Journal of the Arkansas Academy of Science

Volume 44 Article 16

1990

Comparison of Pressurized and Gravity Distribution Systems for Wastewater Treatment

Mark A. Gross
University of Arkansas at Little Rock

Stan Neal

Belinda Ederington

Robert Muldoon

A COMPARISON OF PRESSURIZED AND GRAVITY DISTRIBUTION SYSTEMS FOR WASTEWATER TREATMENT

MARK GROSS, STAN NEAL,
and BELINDA EDERINGTON
Department of Electronics and Instrumentation
University of Arkansas at Little Rock
2801 S. University
Little Rock, AR 72204

ROBERT MULDOON
Department of Pharmacology and Therapeutics
Louisiana State University Medical Center
P.O. Box 33932
Shreveport, LA 71130-3932

ABSTRACT

Pressurized distribution of domestic wastewater over a sand filter surface achieves better treatment than gravity distribution. The pressurized distribution system caused the filter to better remove organics (BOD_5) and suspended solids. Pressurized distribution also caused the sand filter to achieve more complete nitrification than the filter having gravity distribution.

Two slow sand filters 15.2 cm wide, 3.1 m long and 15.2 cm deep were built and loaded with domestic septic tank effluent for 250 days at a rate of 5.1 cm per day. Influent and effluent samples were collected and analyzed for five-day Biochemical Oxygen Demand (BOD_5), suspended solids, ammonia-nitrogen, and nitrate-nitrogen. One filter received septic tank effluent through a 10 cm nominal diameter PVC perforated pipe via a distribution box dosed by a pump with gravity flow from the distribution box to the pipe. The other filter received water through a 2.5 cm nominal diameter PVC pipe having 0.4 cm diameter holes drilled 76.2 cm on center.

The gravity distribution filter system achieved mean effluent values of 36.4 mg/l BOD_5, 19.8 mg/l suspended solids, 37.6 mg/l ammonia-nitrogen, and 46.6 mg/l nitrate-nitrogen. The pressurized distribution system achieved 19.1 mg/l BOD_5, 12.2 mg/l suspended solids, 25.3 mg/l ammonia-nitrogen, and 64.03 mg/l nitrate-nitrogen. Influent to the filters averaged 132.1 mg/l, 90.3 mg/l, 70.3 mg/l, and 3.6 mg/l BOD_5, suspended solids, ammonia-nitrogen, and nitrate-nitrogen, respectively.

INTRODUCTION

Gravity distribution of wastewater over sand filters and into soil absorption trenches is the traditionally accepted method of placing the wastewater on the treatment surface. The work described in this paper shows that improving distribution of the wastewater over the filter surface also improves the quality of treated water.

Gravity distribution for soil absorption trenches generally consists of a distribution box with 10 cm diameter pipe leading to the trenches. The trenches receive septic tank effluent from perforated 10 cm diameter pipe laid at a grade varying from 5 cm per 30.5 m to 10 cm per 30.5 m (Arkansas Department of Health, 1987). The septic tank effluent flows down the perforated pipe and out onto the treatment surface (gravel) through 1 cm diameter holes. With the large pipe and holes and the small flows from the septic tank in the distribution box, most of the effluent flows from only a few holes. Soil absorption trenches may clog due to unequal distribution and overloading a small soil absorption area under the holes receiving flow (Otis, 1985; Mote and Griffis, 1986). The filter used in the gravity distribution system for this study exhibited the flow pattern with most of the septic tank effluent passing through a few holes and heavily loading a small portion of the filter surface.

Gravity distribution of wastewater over buried intermittent sand filters typically uses 10 cm diameter perforated pipe, spaced 0.9 m on center. Unless the pipe is dosed by means of a pump large enough to fill the pipe and cause wastewater to flow from most of the holes, the same heavy loading of an area under a few holes occurs.

