Subsurface Drip Irrigation Using Livestock Wastewater: Dripline Flow Rates

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Abstract. *Using subsurface drip irrigation (SDI) with lagoon wastewater has many potential advantages. The challenge is to design and manage the SDI system to prevent emitter clogging. The objective of this study was to measure the flow rates of five types of driplines (with emitter flow rates of 0.57, 0.91, 1.5, 2.3, and 3.5 L/h/emitter) when used with lagoon wastewater. A disk filter with openings of 55 µm (200 mesh) was used and shock treatments of chlorine and acid were injected periodically. During the 1998 growing season, 530 mm of wastewater were applied through the SDI system and 390 mm were applied in 1999. During the growing seasons, the two lowest flow rate emitter designs decreased in flow rate, indicating that some emitter clogging had occurred. The magnitudes of the decreases were 15% and 11% of the original flow rates in 1998 and 22% and 14% in 1999 for the 0.57 L/h/emitter and 0.91 L/h/emitter driplines, respectively. After the winter idle period, the flow rates of both driplines returned to the initial flow rates. The three emitter designs with higher flow rates showed little sign of clogging; their flow rates decreased by 4% or less through both growing seasons. Observations showed that the disk filter and automatic backflush controller performed adequately in 1998 and 1999. Based on these preliminary results, the use of SDI with lagoon wastewater shows promise. However, the smaller emitter sizes (0.91 L/h/emitter or less) may be risky for use with wastewater and the long-term (greater than two growing seasons) effects are untested.*

Keywords. *Microirrigation, Drip irrigation, Trickle irrigation, Animal waste management, SDI, Wastewater.*

Approximately 8 million cattle are on feed in the central and southern Great Plains of the USA; more than 2 million are in Kansas alone. Using the Kansas design parameter of 23 m^2 per animal, the land area of feedlots in the Great Plains is approximately 18 400 ha, and that in Kansas is approximately 4600 ha. Phillips (1981) estimated that 20 to 33% of average annual precipitation in the Great Plains could be collected as runoff from feedlots. Using the lower end of that range (20%) and assuming an average annual precipitation of 500 mm, averages of approximately 4.6×10^6 m^3 of runoff from feedlots might be available annually in Kansas and 18.4×10^6 m^3 in the Great Plains. Areas of higher rainfall would collect more runoff, and the amount collected would vary from year to year, based on precipitation. This feedlot runoff, minus any evaporation from the lagoons, must be disposed of by land application.

Using subsurface drip irrigation (SDI) with water from animal waste lagoons (hereinafter called wastewater) has many potential advantages. These include, but are not limited to, reduced human contact with wastewater; reduced odor; reduced runoff of wastewater into surface waters; placement of phosphorus-rich water beneath the soil surface where runoff potential is reduced; greater uniformity of water application resulting in better control of the water, nutrients, and salts; reduced corrosion of irrigation systems; reduced application constraint by weather (especially high winds and low temperatures); and increased flexibility in matching field and irrigation system sizes.

Research has shown that soil acts as an additional treatment (or filter) for municipal wastewater applied through an SDI system. Oron (1996) injected poliovirus into the soil with an SDI system. He found limited virus content in the leaves of tomato (*Lycopersicon esculentum* Mill.) plants but none in the fruit. No fecal coliforms were found in the ears or husks of sweet corn (*Zea mays* L.) irrigated using secondary treated municipal wastewater with SDI; whereas, some contamination was found in corn irrigated with surface drip irrigation (Oron et al., 1991). Oron et al. (1992) noted that sprinkler irrigation with secondary treated municipal wastewater was less desirable than drip irrigation with respect to viral and bacterial contamination of soils and plants. Treated wastewater also has been applied successfully though SDI systems in Hawaii (Gushiken, 1995).

Treated residential wastewater, which is not as highly treated as municipal effluent, has also been disposed with

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SDI systems. Lesikar et al. (1998) successfully applied wastewater through two SDI systems with emitter flow rates of 2.0 L/h and 4.0 L/h. The treated wastewater had BOD_5 between 4.01 and 33.33 and TSS between 21.25 and 68.00 mg/L. Salts and sulfur accumulated in the soil profile but nutrient loading rates were less than crop uptake so nutrients did not accumulate. Venhuizen (1998) described system designs using emitter flow rates of about 3.8 L/h to be used with effluent that has been treated with a sand filter treatment system.

