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Filtration rates in inorganic filters submitted to different repose periods

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ABSTRACT. This work aimed to evaluate the filtration rate in organic filters after being subjected to different repose periods in the primary treatment of swine wastewater (SWW). Filtration columns were mounted in PVC pipes measuring 100 mm in diameter and 600 mm in length and filled with 2-5 mm sawdust particles. Five different repose periods were evaluated: 1, 2, 4, 8 and 16 days after the first filtration, carrying out three batches. The SWW filtration rate decreased with the operating time of the filters, which can be attributed to clogging of pores resulting from high concentrations of suspended solids (SS) present in this type of wastewater. In the three batches, it was observed that the repose periods of 1, 2 and 4 days were not sufficient to unclog the pores, however, repose periods of 8 and 16 days for the filter medium resulted in increases of the filtration rate, only 59 and 72% of the initial rate, respectively.

Keywords: solids removal, wastewater treatment, repose period.

Taxa de filtração em filtros orgânicos submetidos a diferentes tempos de repouso

RESUMO. Com a realização deste trabalho, objetivou-se avaliar a taxa de filtração em filtros orgânicos, após terem sido submetidos a diferentes tempos de pousio, no tratamento primário da água residuária da suinocultura. Colunas de filtragem foram montadas em tubos de PVC de 100 mm de diâmetro e 600 mm de comprimento, tendo sido preenchidas com serragem de madeira, na granulometria de 2-5 mm. Foram avaliados cinco diferentes períodos de pousio: 1; 2; 4; 8 e 16 dias após efetuada a primeira filtração, realizando-se 3 bateladas. A taxa de filtração da ARS decresceu com o tempo de operação dos filtros, o que pode ser atribuído à obstrução dos poros decorrente das elevadas concentrações de sólidos suspensos (SS) presentes neste tipo de água residuária. Nas três bateladas, observou-se que os períodos de pousio de 1; 2 e 4 dias não foram suficientes para desobstrução dos poros, no entanto, períodos de pousio de 8 e 16 dias do material filtrante, proporcionaram aumento na taxa de filtração do material, ainda que tenha sido recuperado, respectivamente, apenas 59 e 72% da taxa inicial.

Palavras-chave: remoção de sólidos, tratamento de efluentes, tempo de pousio.

Introduction

Modern swine production systems, characterized by the confinement of animals, generate large volumes of highly pollutant wastewater. According to Matos (2008), when these wastewaters are disposed into the environment without prior treatment they can cause major environmental problems such as degradation or destruction of flora and fauna, and also compromise water and soil quality. Because environmental legislation has established standards for discharge of effluents in water bodies, it is necessary that these wastewaters are treated if this is to be the final form of disposal. Futhermore, Fia et al. (2012) warn that construction ease and costs are factors are vital importance to further disseminate the practice of adequate treatment of wastewater. If selecting to use these wastewaters for local fertigation, a preliminary and primary treatment is needed to reduce the risk of clogging the fertigation equipment.

Among primary treatments for removal of pollutants from wastewater is filtration, which is based on the principle that a porous medium can retain impurities of dimensions even smaller than those of the pores on the filter layer (LO MONACO et al., 2009). However, these removal mechanisms are temporary or finite since there is a gradual obstruction of the pores in the filter bed, with consequent increase in filter load loss (MATOS et al., 2010).

Raw wastewaters from pigpens present variable total solid contents, since the adopted management method significantly influence these values. According to Brandão et al. (2003), because they are rich in solids, the use of conventional sand filters is typically not recommended for the treatment of wastewater from pig farms which results in rapid surface clogging and prevents normal flow of wastewater.

The use of alternative filter materials originating from agricultural activities can be a good option due to their abundance, low cost and also because the material can be subjected to composting after use as a filtering material (MATOS, 2008), and followed by used as agricultural fertilizer.

Therefore, some residues used as organic filters have been studied, including crushed sugarcane bagasse (BRANDÃO et al., 2003; LO MONACO et al., 2002, 2011a; MAGALHÃES et al., 2005, 2006a), sawdust (BRANDÃO et al., 2003; LO MONACO et al., 2002, 2004; MAGALHÃES et al., 2005, 2006a), rice husks (BRANDÃO et al., 2003), ground corn cobs (BRANDÃO et al., 2003; LO MONACO et al., 2011a), fine coal (BRANDÃO et al., 2003), coffee berry pulp (BRANDÃO et al., 2003), coconut fiber (LO MONACO et al., 2009) and coffee bean husks (MATOS et al., 2006; LO MONACO et al., 2011b).

