# USING BEEF LAGOON WASTEWATER WITH SDI

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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. A study was initiated in 1998 to test the performance of five types of driplines (with emitter flow rates of 0.15, 0.24, 0.40, 0.60, and 0.92 gal/hr-emitter) with beef lagoon wastewater. A disk filter (200 mesh, with openings of 0.003 inches) was used and shock treatments of chlorine and acid were injected periodically. Over the course of four seasons (1998-2001) a total of approximately 66 inches of irrigation water was applied through the SDI system. It is estimated that approximately 9300 lbs/acre of total suspended solids have passed through the driplines. The flow rates of the two smallest emitter sizes, 0.15 and 0.24 gal/hr-emitter decreased approximately 40% and 30%, respectively, during the four seasons, indicating considerable emitter clogging. The three driplines with the highest flow rate emitters (0.40, 0.60, and 0.92 gal/hr-emitters) have had approximately 7, 8, and 13% reductions in flow rate, respectively. Following an aggressive freshwater flushing, acid and chlorine injections in April of 2002, the flowrates of the lowest two emitter sizes (0.15 and 0.24 gal/hr-emitter) were restored to nearly 80 and 97% of their initial flowrates, respectively. Further laboratory tests on individual emitters from excavated driplines showed the lowest flow dripline experiencing partial clogging of most emitters with full clogging of about 4% of the emitters. These results indicate SDI can be used to successfully apply beef lagoon wastewater. However, the smaller emitter sizes normally used with groundwater sources in western Kansas may be risky for use with lagoon wastewater.*

## INTRODUCTION

In response to increasing nationwide concern with livestock wastewater generated by confined animal feeding operations, K-State Research and Extension initiated a project to address odor, seepage into groundwater and runoff into surface water supplies. Subsurface drip irrigation (SDI) is a potential tool that can alleviate all three problems, while still utilizing livestock wastewater as a valuable crop production resource. A study was begun in 1998 on a commercial beef feedlot to answer the engineering question, "***Can SDI be successfully used to apply livestock 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 250 $ft^2$ per animal, the land area of feedlots in the Great Plains is approximately 45,500 ac, and that in Kansas is approximately 11,400 ac. Perhaps 20 to 33% of average annual precipitation in the Great Plains could be collected as runoff from feedlots. Assuming 20% runoff and an average annual precipitation of 20 inches, approximately 3,700 to 15,000 ac-ft of runoff from feedlots might be available annually in Kansas and the Great Plains, respectively. This feedlot runoff, minus any evaporation from the lagoons, must be disposed of by land application.

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Using subsurface drip irrigation (SDI) with this livestock wastewater has many potential advantages:

- Saves fresh water for other uses
- Reduces groundwater withdrawals in areas of low recharge
- Rich in nutrients, such as N, P, and K, for crop growth
- Reduced human contact with wastewater
- Less odors and no sprinkler aerial pathogen drift
- No runoff of wastewater into surface waters
- Subsurface placement of phosphorus-rich water reduces hazards of P movement into streams by surface runoff and soil erosion
- Greater water application uniformity resulting in better control of the water, nutrients, and salts
- Reduced irrigation system corrosion
- Reduced weather-related water application constraints (especially high winds and freezing temperatures)
- Increased flexibility in matching field and irrigation system sizes
- Better environmental aesthetics

Worldwide, the leading cause of microirrigation system failure is clogging of the emitters. Therefore, it is easy to recognize that prevention of emitter clogging will be the primary design and management challenge of using SDI with this particle-rich, biologically active wastewater. Given that challenge, the objective of this project was to measure the performance of five different dripline types as affected by irrigation with filtered but untreated water from a beef feedlot runoff lagoon.

## METHODS

This project was conducted adjacent to a beef cattle feedlot in Gray County, KS. The soil type is a Richfield silt loam. As is typical for beef feedlots in the region, precipitation runoff water from beef cattle pens was collected in a single-cell lagoon. Selected wastewater characteristics are shown in Table 1.