Free access or open-top sand filters may be designed with distribution pipes with open ends over a splash plate. A pump forces the wastewater through the pipe to a fitting with the open end pointing toward the splash plate so the wastewater hits the plate and splashes out onto the filter surface (U.S. Environmental Protection Agency, 1980). Of course, this distribution method also heavily loads a small area of the filter around the splash plate unless enough wastewater is pumped onto the filter to cause flooding of the entire surface. Recognizing these problems, designers and researchers began developing better wastewater distribution systems in the late 1970s. About the same time, sewage effluent pumps emerged as a reliable technology with simple, understandable control systems (Carlisle, 1985). Combining effluent pump technology with hydraulic principles led to development of pressurized distribution systems for septic tank-soil absorption systems and sand filters, with North Carolina using the so-called low pressure pipe (LPP) system extensively in the mountainous areas of the state (Cogger, *et al.*, 1982). Meanwhile, Mote *et al.*, 1981; Mote and Pote, 1982 were developing techniques in Arkansas to overcome unequal pressure (and therefore uneven flow) in soil absorption trench distribution systems located on unlevel sites.

The pressurized distribution system for wastewater treatment through sand filters or soil absorption trenches is now commonly recognized as an alternative for overcoming soil and site restrictions that do not allow gravity distribution to function properly (Perkins, 1989; Oregon Department of Environmental Quality, 1988). Pressurized distribution systems are performing well in their function to load the soil or sand treatment surface evenly, spreading the wastewater over a larger area, and preventing failure of the treatment system due to clogging the filter or soil surface. Until recently, however, little information has been available regarding the effectiveness of wastewater treatment due to distributing the wastewater more uniformly over the treatment surface. Certainly no comparison of uniform distribution to "standard" or gravity distribution has been reported.

MATERIALS AND METHODS

Two identical filter trenches were constructed in the laboratory and loaded with domestic septic tank effluent by different distribution techniques. One filter received wastewater by gravity distribution and the other by pressurized distribution.

The filter trenches were 3 m long and 15.2 cm wide built in wooden frames lined with polyethylene. Each filter consisted of 15.2 cm depth of Arkhola Sand and Gravel Company's-28 filter sand with an effective size of approximately 0.25 mm and a uniformity coefficient of approximately 2.0. The filter sand was underdrained by a 10 cm diameter perforated PVC pipe in 15.2 cm of 1.3 cm pea gravel. The distribution pipe was placed on 5 cm of 1.3 cm pea gravel to protect the sand surface from erosion. Figure 1 illustrates a cross-section of the filters.

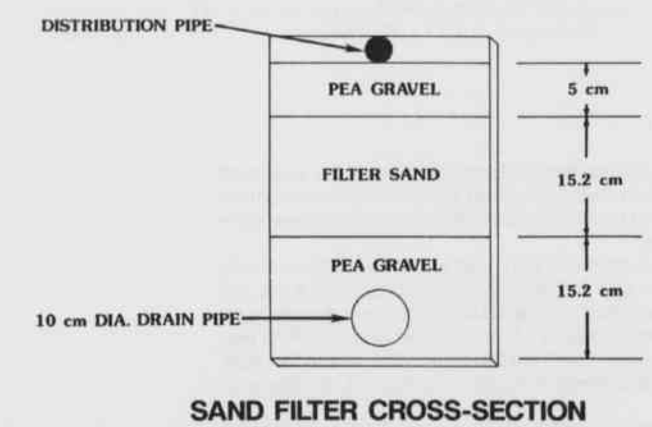

Figure 1. Sand Filter Cross-Section.

