This is not a peer-reviewed article.
Pp. 084-091 in the *On-Site Wastewater Treatment X*, Conference Proceedings,
21-24 March 2004 (Sacramento, California USA), Publication Date 21 March 2004.
ASAE Publication Number 701P0104, ed. K.R. Mankin.

CLOGGING INCIDENCE OF DRIP IRRIGATION EMITTERS DISTRIBUTING EFFLUENTS OF DIFFERING LEVELS OF TREATMENT

M. Rowan, K. Mancl, O. H. Tuovinen

ABSTRACT

Four types of drip irrigation emitters from three manufacturers were used to distribute effluents of different qualities. The control emitters were embedded in commercial grade landscape dripline, which was not designed for use with treated wastewater. The experimental emitters included one non-pressure compensating, turbulent flow emitter and two pressure compensating diaphragm regulated emitters. The experimental emitters were specifically designed for use with treated wastewater and contained antimicrobial agents to prevent emitter clogging. The emitters distributed tap water, primary septic tank effluent and secondary sand bioreactor effluent. All three effluents were run through a 100-micron filter. Each effluent was distributed through each emitter type for ten minutes every six hours, seven days a week for twelve months. Emitter flow rates were measured each month to evaluate system performance and identify clogged emitters. The control emitters exhibited the greatest reduction in flow rates with an average reduction of 16% for septic tank effluent and 3% for sand bioreactor effluent. With experimental emitters, the average flow rates were reduced by as much as 11% for septic tank effluent and 2% for sand bioreactor effluent. By the end of the experiment, many of the clogged emitters had recovered to near their original flow rates. The emitters distributing the septic tank effluent exhibited the most significant reduction in flow, with a maximum of 80% in the most severely restricted experimental emitter. The sand bioreactor, which reduced the effluent 5-day biochemical oxygen demand from 147 mg/l to 0.5 mg/l and total suspended solids from 55 mg/l to 3 mg/l, also reduced the degree of clogging in all four types of emitters. After one year of use, the control emitters distributing primary septic tank effluent showed the greatest amount of clogging. The three driplines designed for irrigating wastewater were functioning as designed.

KEYWORDS. Biofilms, Clogging, Drip/Trickle irrigation, Emitter, On-site wastewater treatment, Sand bioreactor, Septic tank, Sewage sludge

INTRODUCTION

The application of treated effluents for agricultural purposes has become widespread in some countries of the arid and semi-arid zones worldwide. Drip irrigation provides many advantages over the traditional spray irrigation method that has been popular in the past. Benefits of drip include: (1) cost savings due to the high nutrient value of the wastewater effluent (Nielsen, 1989); (2) improved public health and safety by avoiding spray drift and exposure to effluent (Asino & Pettygrove, 1987); (3) energy conservation (Batty et al., 1975); and (4) water conservation (Schleiche, 1977).

Drip irrigation technology has been suggested as an alternative to traditional on-site wastewater treatment and dispersal systems. Drip systems offer a solution where other soil treatment systems are inappropriate due to a seasonally high water table, a shallow dense soil layer, vegetative cover, space constraints, or other site limitations. Drip dispersal is a technique of applying treated wastewater effluent in an even and controlled manner to take full advantage of the entire application area over the course of the entire day. The goals of drip dispersal are to attain unsaturated flow, encourage lateral movement through capillary action rather than gravitational flow, and distribute the effluent over the entire application area to exploit soil physical, chemical and biological processes for the entire 24-hours.

