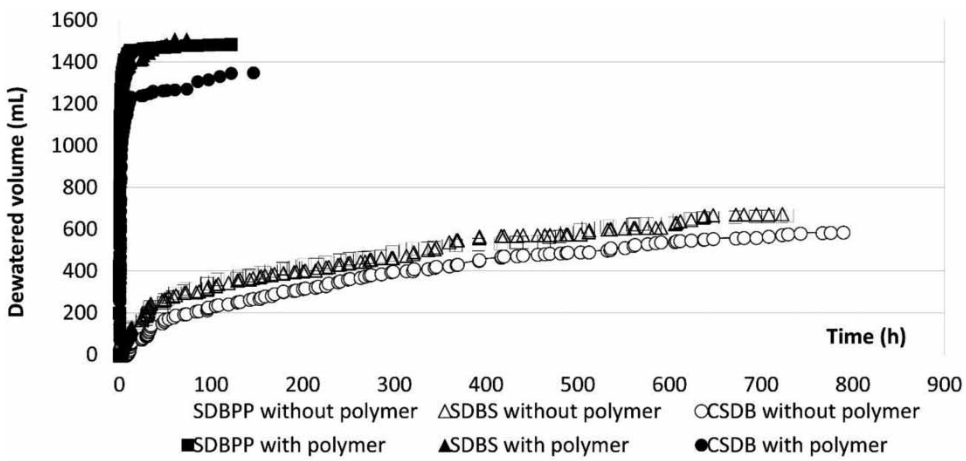

Figure 4 | Water that percolates by the systems as a function of time.

Therefore, in terms of infiltration rate and volume of percolated liquid, the use of a small layer of sand does not entail a significant loss of efficiency of the draining pavement. The assessment of the need of this layer should be conducted considering the benefits that this layer may bring in regard to the lifespan of the drainage pavement. However, the use of the draining pavement brings important benefits when compared to the results obtained with the traditional system.

Solids content

We observed that the use or not of polymer did not interfere in the solids content of the sludge cake in the same type of sludge drying bed (Table 2). This may be explained by the fact that the dewatering period was different in each situation. For the sludge without polymer, 35 days were necessary until the completion of the percolated collection, and for the sludge with polymer only 6 days were required. In other words, the longest period of dewatering allowed greater evaporation of water in the sludge.

In addition, for the same situation (use or not of polymer), there was no significant difference for TS concentration between the SDBPP and the SDBS.

However, a significant difference was found between these beds and the CSDB (Table 2). That is, among all the situations evaluated (use or not of polymer), the CSDB provided a sludge cake with a higher concentration of solids than the ones obtained in alternative beds. Again, the longest period of dewatering allowed greater evaporation of water in the sludge. Possibly, this greater time may have caused an improvement in the solids concentration of the CSDB. Thus, the values of its solids concentration were not significantly different from those obtained in the alternative beds.

When compared with the values of dewatered liquid, the CSDB had the smallest volume of liquid collection (Volume dewatered, Table 2). This result probably derives from the retention of part of the percolated water in the sand layer of the CSDB, which had a thickness of 0.15 m. With that, part of the water dewatered from the sludge ended up being adsorbed by the sand, instead of leaving the bed and allowing its collection.

This adsorbed value became significant because the bed studied had a small surface area in relation to the depth of the sand layer. In full-scale this relation would be minimized, considerably diminishing this adsorption effect. In addition, this may have favored greater evaporation of the liquid rather than its percolation.

Therefore, we can conclude that the use of the permeable pavement allows faster percolation of the free water. However, until the end of this percolation process, the evaporation of the water left in the sludge too long was enough to cause the efficiency of the three systems to become quite similar.

Maintenance of pavements

After using pavements in each repetition (series I, II and III), its cleaning was performed to carry out a new infiltration test. To this end, all the three different sludge drying beds (CSDB, SDBPP and SDBS) were disassembled. Subsequently, the entire permeable pavement was cleaned with a high-pressure washer before the test, aiming to remove the sludge that remained stuck to the pavement. The results for the infiltration rate before (2,521.0 ± 227.9) and after (2,218.5 ± 324.1) the application of sludge showed that the value obtained for the infiltration test was, on average, 12.6 ± 10.2% lower than the first assessment. Possibly, the oils and greases in the sludge may have adhered to the pavement, hindering the water passage.

In addition, no significant differences (Tukey's test at $p < 0.05$) were found between the new values for the infiltration rate of the different systems studied (CSDB, SDBPP, SDBS), indicating that the use of a small layer of sand does not benefit the useful life of the permeable pavement.

Therefore, we used a wash with detergent solution to achieve the full recovery of the infiltration rate. The pavements were soaked for a week in this liquid solution. Then, the infiltration rate assessment was repeated, being 24.2 ± 13.3% greater than the original. The results found for the infiltration rate before and after a wash with detergent solution were 2,521.0 ± 227.9 and 3,131.1 ± 433.1, respectively.

Thus, this detergent solution enabled the complete withdrawal of the oils and greases. Possibly, the highest values found in relation to the original infiltration rate can be explained by the high-pressure washing. This energetic washing may have removed some grains of basalt and sand from the pavement, enlarging the empty spaces in it, and thus increasing the infiltration rate.

Reuse of pavements was proven possible; however, it demands washings that require the use of a considerable volume of water and a high-pressure washer.

CONCLUSIONS

The use of synthetic polymer allowed the dewatering in sludge drying beds to occur in a shorter operating time. This would result in more drying cycles in the same bed area, or in the size reduction of the sludge drying beds if the same volume of sludge is employed.

The use or not of polymer does not interfere in the solids content of the cake.

The use of an SDBPP or an SDBS showed no significant difference between the volume dewatered regarding the humidity in the sludge cake and the maintenance. Thus, in this alternative system, adding sand to the pavement would be unnecessary.

The SDBPP generated a superior volume of liquid dewatered in a lower time period. However, it provided a sludge cake with a similar concentration of solids as the one obtained in the conventional bed.

The reuse of the pavement was proven possible, but it requires a large volume of water, detergent and mechanical equipment (high-pressure washer).

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