Paper No. 964053
An ASAE Meeting Presentation

USE OF A MEDIA FILTER FOR SWINE WASTEWATER TREATMENT

by

A.A. Szögi	F.J. Humenik	J.M. Rice	P.G. Hunt
Soil Scientist	Agricultural Engr.	Agricultural Engr.	Soil Scientist
USDA-ARS	NC State Univ.	NC State Univ.	USDA-ARS
Florence, SC	Raleigh, NC	Raleigh, NC	Florence, SC

Written for Presentation at the
1996 Annual International Meeting
Sponsored by ASAE

Phoenix Civic Plaza
Phoenix, AZ
July 15-17, 1996

Summary:

A media filter was constructed to treat swine wastewater after anaerobic lagoon treatment. The media filter consisted of a tank (1.8-m diameter × 0.9-m height) filled with marl gravel. Wastewater flow rate was 456 L m^{-2} d^{-1}, and total Kjeldahl nitrogen (TKN) load was 147 g m^{-2} d^{-1}. Up to 24% of TKN was converted to nitrate-N (NO_3-N). Effluents with high NO_3-N levels can be treated further for denitrification with constructed wetlands or anaerobic lagoon. This is important in cases where land is limited for wastewater application.

Keywords:

Nitrification, Phosphorus, Aeration, Anaerobic lagoon, Trickling filter

INTRODUCTION

Wastewater from hog operations is typically stored and treated in anaerobic lagoons prior to land application. Limited land or long pumping distances between lagoons and application sites can make land treatment nonfunctional or very expensive. Since over-application of lagoon wastewater may contaminate streams and shallow groundwater, treatment of lagoon effluent prior to land application is of major interest for the hog industry.

Lagoon effluents are rich in ammonia-N (NH_3-N) and phosphorus. Most ammonia-N in the lagoon is lost via volatilization and nitrification/denitrification processes. Nitrification is the most limiting factor in anaerobic lagoons and is needed to convert excess NH_3-N into nitrogen gas (N_2). Nitrification is carried out by autotrophic bacteria that require adequate aeration, pH, and low levels of organic carbon. Media filters made of sand, rock fragments, or plastic material (widely known as trickling filters) have been extensively used for aeration treatment of municipal and industrial wastewater (U.S. EPA, 1971) and may provide sufficient aeration for nitrification of lagoon swine wastewater. Unlike nitrogen, phosphorus is not lost to the atmosphere; it remains in solution (organic and inorganic P) or tied to suspended matter in the wastewater. Therefore, phosphorus treatment relies on precipitation of solids or sorption to the media filter substrate.

Even though media filters have been used extensively for water treatment, limited data exists on the use of media filters for treatment of livestock wastewaters (Loehr et al., 1973). Our objective was to determine if a marl gravel media filter can be used for treatment of anaerobic lagoon effluent. This study is part of a larger project to evaluate the sequencing of different land treatment methods (constructed wetlands, overland flow, and media filters) for renovation of swine wastewater in North Carolina (Humenik et al., 1995).

MATERIALS AND METHODS

Wastewater effluent was provided by a single-stage anaerobic lagoon used to treat the waste generated by a pig nursery in Duplin Co., N.C. The media filter consisted of a 1.8-m-diameter $\times$ 0.9-m-high tank filled with marl gravel. Although sand filters have become popular for small waste generators, especially where soil conditions are not suitable for subsurface disposal systems (Rubin et al., 1994), our filtration unit used marl gravel instead of sand to avoid clogging. The gravel material also allowed for very good natural aeration of the lagoon effluent, rapid vertical flow rates, fast growth of biofilms, and some phosphorus sorption. The marl gravel used is a marine sediment composed of a mixture of clay, magnesium and calcium carbonates, and shell fragments. The average particle size of the gravel is 0.5 to 1.2 cm. In the laboratory, a carbonate content of 30% was measured by the Van Wesemael method (Houba et al., 1986) and P sorption isotherm was estimated according to the Fox and Kamprath (1970) method.