Emitter clogging is a major problem associated with all microirrigation systems, (Nakayama and Bucks, 1986; Pitts et al., 1996). The small emitters in SDI systems are prone to clogging by the various constituents of the wastewater. Chlorination of the system to prevent biomass accumulation is key to maintaining adequate flow rates in emitters of SDI systems when using treated municipal wastewater (Ravina et al., 1995). In the same study, emitters operated equally well with either 80 mesh filtration or 120 mesh filtration. Sagi et al. (1995) documented emitter clogging by sulfur bacteria and colonial protozoa in SDI systems using treated municipal wastewater. Chlorination was required to prevent emitter clogging. Intermittent chlorination with 1 mg/L free residual chlorine and filtration with no. 20 sand media were adequate to maintain good uniformity with turbulent flow emitters (Hills and Tajrishy, 1995). The same result was obtained with 2 mg/L free residual chlorine and 150 mesh (100 µm) screen filtration. They also found that either concentration (1 or 2 mg/L) was as effective as continuous injection (maintaining 0.4 mg/L residual chlorine) but required only about 25% of the chlorine. Ultraviolet disinfection required filtration of all particles greater than 40 µm.

The design and management challenge of using SDI with wastewater is to prevent emitter clogging. Given that challenge, the objective of this project was to measure the flow rates of five different dripline types as affected by irrigation with filtered but untreated water from a beef feedlot runoff lagoon. This article explores the technical feasibility of the use of wastewater and SDI. There are many other issues—including optimal nutrient and salt management, cost:benefit analysis, optimal filtration, and others—that require further research but are beyond the scope of this article.

METHODS

This project was conducted at a beef cattle feedlot in Gray County, Kansas. The soil type is a Richfield silt loam (fine, smectitic, mesic *Aridic Argiustoll*) (USDA-SCS, 1968). Water collected in the lagoon was runoff from pens containing beef cattle. Selected wastewater characteristics are shown in table 1.

In April 1998, driplines were installed 0.43 m deep and on a lateral spacing of 1.5 m. Each plot was 6 m wide (four driplines) and 137 m long. The system installation and testing were completed on 16 June. The first irrigation with wastewater was 17 June. After completion and testing of the system, the lagoon wastewater was the only water applied with the SDI system; no clean water was used for irrigation, flushing, or dripline chemical treatment. Plots were arranged in a randomized complete block design

Table 1. Selected wastewater characteristics*, Midwest Feeders, Kansas, 1998-1999

Sampling Date	pH	EC (S/m)	SAR	N (mg/L)	P (mg/L)	K (mg/L)	Ca (mg/L)	BOD (mg/L)	TSS (mg/L)
6 Mar 1998	8.0	0.29	1.8	118	35	336	105	N/S†	N/S
5 Jun 1998	7.9	0.25	2.0	92	30	341	111	N/S	N/S
17 Jul 1998	7.8	0.25	2.0	67	30	349	119	N/S	N/S
31 Jul 1998	7.6	0.27	2.0	89	30	383	119	N/S	N/S
21 Aug 1998	7.6	0.29	2.2	51	33	428	115	N/S	N/S
1 Sep 1998	7.9	0.36	2.3	84	32	467	126	96	190
12 May 1999	8.2	0.53	8.7	260	39	724	160	1033	580
13 Aug 1999	7.6	0.43	2.9	160	39	672	120	405	1320
10 Sep 1999	8.0	0.53	2.8	140	31	724	120	255	440

* Abbreviations: EC, electrical conductivit; SAR, sodium adsorption ratio; N, nitrogen; P, phosphorus; K, potassium; Ca, calcium; BOD, biochemical oxygen demand; TSS, total suspended solids.
† N/S: Not sampled.

with three replications. There was a border plot (using the 1.5 L/h/emitter laterals) at each of the north and south ends for a total of 17 plots. Corn was irrigated in both 1998 and 1999.

Five drip irrigation lateral line (dripline) types, each with a different emitter flow rate (and thus different emitter size), were tested (table 2). These products (table 2) are not necessarily marketed for use with wastewater but were selected to provide a range of flow rates and emitter sizes. Agricultural designs in the Great Plains for SDI with groundwater typically use lower flow rate emitters to allow larger zone sizes, but these smaller emitters are more susceptible to clogging. The emitter flow rates and flow path dimensions were obtained from the manufacturers. Each product was operated at the nominal inlet pressure listed in the manufacturer's literature.