Clogging of emitters has been a major problem in dripline systems because of the high levels of suspended solids and nutrients associated with treated wastewater effluents. Biofilms that develop inside the driplines accumulate inorganic and organic materials, which can eventually block the small orifices of the emitters. Previous research indicates that the cause of clogging in drip irrigation systems fall into three main categories: (1) physical, caused by suspended solids; (2) chemical, caused by precipitation reactions; and (3) biological, caused by bacterial and algal growth (Bucks et al., 1979). Emitter clogging is usually the result of two or more of these processes working in concert (Nakayama, 1978). Much research has been performed to determine the causes and prevention of emitter clogging (Oron et al, 1979; Adin, 1987; Adin and Sacks, 1991; Ravina et al., 1992; Tajrishy et al., 1994; Taylor et al., 1995; Ravina et al., 1997). The following recommendations have been made in the literature to prevent emitter clogging and ensure long-term success:

- Filter the effluent prior to dispersal and flush the filters frequently.
- Provide chlorination to help prevent and eliminate slimes and biofilms.
- Maintain turbulent flow through the emitter to prevent particle settling and biofilm formation.
- Flush all lateral lines with a scoring velocity of 0.30-0.61 m sec^{-1} (1-2 ft sec^{-1}) to remove slimes and biofilms.
- Use pressure-compensating emitters to prevent non-uniformity in the discharge rate of emitters within the system.

The manufacturers of wastewater drip irrigation systems have made numerous modifications to emitter design and other system components to incorporate these suggestions.

The purpose of this study was (1) to determine if drip irrigation systems provide an effective long-term solution to wastewater reuse and disposal; (2) to compare different filtration and drip tubing strategies with respect to their resistance to clogging and biofilm development; and (3) to determine the relationship between effluent treatment levels and the incidence of clogging.

METHODS

Experimental Design

This study used a laboratory scale drip irrigation setup with 12 lines of irrigation tubing, each 3.7 m in length. Three different types of wastewater drip tubing were selected for analysis and agricultural/horticultural drip tubing was used as control. Two sources of wastewater, septic tank effluent and sand filter effluent, were irrigated. A third source, tap water, was used as control.

Water Source

Three laboratory scale septic tanks were established using a protocol described by Peeples and Mancl (1998). Two tanks were loaded at 24-hr cycles with approximately 57 liters of tap water, 500 ml of primary sludge and 250 ml of 0.363 M ammonium chloride. The primary sludge was acquired from the Southerly Wastewater Treatment Plant (Columbus, Ohio). The third tank matched all aspects of the protocol except that the primary sludge and ammonium chloride were not added. This tank served as the control. Biochemical oxygen demand (BOD_5) and total suspended solids (TSS) were analyzed using Standard Methods 5210 B and 2540 D (APHA, 1998). Ammonia was measured using Quickchem Method number 12-107-06-2-A. The effluent characteristics are given in Table 1.

Table 1. Wastewater Effluent Characteristics.

Water Source	Characteristics			
	BOD_5 (mg/l)	TSS (mg/l)	Ammonia (mg/l)	pH
Septic Tank Effluent	147	55	18	6.5
Sand Filter Effluent	0.5	3	1	7.2

Water Delivery

At 24-hr intervals, approximately half of the contents from one of the septic tanks was discharged into a sand bioreactor for secondary treatment. The sand bioreactor consisted of a cylindrical polyethylene container, 0.79 m high and 0.55 m in diameter filled with 76 cm of sand. The sand had an effective size of 0.5 mm with a uniformity coefficient of 4. After secondary treatment, the effluent was transferred to a dosing tank that was identical to the septic tank in size and design. The effluents from the second septic tank and the tap water control tank were transferred to their respective dosing tanks with no further treatment. Each dosing tank contained a ¼ h.p. submersible pump that delivered 0.06 l s^{-1} of effluent through 0.03 m clear flexible tubing to a Netafim Low Volume Control Zone (LVCZ) unit. The LVCZ combines a 24 V solenoid controlled valve, a 100-micron disc filter and a 137,895 Pa (20 psi) pressure regulator into a single unit. Each LVCZ unit was connected to a 0.10 m PVC manifold with four 0.01 m male adapters. The pressure at the PVC manifold was 89,631 Pa (13 psi). The 3.7 m sections of drip irrigation tubing were connected over the 0.01 m adapters to another identical manifold where the remaining effluent was collected and returned to the dosing tanks. The flow rate through the dripline tubing was 0.61 m s^{-1} (2 ft per sec).

Dripline and Emitters

Four different types of irrigation tubing were examined.