**Table 1. Selected wastewater characteristics, Midwest Feeders, KS, 1998-2001.**

| Sampling Date | pH | EC mmho/cm | SAR | N ppm | P ppm | K ppm | TDS ppm | BOD ppm | TSS ppm |
|---|---|---|---|---|---|---|---|---|---|
| Mar. 6, 1998 | 8.00 | 2.93 | 1.8 | 118 | 35 | 336 | 1875 | N/S | N/S |
| Jun. 5, 1998 | 7.81 | 2.56 | 1.9 | 92 | 30 | 341 | 1613 | N/S | N/S |
| Jul. 17, 1998 | 7.84 | 2.54 | 2.0 | 67 | 30 | 349 | 1625 | N/S | N/S |
| Jul. 31, 1998 | 7.64 | 2.70 | 2.0 | 89 | 30 | 383 | 1728 | N/S | N/S |
| Aug. 21, 1998 | 7.60 | 2.90 | 2.2 | 51 | 33 | 428 | 1856 | N/S | N/S |
| Sep. 1, 1998 | 7.90 | 3.60 | 2.3 | 84 | 32 | 467 | 2304 | 96 | 190 |
| May 12, 1999 | 8.20 | 5.29 | 2.9 | 260 | 39 | 724 | 3386 | 1033 | 580 |
| Aug. 13, 1999 | 7.60 | 4.30 | 2.9 | 160 | 39 | 672 | 2739 | 405 | 1320 |
| Sep. 10, 1999 | 8.00 | 5.30 | 2.8 | 140 | 31 | 724 | 3379 | 255 | 440 |
| Jun. 23, 2000 | 7.80 | 4.90 | 2.9 | 240 | 53 | 828 | 3136 | 998 | 533 |
| Jul. 13, 2000 | 8.10 | 5.20 | 2.7 | 250 | 53 | 828 | 3328 | 834 | 740 |
| Aug. 25, 2000 | 8.00 | 5.10 | 3.0 | 210 | 31 | 888 | 3290 | 228 | 940 |
| Jul. 13, 2001 | 8.20 | 6.40 | 2.8 | 360 | 48 | 991 | 4109 | 154 | 1225 |
| Aug. 24, 2001 | 8.20 | 5.00 | 2.5 | 160 | 26 | 784 | 3194 | 142 | 390 |

N/S: Not sampled.

Abbreviations: N: nitrogen, P: phosphorus, K: potassium, TDS: total dissolved solids, TSS: total suspended solids, BOD: biochemical oxygen demand.

In April 1998, driplines were installed 17 inches deep and on a lateral spacing of 60 inches. Each plot was 20 ft wide (4 driplines) and 450 ft long. Plots were arranged in a randomized complete block design with three replications. There was a border plot at the north and south ends for a total of 17 plots. The system installation and testing were completed on June 16. The first wastewater was used for irrigation on June 17. After completion and testing of the system, the lagoon wastewater was the only water that was applied with the SDI system; no fresh, clean water was used for irrigation, flushing, or dripline chemical treatment during the first three years of the study. On June 19-20, 2001, two fresh water events were conducted to examine the potential for cleaning the driplines and also to enhance chemical treatment (acid and chlorine are more effective with fresh water). Corn was the irrigated crop in all four seasons. On April 16, 2002, the system was flushed with fresh water and an aggressive acid and chlorination program was performed with fresh water. This was repeated the next day (April 17, 2002) and was followed with the final pressure and flow test. Eight driplines were excavated on April 18, 2002. Three lines were selected from the lowest flow treatment, three from the medium flow treatment and two from the highest flow treatment. These driplines were refrigerated until flowrates from individual emitters could be tested in the lab on August 8, 2002.

Five drip irrigation lateral line (dripline) types, each with a different emitter flow rate (and thus different emitter size), were tested (Table 2) to determine the optimum emitter size that would be less prone to clogging with the wastewater. Agricultural designs of SDI in the Great Plains with groundwater typically use lower flow rate emitters to allow for longer lateral run lengths. The emitter flow rates and flow path dimensions were obtained from the manufacturers.