As proven by Matos et al. (2010), it is known that the filters can adequately operate for only a certain period of time, since with continuous clogging of macropores in the filter material the load loss increases, and consequently the wastewater filtration rate decreases. After the filtration rate decreases significantly, which is generally considered about 10% of the initial rate, the filter material must be exchanged. The same authors recommended that the ideal time for uninterrupted operation of filters, without exchange of filter material, should be approximately 1.5h and after this time the filter material should be replaced. Filter material removed from the filters can be submitted to the composting process, and thus be of economic value (MAGALHÃES et al., 2006b).

For sizing of a filtration system, considering the medium filtration rate as being equivalent to 0.5 m^{-2} s or 43,200 L m^{-2} day, obtained after stabilization of filtration rate and assuming the generation of 20 L pig^{-1} day of SWW, it is estimated that when operating the filter for about 2h it is possible to promote the treatment of SWW generated by 180 animals for each square meter of the filter surface area (MATOS, 2008).

Thus, because the objective is to reduce labor needs and costs in water treatment units, it is sought to use the same filter material for a longer period of time. However, for this to be possible the establishment of a repose period for the filter is necessary, so the filtration capacity of the material can be at least partially restored. Little is known about the effects of repose time on the filtration rate of the material already used. For this reason, the objective here was to evaluate the filtration rate in sawdust packed filters, after having been submitted to different repose times following primary treatment of swine wastewaters.

Material and methods

The experiment was arranged and conducted in a greenhouse located in the Experimental Area for Storage and Processing of Agricultural Products, Agricultural Engineering Department/Universidade Federal de Viçosa (UFV).

Swine wastewater (SWW) used in the tests was collected directly in an effluent storage tank from pens where animals in different stages of development were bred, at the Sector for Swine Production at that UFV, and stored in a fiberglass reservoir throughout the experimentation period. For physical characterization of the SWW, concentrations of total solids (TS), suspended solids (SS) and total volatile solids (TVS) were quantified, as recommended in APHA, AWWA, WEF (2005).

The filtration columns were mounted in PVC tubes measuring 100 mm in diameter and 600 mm in length, having been filled with wood sawdust which was previously air dried and triturated using the Disintegrator/Chopper-grinder (DCG), no. 1, consisting of 4 sets of 3 hammers (total of 12 hammers), a 10 mm mesh sieve and 5 hp motor. After grinding, the sawdust was sieved so as to obtain a particle size range of 2-5 mm. Selection of the granulometric ranges for the filter material was based on the results obtained by Lo Monaco et al. (2004), which recommended the use of granulometries between 2.0 and 3.0 mm since they resulted in the greater filtration rate without excessively increasing load losses in the system. A cap was placed at the bottom of the tube using a flange where the treated effluent was collected. Inside the cap a screen (1 mm mesh) was installed avoid that the filter material be pushed out of the column.

The filter material was gradually added to the columns in 50 mm layers and submitted to compression of 12,490 N m^{-2} (pressure equivalent to that applied by trampling of a man weighing 70 kg), until reaching the height of 500 mm.

To minimize the preferential flow along the interior wall of the column, the filter material was glued to the inner walls of the tube to increase surface roughness and thus the tortuosity of the inside walls of the filters.

Five filters were constructed to permit evaluation of five different repose periods: 1, 2, 4, 8 and 16 days after the first filtration. This first filtration, always performed with a new filter material (*in natura*), was sufficient to clog the filters, i.e. lower of filtration rate to less than 10% of the initial flow. After reaching this low efficiency the individual treatments were applied to the filters, which included reapplication of SWW after different repose periods for the filters. These evaluations (first filtration followed by a second filtration after a pre-determined repose period) were performed three times (three batches or replications), conducted over a period of approximately 50 days.

In the first batch of tests, the SWW was used immediately after collection; in the second batch the SWW remained stored in the tank, which may have resulted in partial anaerobic degradation of wastewaters; while in the third batch the effect of this degradation may be more striking because of the increased wastewater storage time. Considering that wastewater was stirred before being applied to the filters, a decrease in organic material could only be due to degradation. The decrease in concentration of suspended solids in SWW was, however, corrected when using a relative concentration for fitting of curves and equations.