The wastewater was filtered with a plastic grooved-disk filter with flow capacity about 25% greater than the filter manufacturer's recommendations for wastewater (0.7535 m^2 for our maximum flow rate of 454 L/min). The selected disks had openings of 55 µm (200 mesh) even though the manufacturers' recommendations for all driplines were filtration of 140 mesh or finer. A controller was used to automatically backflush the filter after every hour of operation or when the differential pressure across the filter reached 48 kPa. When backflushing, individual disks separate slightly and spin independently. To help keep bacteria and algae from growing and accumulating in the driplines and to clean lines of existing organic materials, acid and chlorine occasionally (table 1) were injected simultaneously into the flow stream at injection points about 1 m apart. Acid was added at a rate to reduce the pH to approximately 6.3 to increase the effectiveness of the chlorine. The acid used was N-pHuric 15/49, and the

Table 2. Selected emitter and operational characteristics for the driplines used in the study of SDI with lagoon wastewater, Midwest Feeders, Kansas, 1998-1999

Emitter Flow Rate (L/h)	Product	Flow Path Dimensions, Width × Height × Length (mm)	Flow Path Area (mm^2)	Emitter Exponent	Measured Flush Velocity (m/s)	Operating Inlet Pressure (kPa)
0.57	Roberts Ro-Drip XL	*	*	0.57	0.79	55
0.91	Roberts Ro-Drip XL	0.538 × 0.754 × *	0.43†	0.52	0.88	55
1.5	Netafim Super Typhoon	0.71 × 0.81 × 20.0	0.58	0.45	0.77	69
2.3	Netafim Python	0.86 × 0.94 × 18.1	0.81	0.45	0.43	69
3.5	Netafim Ram	1.3 × 1.3 × 15.5	1.7	‡	1.59	‡

* These dimensions were not available from the manufacturer.
† The flow path was not rectangular, so the area is not the product of the flow path width multiplied by the height.
‡ The 3.5 L/h/emitter product had a pressure-compensating emitter. Inlet pressure was greater than 200 kPa.

chlorine source was commercial chlorine bleach (5.25% sodium hypochlorite). Flushing (10 dripline volumes) to clean the lines and injections took place on the schedule shown in table 3. Actual acid and chlorine injection volumes and times are also shown in table 3. Average flush velocities from the 4 August 1998 event are shown in table 2.

To test the system, irrigations of 6 to 10 mm were applied daily from June through early September in 1998. During the growing season of 1999, occasional irrigations of 6 mm were applied in June and July and daily irrigations of 7 to 10 mm were applied from mid-July until early September. Each plot received the same application amount for a given day, so the run times for plots varied according to their emitter flow rates and emitter spacings. The average seasonal applications per plot were 530 mm (range: 524 to 531 mm) in 1998 and 390 mm (range: 388 to 395 mm) in 1999. The 1998 amount greatly exceeded the crop water requirements but allowed a more thorough test of the SDI system. Operations were conducted frequently during the growing seasons and infrequently or not at all during the winter idle period. Between the growing seasons, the system was used on 6 and 7 October and 17 November 1998 (DOY 279, 280, and 321) when the system flow rates were tested. In Kansas, few crops require irrigation during the winter months even though wastewater disposal occasionally is mandated by external factors. Therefore, to reflect typical conditions, the system was allowed to remain idle from November 1998 to June 1999. This stagnation period might increase the potential for system degradation from clogging, but it represents practical operating conditions for our climate. The final operation prior to an idle period was chemical injection.

Flow rates of entire plots were measured approximately weekly. Pressure gauges at the inlet end of the plots were used to measure the pressure at the dripline inlets. Pressure measurement at this location should be able to detect partial clogging of as little as 5% of the emitters in a lateral (Povoa and Hills, 1994). Totalizing flow meters measured the amount and rate of wastewater delivered to each plot. To test the flow rate of the driplines in an entire plot, the flow amount to each plot was measured and timed for approximately 30 min, after the system was filled. Inlet pressures were recorded. To account for the variation due to minor fluctuations of inlet pressures from test to test, the flow rate was normalized to the design pressure (table 2) using the manufacturer's emitter exponent for that dripline type.

Table 3. Dripline flushing and injection operations, Midwest Feeders, Kansas, 1998-1999

Date	Flush ?	Injection Duration (h)	Volume Injected: Acid (L)	Volume Injected: Chlorine (L)
9 July 1998		1.5	25	11
27 July 1998		1	15	8
4 August 1998	Y	2	54	4
31 August 1998		1.4	17	26
2 September 1998	Y	1.5	14	5
4 September 1998		1	6	
6 October 1998	Y	1.5	26	3
17 November 1998	Y	1.5	25	9
8 June 1999	Y	1.5	23	8
9 June 1999	Y			
28 July 1999		3	45	12
5 August 1999	Y	3	42	3
6 August 1999	Y			
24 August 1999	Y	3	50	12
25 August 1999	Y			
10 September 1999		3	54	7

NOTE: A blank means the operation did not take place on that day. When a flush and injection took place on the same day, the flush was performed first.