- Type 1: Netafim Bioline. Pressure compensating dripline for wastewater: a pressure compensating diaphragm emitter spaced 0.61 m (24 in) on center and impregnated with the biocide Vinyzene. The Netafim Bioline has a nominal discharge rate of 2.31 l hr^{-1} (0.61 gal hr^{-1}) at 48,263 – 413,685 Pa (7-60 psi).
- Type 2: Geoflow PC Wasteflow. Pressure compensating dripline for wastewater: a pressure compensating turbulent flow emitter spaced 0.61 m (24 in) on center with the root intrusion preventing ROOTGUARD (Treflan) and the bactericide Ultra Fresh DM-50 in the dripper line. The Wasteflow PC Dripline has a nominal discharge rate of 2.01 l hr^{-1} (0.61 gal hr^{-1}) at 48,263 – 413,685 Pa (7-60 psi).
- Type 3: Geoflow NPC Wasteflow. Non-pressure compensating dripline for wastewater: a non-pressure compensating turbulent flow emitter spaced 0.61 m (24 in) on center with the root intrusion preventing ROOTGUARD (Treflan) and the bactericide Ultra Fresh DM-50 in the dripper line. The Wasteflow Classic Dripline has a nominal discharge rate of 4.92 l hr^{-1} (1.3 gal hr^{-1}) at 137,895 Pa (20 psi).
- Type 4: Non-pressure compensating dripline for traditional agricultural/horticultural irrigation applications.

Irrigation Schedule

A Netafim Miracle AC 12 Irrigation Controller controlled the irrigation schedule. This unit controlled the solenoid valves and the dosing pumps and was programmed to irrigate with each effluent for ten minutes, four times each day, seven days a week.

Emitter Performance

To evaluate emitter performance, an initial flow rate was measured for each emitter in the system prior to beginning the experiment. The flow rate was determined by measuring the volume of effluent, using a100 ml graduated cylinder, over a fixed unit of time. This procedure was repeated each month during the experiment.

RESULTS AND DISCUSSION

Control Emitters-Traditional Agricultural/Horticultural Dripline

The initial and ending flow rates and relative changes over a one-year period are given in Table 2. After one year of continuous irrigation the control emitters distributing tap water showed no signs of clogging. The flow rates of control emitters distributing septic tank effluent were reduced by 16 % overall with the most severe reduction being 63 % for emitter 7. The flow rates of control emitters distributing sand bioreactor effluent were reduced 3%.

Table 2. Initial and Final Flow Rates of Control Emitters for One Year.

Emitter	Tap Water			Septic Tank Effluent			Sand Bioreactor Effluent		
	Initial	Final	%Change	Initial	Final	%Change	Initial	Final	%Change
1	42	44	5	44	45	2	45	44	-2
2	44	48	8	42	45	7	45	47	4
3	42	44	5	45	47	4	45	39	-13
4	44	46	5	43	33	-23	44	44	0
5	41	44	7	40	38	-5	47	48	2
6	44	47	7	41	28	-32	47	46	-2
7	43	45	5	43	16	-63	49	45	-8
8	44	47	6	43	26	-40	47	50	6
9	43	45	5	41	31	-24	47	41	-13
10	45	45	0	41	42	2	48	48	0
11	45	47	4	44	40	-9	48	46	-4
% change (average)			5			-16			-3

<u>Geoflow NPC Emitters</u>

The initial and ending flow rates and relative changes over a one-year period are given in Table 3. The emitters distributing tap water and sand bioreactor effluent showed no signs of clogging. The flow rates of emitters distributing septic tank effluent were reduced by 6% overall.

Table 3. Initial and Final Flow Rates of Geoflow NPC Emitters for One Year.