The filtration unit was placed inside another tank with a slightly larger diameter that collected the effluent for recirculation. The wastewater flowed by gravity from the lagoon to a storage tank. The wastewater was pumped from the storage tank and applied onto the surface of the media filter with fixed sprinklers that provided a fine spray (Fig. 1). Lagoon wastewater was applied continuosly and recirculated between the media filter and the storage tank up to four cycles or passes during six hours a day. Treated effluent was obtained with four passes through the filter. The experiment was repeated four times in four consecutive days. The flow rate was 456 L m^{-2} d^{-1}. Mean application rates for TKN and total phosphorus (TP) were 147 and 37 g m^{-2} d^{-1}, respectively. The flow was measured with a mechanical flowmeter, and grab samples for water analysis were obtained at the end of each cycle. Water samples were analyzed for TSS, TKN, NO_3-N, NH_3-N, TP, COD, and pH (Kopp and McKee, 1983). The proportion of TKN in the influent that was converted to NO_3-N was estimated by a nitrification ratio [NO_3-N (mg L^{-1}):TKN (mg L^{-1})$\times$100] (Loehr et al., 1973).

RESULTS

Data in Fig. 2 indicate that wastewater with very high NH_3-N concentrations can be treated by media filtration to obtain significant reduction in TKN and NH_3-N. Nitrate-N concentration increased and ammonia-N and TKN decreased with increasing number of cycles through the media filter. The nitrification ratio (fraction of initial TKN converted to NO_3-N) after four cycles was 24%. Organic nitrogen, which is shown in Fig. 2 as the difference between the TKN and NH_3-N, was also reduced with increased number of cycles. Process conditions such as pH, temperature, and organic loadings were favorable for nitrifying bacteria to transform NH_3-N into NO_3-N. Mean NO_3-N concentration was 88 mgL^{-1} after four cycles a day. Water pH, an important parameter for nitrification, did not change significantly and remained buffered in the range of 8.0 to 8.5 units. The decrease in organic loading necessary for nitrification is explained by the COD and TSS results in Fig. 3.

The media filter removed 54% of COD content after one cycle, but increased cycling did not produce additional COD reduction (Fig. 3). Total suspended solids removal after one cycle was similar to COD at 50% of initial levels, and additional cycles reduced TSS levels at a much lower rate of 7% per cycle (Fig. 3).

Figure 5 shows that total P decreased with increasing number of cycles, and the trend was similar to the TSS reduction curve (Fig. 3). This indicates that TP probably precipitated together with the suspended solids. Removal efficiencies for TP ranged from 37% to 52% with one to four cycles, respectively. Phosphorus removal was expected to be by precipitation and sorption to the gravel substrate since phosphorus in the wastewater was present mostly in inorganic forms as phosphates (Humenik et al., 1995). Results of the laboratory sorption experiment using the same marl gravel of the media filter prototype experiment show a high capacity for phosphorus sorption per gram of marl gravel (Fig. 4). These results are similar to phosphorus sorption to iron rust obtained by James et al. (1992).

Results show that functioning of this media filter is analogous to recirculating sand filters that provide excellent biochemical oxygen demand (BOD) and suspended solids removal as well as an acceptable degree of nitrification (Hines and Favreau, 1975; Mote et al., 1991). Total P concentration only decreased rapidly with one cycle. This indicated that the media filter substrate had a limited P treatment capacity under field conditions.

SUMMARY

The media filter removed 54% of COD content after one cycle, but increased cycling did not produce additional COD reduction. Total suspended solids removal after one cycle was 50% of initial levels, and additional cycling reduced TSS levels at a much lower rate of 7% per cycle.

Conditions for nitrification were good with up to 24% of TKN converted to NO_3-N and consequent reduction of NH_3-N when wastewater was recycled four times a day. Mean NO_3-N concentration after four cycles was 88 mg L^{-1}.

Removal efficiencies for TP ranged from 37% to 52% (one to four cycles), but long-term P removal would be limited by the sorption capacity of the gravel.

Media filtration can be an acceptable method to treat lagoon wastewater if land is limited for waste application. This method may provide effluents with NO_3-N levels that can be treated further in constructed wetlands or be returned to the anaerobic lagoon for denitrification.

ACKNOWLEDGMENTS

This research has been funded by NC Herrings Marsh Run Water Quality Demonstration Project, USDA Project No. 90-EWQD-1-9504; NC Goshen Swamp Hydrologic Unit Area Project, USDA Project No. 90-EHUA-1-0013; and Evaluation of Alternative Constructed Wetland Systems for Swine Wastewater Treatment, USEPA Project No. CR823808-01-0.