**Table 2. Selected emitter characteristics for the driplines used in the SDI study using livestock wastewater, Midwest Feeders, KS, 1998-2002.**

| Emitter flow rate, (gal/hr) | Flow path dimensions, width by height by length (inch) | Flow path area, ($inch^2$) | Operating inlet pressure (psi) |
|---|---|---|---|
| 0.15 | * | * | 8 |
| 0.24 | 0.0212 by 0.0297 by * | 0.000663 ** | 8 |
| 0.40 | 0.028 by 0.032 by 0.787 | 0.000896 | 10 |
| 0.60 | 0.034 by 0.037 by 0.713 | 0.001258 | 10 |
| 0.92 | 0.052 by 0.052 by 0.610 | 0.002704 | *** |

* These dimensions were not available from the manufacturer.
** Flow path was not rectangular, so the area differs from the product of the width X height.
*** This product was a pressure-compensating emitter. Inlet pressure was greater than 30 psi.

The wastewater was filtered with a plastic grooved-disk filter with flow capacity about 25% greater than the filter manufacturer's recommendations for wastewater (1168 $in^2$ for our maximum flow rate of 120 gal/min). The disks were selected to provide 200-mesh equivalent (openings of 0.003 inches) filtration 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 7 psi. 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 were injected simultaneously into the flow stream at injection points about 3 ft apart. Acid was added at a rate to reduce the pH to approximately 6.3. For the special freshwater events in June 2001 and April 2002, the pH was lowered to approximately 4.0. The acid used was N-pHuric 15/49, and the chlorine source was commercial chlorine bleach (2.5% Cl). Flushing (10 dripline volumes) to clean the lines and injections took place on the schedule shown in Table 3.

Generally, daily irrigations of 0.25 to 0.40 inch were made each season from June to early September, except when crop water use did not exceed precipitation or when the irrigation pump was inoperable. Each plot received the same daily application amount, so plot run times varied according to dripline flow rate. Seasonal applications were 22, 15, 17 and 12 inches in 1998, 1999, 2000, and 2001, respectfully. The 1998 amount greatly exceeded the crop water requirements but allowed more rigorous testing of the system. Additional flow tests were conducted between growing seasons (Oct. 6-7 and Nov. 17, 1998 and Nov. 3, 2000). In Kansas, few crops require irrigation during the winter months, so the system was allowed to remain idle during the overwinter periods. This stagnation period might increase the potential for system degradation from clogging, but it represents practical operating conditions for this climate.

The flow rates for entire plots were measured approximately weekly during the season whenever the system was operational. Totalizing flow meters were used on each plot to measure the amount of wastewater delivered during an approximately 30 minute test. Pressure was measured at the dripline inlets during each flow test. To account for the variation due to minor fluctuations of pressures from test to test, the calculated flowrates were normalized to the design pressure (Table 2) using the manufacturer's emitter exponent for that dripline type.

**Table 3. Dates of flushing and injection, Midwest Feeders, KS, 1998-2002.**

| Date | Flush | Injection | Date | Flush | Injection |
|---|---|---|---|---|---|
| July 9, 1998 | | Y | May 3, 2000 | | Y |
| July 27, 1998 | | Y | June 13, 2000 | | Y |
| Aug. 4, 1998 | Y | Y | June 21, 2000 | | Y |
| Aug. 31, 1998 | | Y | June 23, 2000 | Y | |
| Sept. 2, 1998 | Y | Y | Aug. 1, 2000 | | Y |
| Sept. 4, 1998 | | Y | Aug. 3, 2000 | Y | |
| Oct. 6, 1998 | Y | Y | Aug. 8, 2000 | Y | |
| Nov. 17, 1998 | Y | Y | Aug. 9, 2000 | | Y |
| June 8, 1999 | Y | Y | Nov. 3, 2000 | Y | |
| June 9, 1999 | Y | | June 5, 2001 | Y | |
| July 28, 1999 | | Y | June 19, 2001 | | Y |
| Aug. 5, 1999 | Y | Y | June 20, 2001 | Y | Y |
| Aug. 6, 1999 | Y | | June 25, 2001 | Y | |
| Aug. 24, 1999 | Y | Y | Aug. 23, 2001 | | Y |
| Aug. 25, 1999 | Y | | Aug. 24, 2001 | Y | |
| Sept. 10, 1999 | | Y | April 16, 2002 | Y | Y |
| April 28, 2000 | Y | | April 17, 2002 | Y | Y |