Emitter	Tap Water			Septic Tank Effluent			Sand Bioreactor Effluent		
	Initial	Final	%Change	Initial	Final	%Change	Initial	Final	%Change
1	34	34	0	33	30	-9	32	33	3
2	32	32	0	32	28	-13	32	34	6
3	31	32	3	31	29	-6	34	36	6
4	31	32	3	32	32	0	34	36	6
5	33	35	6	32	30	-6	34	34	0
6	33	35	6	32	32	0	34	36	4
% change (average)			3			-6			4

<u>Geoflow PC Emitters</u>

The initial and ending flow rates and relative changes over a one-year period are given in Table 4. The emitters distributing tap water showed no signs of clogging. The emitters distributing sand bioreactor effluent showed no clogging with the exception of emitters 2 and 5. The flow rates of emitters distributing septic tank effluent were reduced by 11% overall.

Table 4. Initial and Final Flow Rates of Geoflow PC Emitters for One Year.

Emitter	Tap Water			Septic Tank Effluent			Sand Bioreactor Effluent		
	Initial	Final	%Change	Initial	Final	%Change	Initial	Final	%Change
1	22	22	0	20	17	-15	23	23	0
2	23	21	-9	22	21	-5	22	19	-14
3	22	22	0	21	19	-10	24	24	0
4	22	22	0	21	21	0	23	24	4
5	21	23	9	21	17	-19	22	21	-5
6	21	22	5	23	19	-17	23	24	4
% change (average)			1			-11			-2

Netafim Emitters

The initial and ending flow rates and relative changes over a one-year period are given in Table 5. The Netafim emitters showed no signs of clogging after one year of continuous operation.

Table 5. Initial and Final Flow Rates of Netafim Emitters for One Year.

Emitter	Tap Water			Septic Tank Effluent			Sand Bioreactor Effluent		
	Initial	Final	%Change	Initial	Final	%Change	Initial	Final	%Change
1	53	55	4	52	55	6	57	56	-2
2	54	53	-2	52	54	4	54	54	0
3	53	54	2	51	54	6	56	58	4
4	53	53	0	52	52	0	55	56	2
5	54	54	0	54	51	-6	56	58	4
6	54	56	4	53	55	4	55	55	0
% change (average)			1			2			2

Recovery of Clogged Emitters

A gradual reduction of flow followed by a partial recovery was observed in emitters of each type (Table 6). The maximum flow reduction occurred after eight to ten months for the control emitters distributing septic effluent (Figure 1). For the experimental emitters distributing septic tank effluent, the maximum flow reduction occurred between six and ten months (Figure 2). The reduction in the Netafim emitters was the least severe. A partial recovery was observed the following month in every case. This phenomenon could represent biofilm formation that is later sloughed off as a result of the scouring velocity of the water or the pressure created by the pumps at the initiation of each cycle. It is plausible that if biofilm growth inside the emitter resulted in a narrower passageway, inorganic particles that would otherwise pass through may get caught up inside the emitter, thus resulting in the observed flow reduction. After several cycles of irrigation, those particles could be flushed out resulting in the partial recovery.

Table 6. Changes in Flow Rates of Septic Tank Effluents from July 2002 to July 2003.

Emitter	Flow Rates (ml/min)						
	Jul 2002	Sep 2002	Nov 2002	Jan 2003	Mar 2003	May 2003	Jul 2003
Control #4	43	47	42	26	21	8	16
Control #5	40	44	37	26	24	7	26
Control #6	41	43	36	19	15	28	31
Geoflow PC #1	20	21	20	19	18	7	16
Geoflow PC #3	21	23	19	10	8	19	18
Geoflow NPC #1	33	34	30	29	28	6	30
Geoflow NPC #3	31	32	29	19	26	13	29
Netafim #4	52	55	51	46	50	52	52