Results and Discussion

Of the five dripline types tested, the three higher-flow emitter sizes (1.5, 2.3, and 3.5 L/h/emitter) showed little sign of clogging (fig. 1). Flow rates at the end of the test for those emitters were within 4% of the initial flow rates, indicating that very little clogging and resultant decrease of flow rate had occurred. The absence of clogging indicates that emitters of these sizes may be adequate for use with lagoon wastewater.

The two lower-flow emitter sizes (0.57 and 0.91 L/h/emitter) showed some signs of emitter clogging (fig. 1) during the 1998 and 1999 growing seasons. Within 30 days of system completion in 1998, the flow rates in plots with both smaller emitter sizes began to decrease. The 0.57 L/h/emitter plots showed a gradual decrease of flow rate throughout the remainder of the test. By 17 November 1998 (DOY 321), the flow rate had decreased by 15% of the initial rate. The 0.91 L/h/emitter plots showed a decrease in flow rate of 11% of the initial rate by 2 September 1998 (DOY 245). Following harvest and the first (32-day) idle period, flow rates in the 0.91 L/h/emitter plots increased approximately 5% over the minimum measured rate. This increase indicates that some cleaning of the emitters had occurred in response to the flushing. The flow rate then stabilized for the rest of 1998 at about 9% less than the initial rate.

Following the winter idle period, all flow rates recovered to the initial flow rates (fig. 1). Possible explanations for this include (a) the longer time that the acid and chlorine remained in the driplines allowed better control of biological clogging agents, (b) the cooler temperatures during the winter resulted in partial control of the biological clogging agents and the acid and chlorine

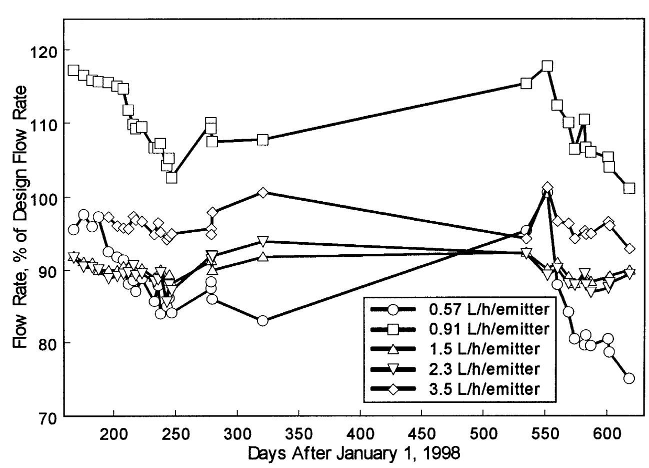

Figure 1–Measured flow rates for five dripline types with different emitter flow rates using lagoon wastewater, Midwest Feeders, Kansas, 1998-1999.

were then more effective at cleaning up the remaining agents, or (c) the biological clogging agents dessicated and reduced in size.

The smaller emitter sizes again showed decreasing flow rates during the 1999 growing season (fig. 1), similar to the response in 1998. By the end of the growing season (10 September 1999), flow rates had decreased by 21.5% in the 0.57 L/h/emitter plots and by 13.7% in the 0.91 L/h/emitter plots compared to the initial (maximum) flow rate. The decreases were constant throughout the growing season except for a two-week period. The rate of decrease was less from 10 August to 24 August 1999. During the second week of that time period, no daily irrigations were applied.

The disk filter and automated backflush controller operated well in both years. Based on our observations, the hourly backflush frequency was adequate to prevent excessive accumulation of differential pressure and the set point of 48 kPa was never reached.

Excavation and visual inspection of dripline samples showed that flushing was effective in removing the accumulations of materials from the driplines. Prior to flushing, a slimy substance containing both silt and biological materials was present in the lines. After flushing, the driplines were clean although some material evidently remained in the two smallest emitters and caused partial clogging. Flushing velocities were measured for the first flushing event (4 August 1998) and were above the recommended flushing velocity of 0.3 m/s (table 2).