REFERENCES

1. Fox, R.L., and E.J. Kamprath. 1970. Phosphate sorption isotherms for evaluating the phosphate requirements of soils. Soil Sci. Soc. Amer. Proc. 34:902-907.

2. Kopp, J.F., and G.D. McKee. 1983. Methods for chemical analysis of water and wastes. U.S. EPA Report No. EPA-600/4-79020. Environmental Monitoring and Support Lab., Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, OH.

3. Hines, M., and R.E. Favreau. 1975. Recirculating sand filter: an alternative to traditional sewage absorption systems. p. 130-136. *In* Proceedings of the National Home Sewage Disposal Symposium. ASAE Pub. Proc.-175. St. Joseph, MI.

4. Houba, V.J.G., J.J. Van der Lee, I. Novozamsky, and I. Walinga. 1986. Soil and Plant Analysis. Part 5 Soil Analysis Procedures. Department of Soil Science and Plant Nutrition. Wageningen Agricultural University, Wageningen, The Netherlands.

5. Humenik, F.J., A.A.Szögi, P.G. Hunt, J.M. Rice and G. Scalf. 1995. Constructed wetlands for swine wastewater treatment. p. 87-97. *In* C.C. Ross (ed.) Proceedings of the Seventh International Symposium on Agricultural and Food Processing Wastes. June 18-20, 1995, Chicago, IL. ASAE Publication 7-95, St. Joseph, MI.

6. James, B.R., M.C. Rabenhorst, and G.A. Frigon. 1992. Phosphorus sorption by peat and sand amended with iron oxides or steel wool. Water Env. Res. 64:699-705.

7. Loehr, R.C., T.B.S. Prakasam, E.G. Srinath, and Y.D. Joo. 1973. Development and demonstration of nutrient removal from animal wastes. Office of Research and Monitoring, Environmental Protection Agency. U.S. Government Printing Office, Washington, D.C.

8. Mote, C.R., J.W. Kleene, and J.S. Allen. 1991. On-site wastewater renovation utilizing a partially saturated sand filter for nitrogen removal and lawn sprinkler for effluent discharge. p. 173-181. *In* Proceedings of Sixth On-Site Wastewater Treatment Conference. ASAE Pub. 10-91. St. Joseph, MI.

9. Rubin, A.R., S. Greene, T. Sinclair, and A. Jantrania. 1994. Performance evaluation of drip disposal system for residential treatment. p. 467-474. *In* Proceedings of the Seventh International Symposium on Individual and Small Community Sewage Systems. ASAE Publication 18-94. St. Joseph, MI.

10. U.S. EPA. 1971. A literature search and critical analysis of biological trickling filter studies. U.S. Government Printing Office, Washington, D.C.

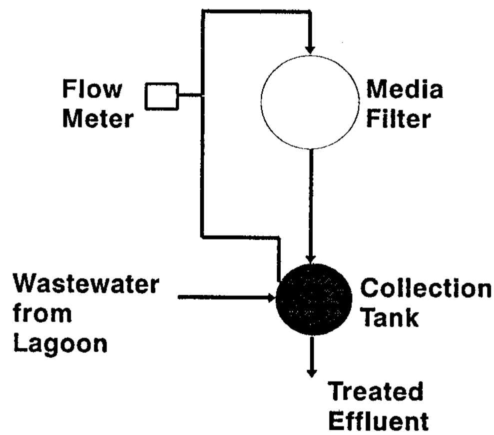

Figure 1. Schematic of the marl gravel media filter system.

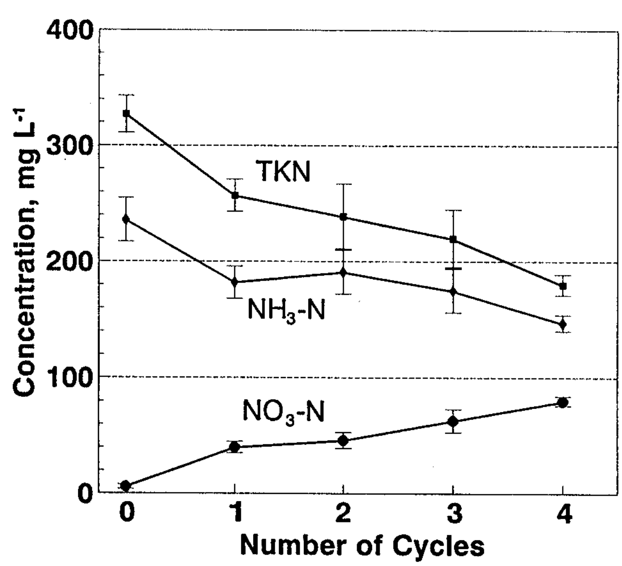

Figure 2. Changes in total Kjeldahl N (TKN), ammonia-N (NH_3-N) and nitrate-N (NO_3-N) concentration with number of cycles. Data points represent means (n = 4), and vertical bars ± 1 standard error of the mean (SEM).