The pressurized distribution filter received septic tank effluent pumped from a 113 liter reservoir through a 2.5 cm schedule 40 PVC pipe with 4 mm diameter orifi drilled 76.2 cm on center. The pipe was pressurized at approximately 46 cm of water head by means of a Little Giant Model 1-A pump. The gravity distribution filter received septic tank through 10 cm diameter perforated PVC pipe (ASTM D2729) laid at 10 cm per 30 m or 0.33% slope. The septic tank effluent was pumped from the 113 liter reservoir into a polyethylene distribution box where it flowed down the gravity distribution pipe. Again, a Little Giant Model 1-A pump was used. Both pumps were connected to an electrical control panel having a 96-pin 24-hour timer in series with a DIP switch relay set for 30 seconds. The pumps were simultaneously and automatically operated for 30 seconds 6 times per day at 7.6 liters per minute. The loading rate for each filter was 5.1 cm per day. Samples were taken from the 113 liter reservoir and from each filter underdrain and analyzed for five day Biochemical Oxygen Demand (BOD_5), total suspended solids, ammonia-nitrogen, and nitrate-nitrogen. The filters were operated for 250 days.

The BOD_5 analyses were performed according to Method 5210 B of *Standard Methods,* (1989) 17th Edition, using a YSI dissolved oxygen meter calibrated against the Azide Modification of the Winkler Method (*Standard Methods,* 1989, 4500-0-C). Total suspended solids were analyzed using Method 2540 D of *Standard Methods,* (1989) 17th Edition. The ammonia-nitrogen was analyzed using Method 4500-NH_3C, Direct Nesslerization Method of *Standard Methods,* (1989) 17th Edition. Colorimetric analyses were performed using a Perkin-Elmer Model 554 UV-Visible double-beam spectrophotometer. Nitrate-nitrogen was analyzed using HACH Chemical Company Nitra Ver 5 reagent powder pillows with colorimetric analyses by means of a Perkin-Elmer Model 554 UV-Visible double-beam spectrophotometer (HACH Company, 1989).

RESULTS

The filter receiving septic tank effluent by pressurized distribution consistently treated the wastewater to a higher quality effluent than did the filter receiving septic tank effluent by gravity distribution. Figure 2 shows second-degree polynominals fitted through the BOD_5 data by least squares. Over the 250 day filter runs, the pressurized distribution produced an effluent with an average of 19.1 mg/ℓ BOD_5 as compared to an average BOD_5 concentration of 36.5 mg/ℓ in the gravity distribu-

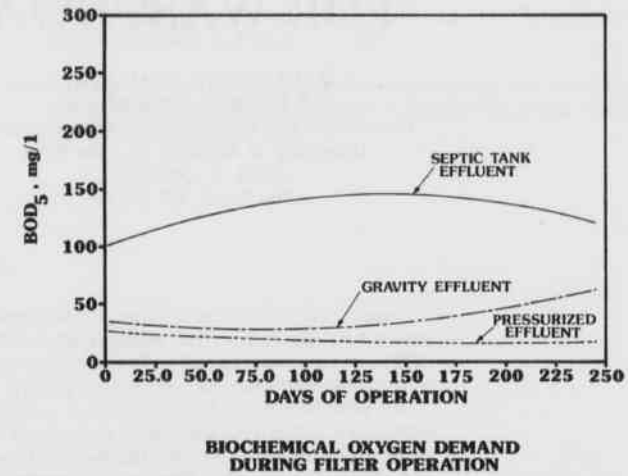

Figure 2. BOD_5 During Filter Operation

tion filter. The average BOD_5 in the septic tank effluent was 132.1 mg/ℓ. The pressurized distribution reduced the BOD_5 concentration by an average of 85.5 percent while gravity distribution achieved only a 72.5 percent BOD_5 removal.

The suspended solids data trends are shown in Figure 3 as second-degree polynominals fitted to the data by least squares. Again, the pressurized distribution system consistently produced an effluent with a lower suspended solids concentration than the effluent from the gravity distribution filter. The average pressurized distribution filter effluent suspended solids concentration was 12.2 mg/ℓ as compared to 19.8 mg/ℓ in the gravity effluent. The suspended solids removal efficiences were 86.5 percent and 78.1 percent for the pressurized distribution and gravity distribution filters, respectively.