A blank means the operation did not take place on that day.

## RESULTS AND DISCUSSION

The three higher-flow emitter sizes (0.40, 0.60, and 0.92 gal/hr-emitter) showed the least amount of clogging (Fig. 1). Flow rates at the end of four seasons for those emitters were between 7 and 13% lower than the initial flow rates, indicating that clogging appears manageable with these emitters. These emitters may be adequate for use with lagoon wastewater. However, the pressure compensating emitter (0.92 gal/hr-emitter) was declining.

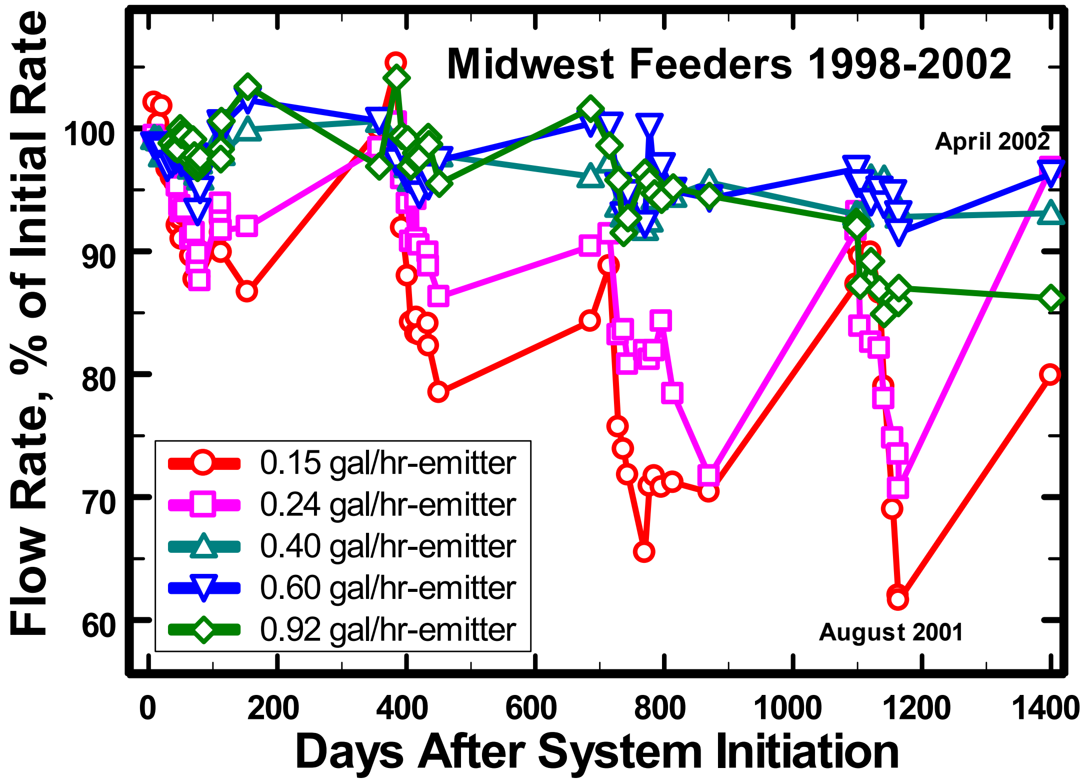


**Figure 1. Measured flow rates for five dripline types with different emitter flow rates using lagoon wastewater, Midwest Feeders, KS, 1998-2002.**

