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FILTRATION AND MAINTENANCE FOR SDI SYSTEMS IN THE U.S. GREAT PLAINS

Freddie R. Lamm
Research Agricultural Engineer
Northwest Research-Extension Center
Colby, Kansas
Voice: 785-462-6281
Email: flamm@ksu.edu

Danny H. Rogers
Extension Agricultural Engineer
Biological and Agricultural Engineering
Manhattan, Kansas
Voice: 785-532-2933
Email: drogers@ksu.edu

Jonathan P. Aguilar
Extension Irrigation Specialist
Southwest Research-Extension Center
Garden City, Kansas
Voice: 620-275-9164
Email: jaguilar@ksu.edu

Kansas State Research and Extension

QUICK FACTS

- *The filtration unit is an important protection component of a subsurface drip irrigation (SDI) system.*
- *While it is justified to minimize investment cost whenever practical, one should not cut corners when considering the filtration system.*
- *The major cause of failure of SDI systems around the world is clogging of the emitters. Poor maintenance and improper design also are major causes of SDI failure.*
- *Economic studies on SDI for corn have shown that the return is very sensitive to system life. As the life expectancy of SDI increases, the system becomes much more competitive with center pivot irrigation systems on a quarter section (160 acres) field. The life expectancy most often depends on appropriate filtration, maintenance, and design. Flushing and chlorination of the driplines should be a part of routine maintenance.*
- *Remediation of severe emitter clogging or system modifications can be costly, if not impractical. Economic losses can occur during the process*

INTRODUCTION

Although all irrigation systems require proper maintenance, maintenance for subsurface drip irrigation (SDI) systems has some different requirements and must be consistently implemented throughout the life of the systems. The major worldwide cause of failures in SDI and other microirrigation systems is emitter clogging. System life is a critical factor in economic competitiveness of SDI with alternative irrigation systems when growing the typical commodity crops of the U.S. Great Plains region. SDI system components, with particular emphasis on the filtration system, the chemical injection system, and the flushlines, are key elements in systems capable of being operated successfully for many years without replacement (See also K-State Research and Extension publication MF2576 ***Subsurface Drip Irrigation (SDI) Components: Minimum Requirements*** at http://www.ksre.k-state.edu/sdi/reports/2003/mf2576.pdf). Additionally, monitoring and evaluation of SDI system hydraulic performance provide important cues about acute and chronic maintenance needs.

The emitters in SDI systems are small (Figure 1), leaving a small margin for error, so it is important to understand the filtration and maintenance requirements of SDI systems and take a proactive approach to the prevention of clogging.

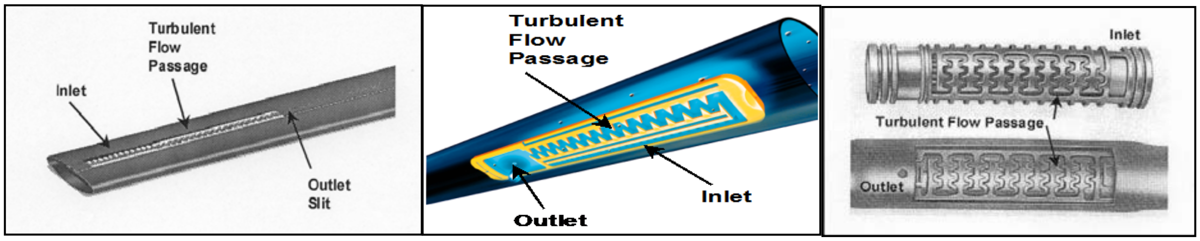

Figure 1. Cut-away examples of the small tortuous passageways in SDI emitters. (After Schwankl and Hanson, 2007. (Photos left to right courtesy of T-Systems International, Inc., Netafim Irrigation Products, Inc., and Toro-Ag, Geoflow, Inc., respectively)

Fortunately, most SDI users in the U.S. Great Plains region are pumping high-quality groundwater, such as from the Ogallala Aquifer. This reduces the potential for clogging, but even then, water quality varies from one location to the next, so the water quality should be assessed before engaging in SDI. No matter how clean the irrigation water source is, proper filtration and maintenance steps must be taken to prevent clogging and maintain effective SDI system operation. Similarly, with proper selection of a filtration system and maintenance strategies, SDI can be used with surface water and other low-quality waters that have a greater contaminant load.

Prevention of clogging and proper maintenance of the SDI system start before it is designed and installed. Chemical and biological analysis of the irrigation water will help in selection of components for the filtration system, and also indicate water treatment measures that may be required to prevent emitter clogging. (See also the immediately preceding conference paper ***Addressing the Basic Design Issues of Subsurface Drip Irrigation (SDI)*** or electronically at http://www.ksre.k-state.edu/sdi/reports/2018/LammBD18.pdf

FILTRATION

There are three terms, *filtration type*, *filtration level*, and *system sizing* that should be understood early in the selection process for filtration systems.

The *type of filtration* system (or, in some cases, a combination of filters are required) is generally determined from information about the water source (i.e., constituents and/or contaminants and their concentrations or loading). Typical types of filtration system are shown in Figure 2. Generally, screen filters are the least expensive and preferred option when the source water is relatively clean. Sand media and disk filtration, which both provide three-dimensional filtration are used when the contaminant loading is greater, particularly when there are biological contaminants. Automatic backflushing capabilities and continuous self-cleaning capabilities (e.g, vortex cleaning) that may be available for the distinct filter types tend to allow some selection overlap concerning the water source, essentially allowing some filter types to have a broader operating range than would normally be considered.