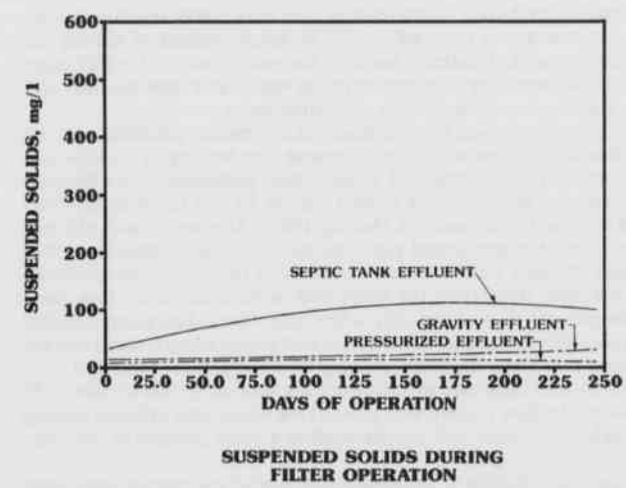

Figure 3. Suspended Solids During Filter Operation.

Figures 4 and 5 show the data for nitrogen conversion in the filters. Although a complete nitrogen balance cannot be computed since total Kjeldahl nitrogen and nitrite nitrogen analyses were not performed, the data still shows the filters' relative performance in terms of nitrification. Again, second-degree polynominals were drawn through the data points by a least-squares fit. The pressurized distribution system consistently produced filter effluent with lower ammonia concentrations and higher nitrate concentrations than in the gravity distribution filter effluent. The ammonia and nitrate concentrations were 25.3 mg/ℓ and 64.0 mg/ℓ respectively in the effluent from the filter with pressurized

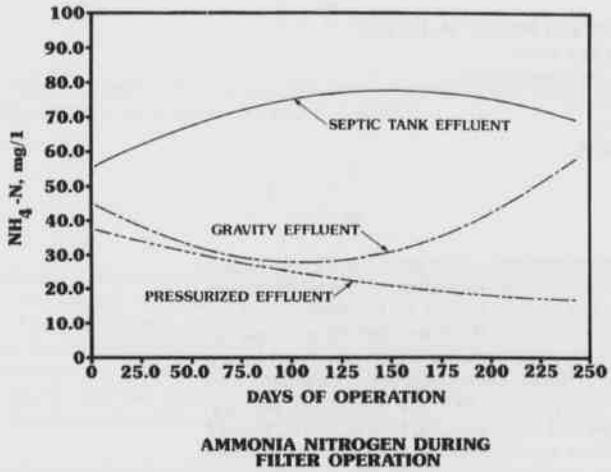

Figure 4. Ammonia Nitrogen During Filter Operation.

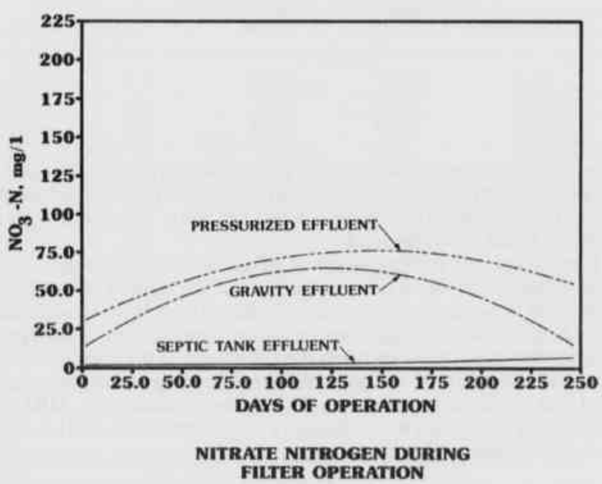

Figure 5. Nitrate Nitrogen During Filter Operation.

distribution. The ammonia and nitrate concentrations in the gravity distribution effluent were 37.6 mg/*l* and 46.6 mg/*l*, respectively. All ammonia and nitrate concentrations are expressed as mg nitrogen per liter.