The concentrations of total solids, suspended solids and total volatile solids in the wastewater used in the three test batches are presented in Table 1.

Table 1. Concentrations of total solids (TS), suspended solids (SS) and total volatile solids (TVS) in the swine wastewater (SWW).

Variables	Batch 1	Batch 2	Batch 3
TS (mg L^{-1})	11.820	10.890	8.520
SS (mg L^{-1})	7.520	7.380	6.600
TVS (mg L^{-1})	8.630	7.800	5.620

Flow through the filters occurred under saturation conditions, where the filter columns were filled with SWW, maintaining the valves closed which were installed at the column base until completely filling the column. After completely filling the filter material, the valves of the filtering columns were opened simultaneously, allowing movement of wastewater through the material contained in the columns and saturated flow was maintained during the entire filtration period with hydraulic load of 100 mm above the upper surface the filter material. During this phase, a timer and 500 mL plastic flasks were used to collect the effluent for determining the filtration rate of the liquid in the filter.

Regression analyses were utilized for obtaining equations that enabled estimating the filtration rate (m^3 m^{-2} h) as a function of filter operation time (minutes). The models were selected based on the significance of the coefficients, the coefficient of determination (R^2) and behavior considered logical for the phenomenon under study.

Results and discussion

Figure 1(a, b and c) represents the curves of filtration rate variation along the filter operation period for the different repose periods, and in Table 2 are the respective regression equations and correlation coefficients. Only those representing the repose times of 0, 8 and 16 days were presented considering that the time of 0 days is the reference and times of 8 and 16 days were the only ones that indicated differences in the SWW filtration rate.

As can be seen in Table 2 and Figure 1(a, b and c), the filtration rate displayed an exponential decay with filter operation time for the different repose periods in the three batches. This decrease may be attributed to clogging of the pores resulting from high concentrations of suspended solids (SS) in this type of wastewater (Table 1). It was observed that after 7.5 to 10 minutes of filter operation, a constant filtration rate was reached. Magalhães et al. (2006a), using sawdust with a particle size ranging from 2.5 to 3.0 mm for filtering SWW found stable filtration rates between 0.2 and 0.7 L m^{-2} s, a range included the values obtained in the present study which were 0.50, 0.58 and 0.34 L m^{-2} s for the first, second and third batches, respectively. Brandão et al. (2000), when filtering SWW through various organic materials and using particle sizes between 2-6 mm, found filtration rates ranging from 0.28 to 0.42 L m^{-2} s, lower than those obtained in the present study.

Table 2. Regression equations fit to the filtration rate in function of the filters operation time for the different repose periods studied.

Batches	Day 0		Day 8		Day 16	
	Equation	R^2	Equation	R^2	Equation	R^2
1º	$\hat{Y} = 5.2584^{**} x^{-1.1169**}$	0.99	$\hat{Y} = 0.9265^{**} x^{-0.6197*}$	0.83	$\hat{Y} = 2.4659^{**} x^{-0.6624**}$	0.95
2º	$\hat{Y} = 3.0163^{**} x^{-1.3499**}$	0.99	$\hat{Y} = 2.0394^{**} x^{-0.8688**}$	0.,98	$\hat{Y} = 1.9190^{**} x^{-1.2718**}$	0.99
3º	$\hat{Y} = 2.0339^{**} x^{-1.2160**}$	0.99	-	-	$\hat{Y} = 0.6683^{**} x^{-1.1416**}$	0.99

* and **, significant at the 5 and 1% probability levels, respectively.