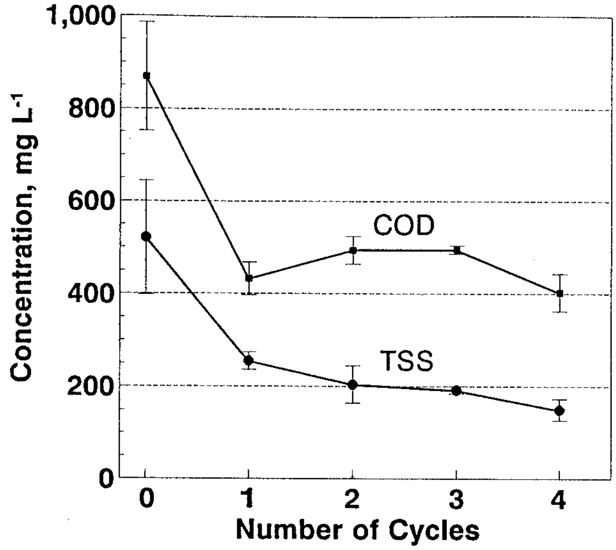

Figure 3. Changes in chemical oxygen demand (COD) and total suspended solids (TSS) concentration with number of cycles. Data points represent means (n = 4), and vertical bars ± 1 SEM.

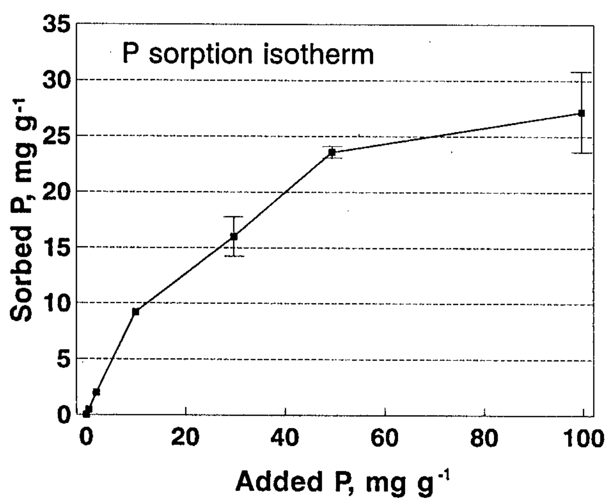

Figure 4. Sorbed phosphorus vs. added phosphorus per gram of marl gravel (laboratory experiment). Data points represent means (n=3), and vertical bars ± 1 SEM (not shown when smaller than data symbol).

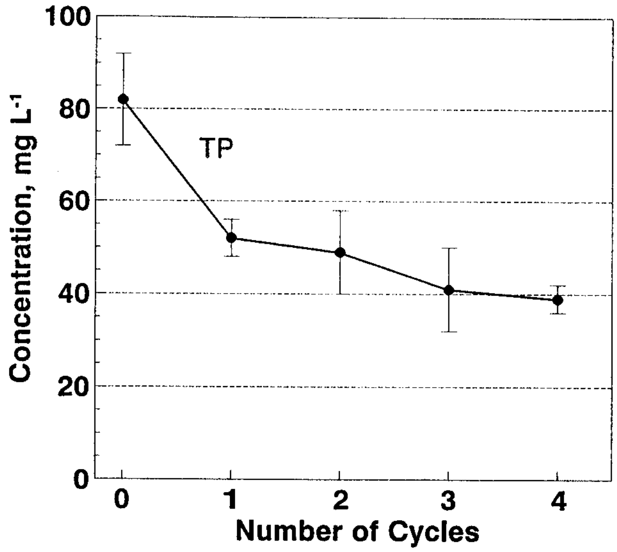

Figure 5. Changes in total phosphorus (TP) concentration with number of cycles. Data points represent means (n=4), and vertical bars ± 1 SEM.