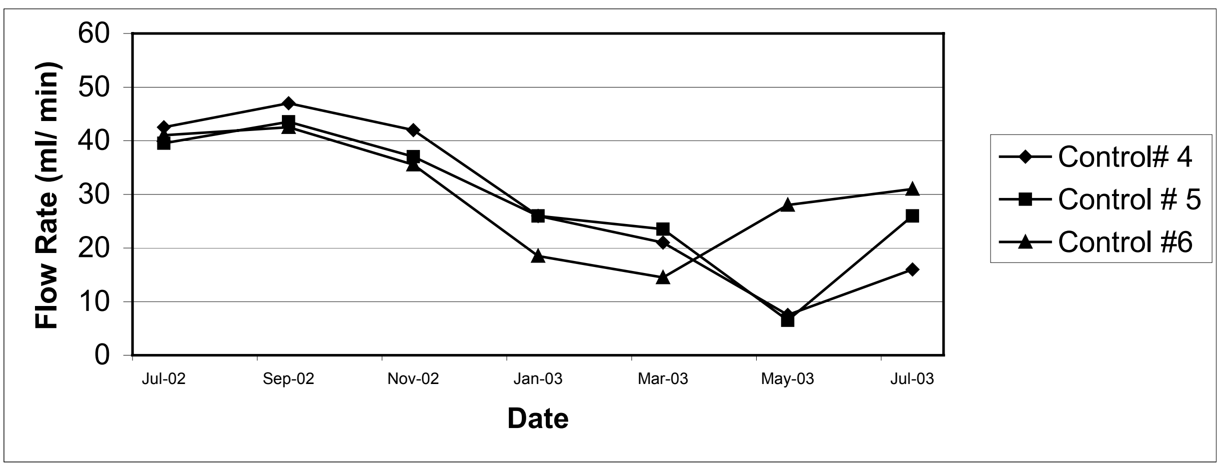

Figure 1. Change in Control Emitter Flow Rates

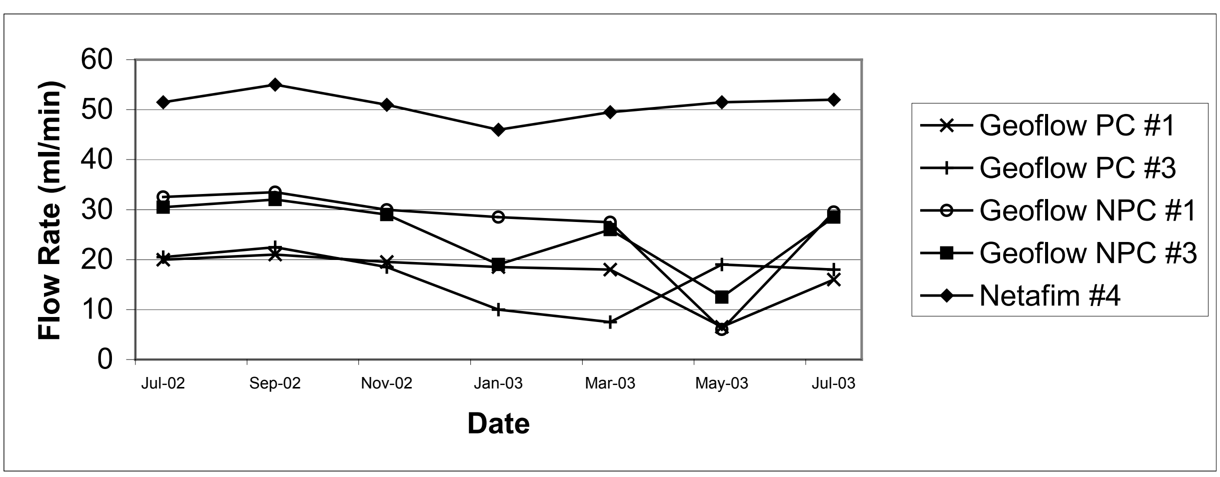

Figure 2. Change in Experimental Emitter Flow Rates

CONCLUSIONS

The purpose of this study was to determine if drip irrigation systems provide an effective long-term solution to wastewater reuse and disposal. These experimental drip irrigation systems, designed and implemented according to the manufacturers' recommendations, functioned properly for at least one year of continuous operation. Pretreating the wastewater with a sand bioreactor provided the best performance. Septic tank effluent was also successfully distributed with drip irrigation tubing that was designed specifically for use with wastewater. Reduced flow of up to 11% occurred in some driplines. In field applications, dosing run times may be increased to compensate for these reduced flows to meet the designed hydraulic load requirements. The control emitters contained in the traditional agricultural/horticultural dripline performed satisfactorily with sand bioreactor effluent but not with septic tank effluent.