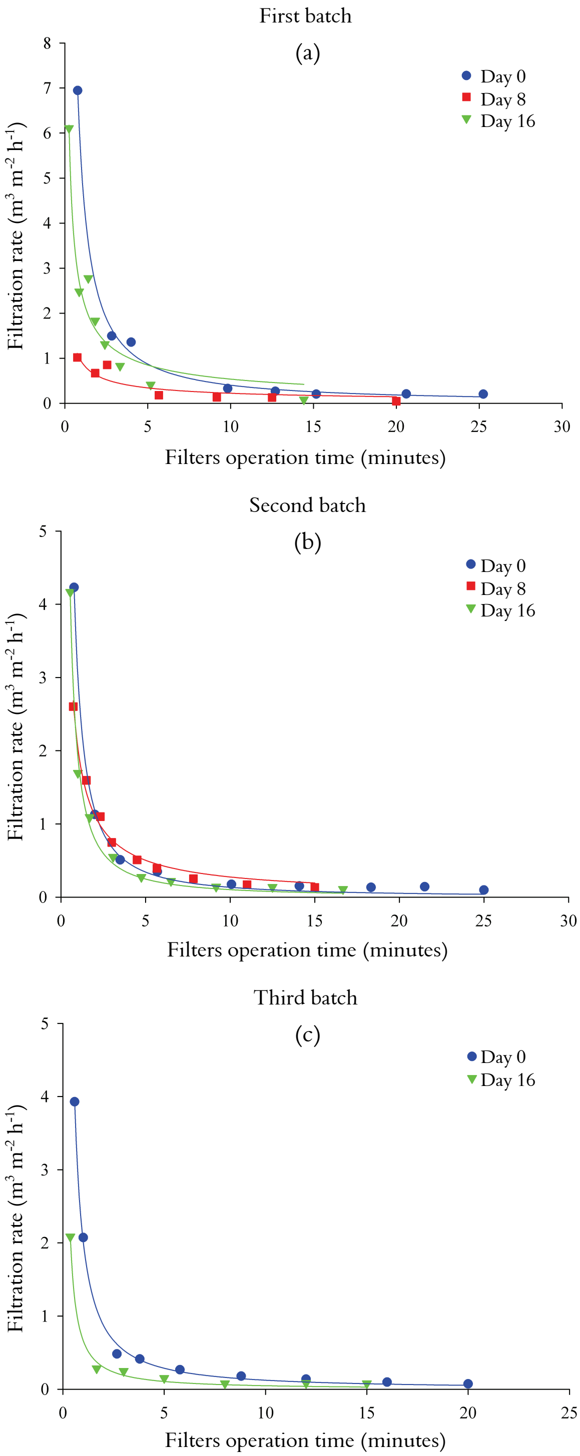

Figure 1. Variation in filtration rate in function of the filter operation time for different repose periods in the first (a), second (b) and third (c) batches.

Clearing of the pores is a mechanism that occurs mainly due to biological degradation processes, which are strongly influenced by humidity, temperature and the physical and chemical characteristics of the filter material. Once stabilized, the humified and less swollen material, due to its drainage, has a higher permeability which allows for partial restoration of the filtration rate. Return of the filtration rate is also due to physical changes caused by drying of the filter material, the creation of fissures and cracks, especially on the surface layer of the filter where clogging is most intense.

In the three batches it was observed that repose periods of 1, 2 and 4 days were not sufficient to unblock the pores, i.e. there was no time for degradation of organic material associated with unclogging of the material which could potentially increase the filter permeability, and thus there was no increase in filtration rate during this period. However, repose periods of 8 and 16 days for the filter material (Figure 1a and b) resulted in increased filtration rates for the material, however still lower than the initial rate. In the third batch (Figure 1c), possibly due to residual water possessing a lower concentration of SVT (Table 1), i.e., a smaller amount of organic material susceptible to degradation, the time required for clearance of the macropores in the filter was greater than 8 days, therefore a relative curve for this time was not obtained.

Although it was found that repose times exceeding 8 days are sufficient to enable reuse of the filter, based on the results obtained nothing can be affirmed with respect to the filter used continuously with the same repose periods. This justifies further studies on the subject.

The results indicate the possibility of reusing clogged filters after being submitted to a repose period. Therefore, in a wastewater treatment unit planning can include filter management, so that the same material can be used one or more times before being discarded for composting.

A trend was verified between increased filtration rates with increase in the repose period for the filter material, indicating that better results may have been obtained if the repose period was longer than 16 days.

Conclusion

Based on the performed study, it can be concluded that:

- The repose periods of 1, 2 and 4 days were not sufficient to clear the pores;
- There was a trend of increased filtration rate with increase in the repose period of the filter material;
- Repose periods of 8-16 days are required in order to obtain filtration rates of 59 and 72% of the initial rate, respectively.

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