The two lower-flow emitter sizes (0.15 and 0.24 gal/hr-emitter) showed signs of emitter clogging (Fig. 1) during all four growing seasons. Within 30 days of system completion in 1998, the flow rates in plots with both smaller emitter sizes began to decrease. The 0.15 gal/hr-emitter plots showed a gradual decrease of flow rate throughout the remainder of the season. By November 17, 1998 (Day 154), the flow rate had decreased by 15% of the initial rate. The 0.24 gal/hr-emitter plots showed a decrease in flow rate of 11% of the initial rate by September 2, 1998 (Day 78). Following harvest and the first (32-day) idle period, flow rates in the 0.24 gal/hr-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 (Day 368), all flow rates recovered to near their 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 or (b) the cooler temperatures during the winter resulted in partial control of the biological clogging agents and the acid and chlorine were then more effective at cleaning up the remaining agents.

The smaller emitter sizes continued to have decreasing flow rates during the 1999, 2000, and 2001 growing seasons (Fig. 1), similar to the response in 1998. By the end of the fourth growing season (August 24, 2001, Day 1164), flow rates had decreased by approximately 40% and 30% in the 0.15 and 0.24 gal/hr-emitter sizes, respectively, compared to the initial (maximum) flow rate.

The aggressive flushing, acid and chlorine program in April 2002 restored a significant portion of the flowrate reductions experienced by the smallest two emitters. Flowrates increased from the August 2001 values of 62 and 71% of the initial flowrates to April 2002 values of 80 and 97% for the 0.15 and 0.24 gal/hr-emitter treatments, respectively. This indicates that aggressive management may remediate wastewater clogging problems. There was substantially less improvement for the larger flowrate emitters and actually no flowrate improvement for pressure compensating emitter (0.92 gal/hr-emitter). It is believed that wastewater particles are being trapped in the flexible diaphragm of these emitters.

Over the course of the four seasons, a total of 66 inches of beef lagoon wastewater was applied with the SDI system and an estimated total of approximately 9300 lbs/acre of suspended solids passed through the system (Figure 2), minus the amounts of suspended solids that were removed in the periodic dripline flushing events. These are relatively harsh operating conditions. The disk filter and automated backflush controller operated well in all four years.

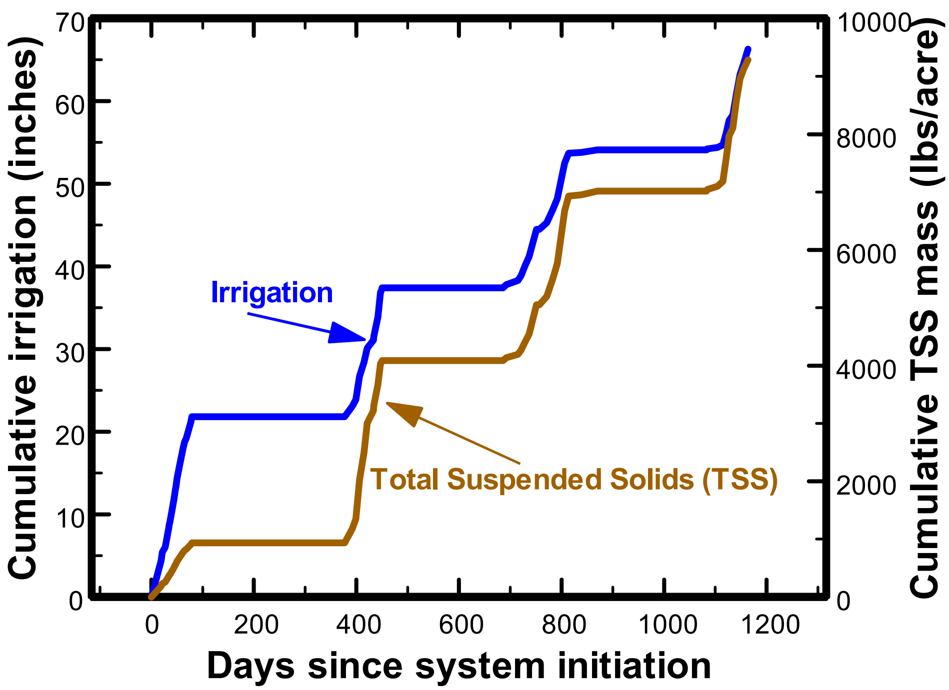


**Figure 2. Cumulative wastewater irrigation amounts and estimated cumulative total suspended solids (TSS) that passed through the driplines during the four seasons, Midwest Feeders, KS, 1998-2001.**