These results show that the drip irrigation laterals used with SDI have potential for use with lagoon wastewater. However, the smaller emitter sizes normally used with groundwater sources in western Kansas may be risky for use with lagoon wastewater. That is, the clogging noted in this study may continue and render the SDI system inoperable, even though the flow rates returned to the initial rates after the winter off-season.

Other management procedures might be employed to prevent performance degradation in the lower flow-rate emitters or remediate it after it occurs. Such procedures might include more frequent flushing, flushing with fresh water, and more frequent and concentrated chemical-injection treatments. However, the objective of this study was to compare the different driplines under difficult but identical conditions. Further studies are warranted to determine if the lower flow-rate driplines can be maintained at a higher performance level with more aggressive management.

The dripline performance was similar during two growing seasons, but questions still remain about the long-term, multiseason performance of SDI systems using livestock wastewater. These concerns are especially important in light of the decrease in flow rates of the two smallest emitters during both growing seasons. Long-term reliable performance probably will be necessary to justify the high investment costs of SDI systems.

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References

Gushiken, E. C. 1995. Irrigating with reclaimed water through permanent subsurface drip irrigation systems. In *Microirrigation for a Changing World. Proc. 5th Int. Microirrigation Congress*, 269-274, ed. F. R. Lamm. St. Joseph, Mich.: ASAE.

Hills, D. J., and M. Tajrishy. 1995. Treatment requirements of secondary effluent for microirrigation. In *Microirrigation for a Changing World. Proc. 5th Int. Microirrigation Congress*, 887-892, ed. F. R. Lamm. St. Joseph, Mich.: ASAE.

Lesikar, B. J., B. A. Neal, G. A. Sabbagh, and I. Jnad. 1998. Subsurface drip systems for the disposal of residential wastewater. In *On-site Wastewater Treatment. Proc. 8th National Symp. on Individual and Small Community Sewage Systems,* ed. D. M. Sievers, 146-154. St. Joseph, Mich.: ASAE.

Nakayama, F. S., and D. A. Bucks. 1986. *Trickle Irrigation for Crop Production*. Amsterdam, the Netherlands: Elsevier.

Oron, G., Y. DeMalach, Z. Hoffman, and Y. Manor. 1992. Effect of effluent quality and application method on agricultural productivity and environmental control. *Water Sci. Tech.* 26: 1593-1601.

Oron, G., Y. DeMalach, Z. Hoffman, Y. Keren, H. Hartman, and N. Plazner. 1991. Wastewater disposal by sub-surface trickle irrigation. *Water Sci. Tech.* 23: 2149-2158.

Oron, G. 1996. Soil as a complementary treatment component for simultaneous wastewater disposal and reuse. *Water Sci. Tech.* 34: 243-252.

Phillips, R. L. 1981. Maps of runoff volumes from feedlots in the United States. In *Livestock Waste: A Renewable Resource. Proc. 4th Int. Symp. on Livestock Waste*, 274-277. St. Joseph, Mich.: ASAE.

Pitts, D., K. Peterson, G. Gilbert, and R. Fastenau. 1996. Field evaluation of irrigation system performance. *Applied Engineering in Agriculture* 12(3): 307-313.

Povoa, A. F., and D. J. Hills. 1994. Sensitivity of microirrigation system pressure to emitter plugging and lateral line perforations. *Transactions of the ASAE* 37(3): 793-799.

Ravina, I., E. Paz, G. Sagi, A. Schischa, A. Marcu, Z. Yecheily, Z. Sofer, and Y. Lev. 1995. Performance evaluation of filters and emitters with secondary effluent. In *Microirrigation for a Changing World. Proc. 5th Int. Microirrigation Congress*, 244-249, ed. F. R. Lamm. St. Joseph, Mich.: ASAE.

Sagi, G., E. Paz, I. Ravina, A. Schischa, A. Marcu, and Z. Yechiely. 1995. Clogging of drip irrigation systems by colonial protozoa and sulfur bacteria. In *Microirrigation for a Changing World. Proc. 5th Int. Microirrigation Congress*, 250-254, ed. F. R. Lamm. St. Joseph, Mich.: ASAE.

USDA-SCS. 1968. Soil survey of Gray County, Kansas. USDA-SCS in cooperation with the Kansas Agric. Expt. Sta. Washington, D.C.: GPO.

Venhuizen, D. 1998. Sand filter/drip irrigation systems solve water resources problems. In *On-site Wastewater Treatment. Proc. 8th National Symp. on Individual and Small Community Sewage Systems,* ed. D. M. Sievers, 356-362. St. Joseph, Mich.: ASAE.