Flow reduction of 80% occurred in some experimental emitters. The clogging occurred gradually over several months, but the flow reductions were partially reversed within a month.

The 100-micron disc filters were manually cleaned daily. Failure to clean the filters resulted in reduced flow and reduced pressure at the dripline manifold due to the accumulation of particulate matter in the filters. Manual cleaning of the filters would present an unreasonable maintenance requirement for any onsite drip irrigation system. Automatic flushing for filter cleaning with each dose cycle is essential for long-term operation of drip systems using either sand bioreactor effluent or septic tank effluent.

Aknowledgements

Support for this project was provided by The Ohio State University Extension, Ohio Agricultural Research and Development Center Site. The project was financed in part through a grant from the Ohio Environmental Protection Agency and the United States Environmental Protection Agency, under the provisions of Section 319(h) of the Clean Water Act. Drip irrigation tubing was supplied by Netafim USA, Geoflow, and Irrigation Supply of Dublin, Ohio. The assistance of Kevin Duemmel and Chris Gecik is greatly appreciated.

REFERENCES

1. Adin, A. 1987. Clogging in irrigation systems reusing pond effluents and its prevention. *Water Science and Technology,* 19(12): 323-331.
2. Adin, A., and M. Sacks. 1991. Dripper clogging factors in wastewater irrigation. *Journal of Irrigation and Drainage Engineering,* 117(6): 813-825.
3. Asano, T., and G. S. Pettygrove. 1987. Using reclaimed municipal wastewater for irrigation. *California Agriculture,* 41(3-4): 15-18.
4. Batty, J. C., S. N. Hamad, and J. Kelly. 1975. Energy inputs to irrigation. *Journal of Irrigation and Drainage Division,* ASCE, 101 (IR4) Proc. Paper 11810, 293-307.
5. Bucks, D. A., F. S. Nakayama, and R. G. Gilbert. 1979. Trickle irrigation water quality and preventive maintenance. *Agricultural Water Management,* 2(2): 149-162.
6. Nakayama, F., R. Gilbert, and D. Bucks. 1978. Water treatments in trickle irrigation systems. *Journal of the Irrigation and Drainage Division,* 104(1): 23-34.
7. Neilsen, G. H. 1989. Nutrition and yield of young apple trees irrigated with municipal wastewater. *Journal of the American Society of Horticulture Science,* 114(3): 377-383.
8. Oron, G. 1996. Soil as a complementary treatment component for simultaneous wastewater disposal and reuse. *Water Science and Technology,* 34(11): 243-252.
9. Peeples, J., and K. Mancl. 1998. Laboratory scale septic tanks. *Ohio Journal of Science,* 48(4/5): 75-79.

10. Ravina, E. P., Z. Sofer, A. Marcu, A. Shisha, and G. Sagi. 1992. Control of emitter clogging in drip irrigation with reclaimed wastewater. *Irrigation Science,* 13(3): 129-139.

11. Ravina, E. P., Z. Sofer, A. Marcu, A. Shisha, G. Sagi, and Y. Lev. 1997. Control of clogging in drip irrigation with stored treated municipal sewage effluent. *Agricultural Water Management,* 33(2-3): 127-137.

12. Schleiche, J. 1977. Drip study shows up to 30% water savings. *Irrigation Agriculture,* 11(4): 37-69.

13. Standard Method, 1998. Standard methods for the examination of water and waste water, 20^{th} ed., American Public Health Association, Washington, D.C.

14. Tajrishy, M., D. Hills, and G. Tchobanoglous. 1994. Pretreatment of secondary effluent for drip irrigation. *Journal of Irrigation and Drainage,* 120(4): 716-731.

15. Taylor, H. D., R. K. X. Bastos, H. W. Pearson, and D. D. Mara. 1995. Drip irrigation with waste stabilization pond effluents: Solving the problem of emitter fouling. *Water Resources,* 29(4): 1069-1078.