Excavation and visual inspection of dripline samples at the end of the first season showed that flushing was generally effective in removing the accumulations of materials from the driplines. Prior to flushing, a slimy substance probably containing both silt and biological materials was present in the driplines. After flushing, the main chamber of the driplines was clean.

Driplines from selected treatments were excavated from the lower 100 feet of the plots after the aggressive flushing, acid and chlorination program of April 16-17, 2002. The flowrates from individual emitters in an approximately 25 ft section of excavated driplines was measured in the laboratory on August 8, 2002 for the lowest, medium and highest flowrate treatments (0.14, 0.40, and 0.92 gal/hr-emitters). Flowrates were measured for 23, 12, and 12 consecutive emitters resulting from the 12, 24 and 24inch emitter spacings, respectively for these three driplines.

The lowest flow dripline (0.14 gal-hr-emitter) had 3 fully clogged emitters in the 3 driplines tested (3 driplines x 23 emitters = 69 total emitters). The average flowrate varied from 0.107 to 0.135 gal/hr-emitter for these three driplines as compared to two new driplines from the same roll that had average flowrates of 0.145 gal/hr-emitter (Fig. 3). The Coefficient of Variation (CV) of flows varied from 7.3 to 36.8% for the wastewater driplines while the CV for new driplines was only 2.5%. Likewise the Distribution Uniformity with the Lower Quartile method (DUlq) ranged from 54.3% to 90.7% for the wastewater driplines as compared to the new dripline DUlq of 97.1%. Clearly, the lowest flow driplines are experiencing some significant clogging problems.

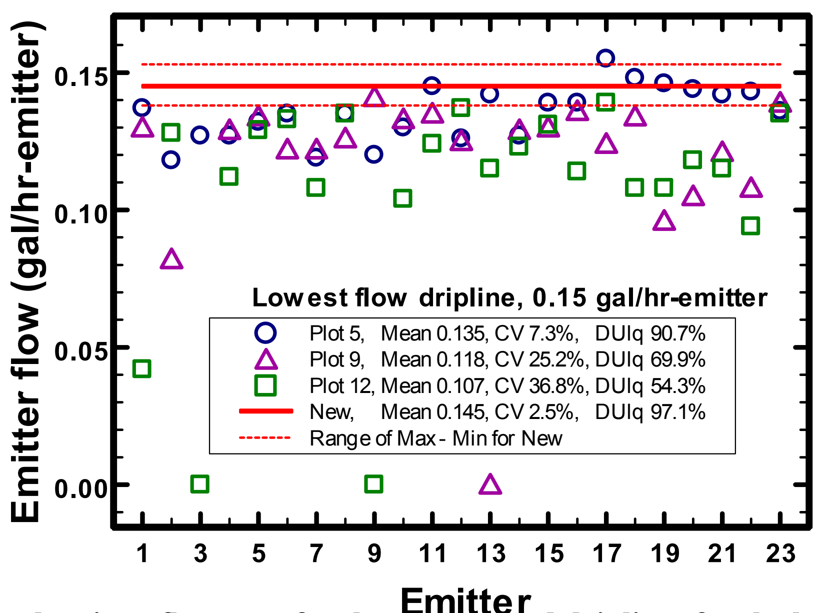


**Figure 3. Individual emitter flowrates for three excavated driplines for the lowest flow dripline at the conclusion of the study as compared to the average flowrate of new dripline. Note, three emitters are fully clogged.**

Flowrates from individual emitters for the wastewater medium flow driplines were very good with only small decreases (<10%) from the average flowrate of new driplines (Fig. 4.). The CV ranging from 2.4 to 2.8% and DUlq ranging from 96.4 to 97.9% for these driplines were excellent and differed very little from the new driplines.