DISCUSSION

The implications and applications of the data from the filter runs range from better selection of technology for onsite wastewater treatment systems to improving sand filter performance for small municipalities. Shallow soil conditions in North Central Arkansas require that septic tank-soil absorption systems treat the septic tank effluent as efficiently as possible in the soil before infiltrating through fractured rock into groundwater supplies. A different condition, but similar treatment requirement exists in the gravelly soils of Northwest Arkansas, where hydraulic conductivity is high and septic tank effluent moves quickly through the soil into the fractured limestone of the Karst terrain. By recognizing the shallow and high-permeability soils and selecting pressurized distribution of septic tank effluent in the soil absorption system, cost-effective efficient treatment can be achieved. Since "out-of-site out-of-mind" has been the traditional approach to septic system performance, rapid movement of low-quality effluent through the soil and out of sight has been considered desirable. Use of pressurized distribution systems in soil absorption systems treat the septic tank effluent more completely and thereby protect the integrity of the groundwater.

Another application of these data is in the area of sand filters used for small community wastewater treatment systems. These filters may be used to treat centrally-collected septic tank effluent or they may be used to polish facultative lagoon (stabilization pond) effluent. Often, the distribution system for these filters is either gravity distribution through 10 cm diameter pipe or splash plate application. Many small communities struggle to stay in compliance with their permitted effluent discharge limits, and changing from gravity to pressurized distribution may be a cost-effective means to meet their permit limits. In any case, pressurized distribution will cause the sand filters to produce a higher quality effluent.

Currently, work is in progress to evaluate dosing length and frequency and their effects upon filter performance. Preliminary data show that small frequent doses produce a much higher quality effluent than large infrequent doses.

ACKNOWLEDGMENT

This project is supported through the Arkansas Onsite Wastewater Renovation Project of the University of Arkansas.

LITERATURE CITED

ARKANSAS DEPARTMENT OF HEALTH. 1987. Rules and regulations pertaining to sewage disposal systems, Designated representatives and installers as provided in Act 402 of 1977, p. 17.

CARLISLE, B.L. 1985. Sewage effluent pumps the future in small scale waste. Southwest and Texas Water Works Journal, pp. 10-12.

COGGER, C., B.L. CARLISLE and D. OSBORNE. 1982. Design and installation of low-pressure pipe waste treatment systems. University of North Carolina UNC-SG-82-03, p. 31.

HACH COMPANY WATER ANALYSIS HANDBOOK. 1989. HACH Company, Loveland, pp. 640-641.

MOTE, C.R., E. RAUSCH, J. POTE, and R. ESTES, 1981. Design of systems for pressure distribution of septic tank effluent in sloping filter fields. Report Series 257. University of Arkansas, Fayetteville, p. 22.

MOTE, C.R. and C.L. GRIFFIS. 1986. Onsite domestic wastewater renovation system designs to overcome soil limitations utilization, treatment and disposal of waste on land. Proc. Soil. Sci. Soc. am., pp. 129-138.

MOTE, C.R. and J.W. POTE. 1982. Computer design and simulation of systems for pressurized distribution of septic tank effluent in sloping filter fields. Report Series 273. University of Arkansas, Fayetteville, p. 23.

OREGON DEPARTMENT OF ENVIRONMENTAL QUALITY ON-SITE SEWAGE DISPOSAL RULES. 1988. Oregon Administrative Rule Chapter 340-Divisions 71, 72, and 73, p. 61.

OTIS, R.J. 1985. Soil clogging: mechanisms and control onsite wastewater treatment. ASAE. 4:238-250.

PERKINS, R.J. 1989. Onsite wastewater disposal. Lewis Pub., Chelsea, Michigan, 251 pp. 113-133.

STANDARD METHODS FOR THE EXAMINATION OF WATER AND WASTEWATER. 1989. 17th Edition. AWWA. pp. 5-4 - 5]-10, 2-75 - 2-77, 4-117 - 4-120.

U.S. ENVIRONMENTAL PROTECTION AGENCY DESIGN MANUAL. 1980. Onsite wastewater treatment and disposal sytems. EPA 625/1-80-012, p. 131.