Flowrates from individual emitters for the wastewater highest flow driplines (0.92 gal-hr-emitter) were generally good, but had two emitters out of a total of 24 with very high flowrates and one additional emitter with an approximately 25% flowrate reduction (Fig. 5.). It is believed these higher flowrate problems are caused by wastewater particles becoming stuck in the flexible diaphragm of this pressure compensating emitter. This problem has been reported elsewhere. These flow variations resulted in higher CVs for the wastewater driplines (10.8 to 20.5% as compared to 2.3% for new driplines) and lower DUlqs (87.1% to 92.6 as compared to 96.7% for the new driplines).

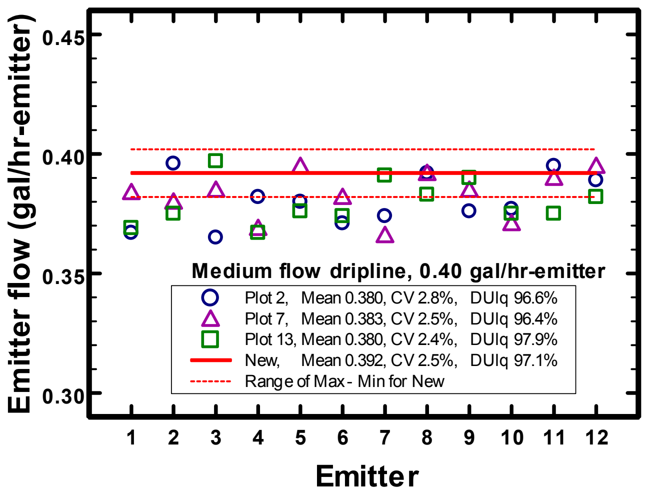


**Figure 4. Individual emitter flowrates for three excavated driplines for the medium flow dripline at the conclusion of the study as compared to the average flowrate of new dripline.**

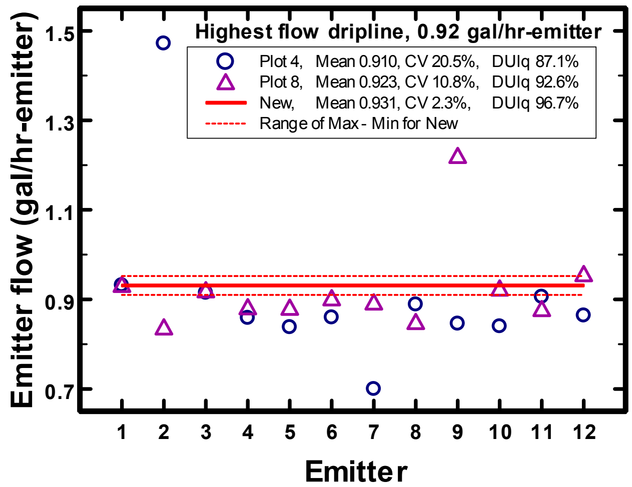


**Figure 5. Individual emitter flowrates for two excavated driplines for the highest flow dripline at the conclusion of the study as compared to the average flowrate of new dripline. Note, two very high flowrate emitters and one lower flowrate emitter.**

Other management procedures might 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. Additionally, many irrigation systems may apply the wastewater as a supplemental application instead of the sole irrigation source as used here. However, the objective of this study was to compare the different driplines under difficult but identical conditions. Further studies are needed to determine if the lower flow-rate driplines can be maintained at a higher performance with more aggressive management.

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. The dripline performance was similar during all four growing seasons, but questions remain about the long-term, multiseason performance of SDI systems using livestock wastewater. Long-term reliable performance probably will be necessary to justify the high investment costs of SDI systems.

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