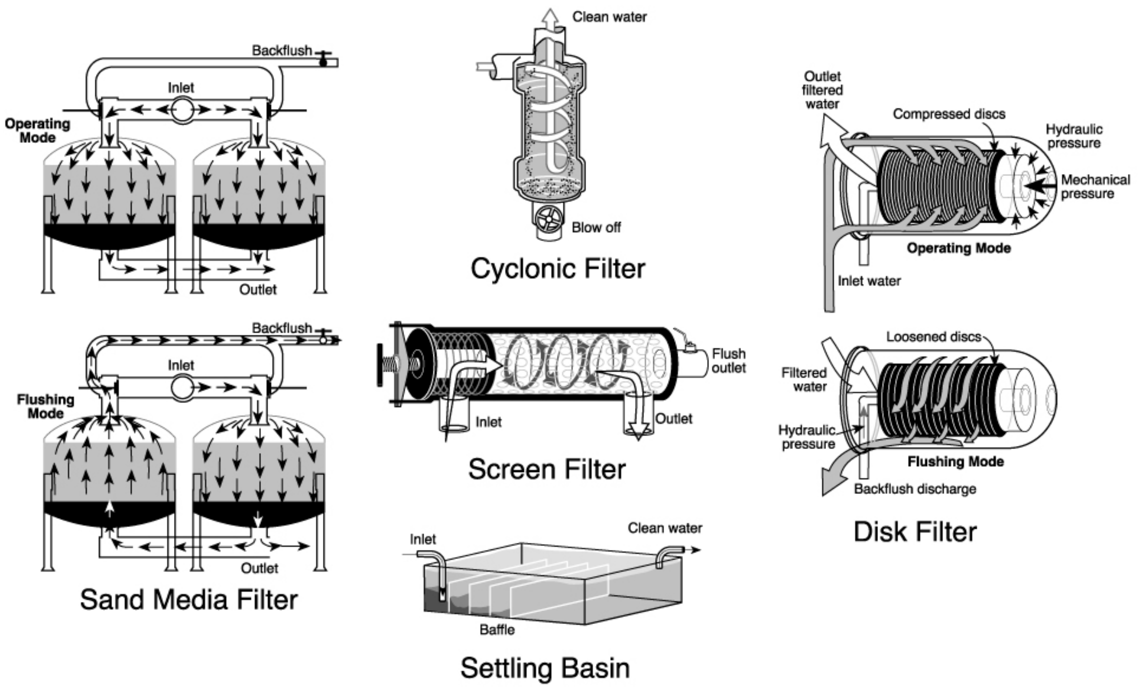

Figure 2. Typical types of filtration systems that may be used in SDI systems. Note: A combination of these systems may be necessary for some systems. For example, a cyclonic filter, which is also known as a sand separator or hydrocyclone filter may be used to remove larger and heavier sand particles from sand-producing wells, prior to using a screen filter for primary filtration of the smaller contaminants. (Drawing courtesy of Kansas State University)

The *level of filtration* should always be specified by the dripline manufacturer because the level refers to the size of particles that are being removed from the water source. Since the dripline manufacturer determines the size of the emitter passageways during the manufacturing process, that fact controls the level of filtration. Flow path dimensions ranging from 538 x 754 microns (width x height) to 1300 x 1300 microns were reported by Trooien et al., (2000) for four different driplines used in a research project with SDI for livestock wastewater. As a general rule, the level of filtration should be 1/10 of the size of the smallest emitter passageway. This would means that a safety factor of 10 is provided to prevent emitter clogging. At first glance, that might seem like an excessive amount of safety being provided, but smaller particles that pass through the filter system may later conglomerate and begin to cause clogging problems. The level of filtration is sometimes called the mesh size which refers to the number of intersecting strands of metal or fabric per inch in screen-type filters. Theoretically, the thickness of the strands could affect the size of the filter openings, so it is more accurate to state the equivalent size of the openings. This latter classification strategy would obviously be preferential for sand media and disk filtration systems where filter opening sizes vary and are not two-dimensional planes. Typical levels of filtration in the various measurement classifications are shown in Table 1.

Table 1. Typical levels of filtration that may be considered for microirrigation systems.

	Opening Size		
Mesh Size	**inches**	**mm**	**microns**
40	0.017	0.425	425
80	0.0071	0.180	180
100	0.006	0.152	152
120	0.0049	0.124	124
150	0.0041	0.104	104
200	0.003	0.076	76
270	0.002	0.053	53

These filtration levels (Table 1) can be compared to some of the particle sizes encountered in microirrigation (Table 2.) There are few, if any, SDI systems in the U.S. Great Plains that use filtration levels smaller than 76 microns (200 mesh), so this means individual silt, clay, bacteria, and virus particles pass through the filter and also would pass through emitters if they do not conglomerate into larger particles. Some of these smaller particles will also begin to accumulate on the bottom of the dripline during idle periods of the SDI system, so periodically they must be flushed from the system.

Table 2. Particle sizes for typical water contaminants.

Particle	Size (mm)
Coarse sand	0.50 to 1.00
Fine sand	0.10 to 0.25
Silt	0.002 to 0.05
Clay	<0.002
Bacteria	0.0004 to 0.002
Virus	< 0.0004

The *sizing of the filtration* system relates to what water flow rate of the original source water can be efficiently handled by an equivalent unit area of filtration. Higher flow rates are handled by either larger filters with greater effective filtration area or through using multiple units or filter banks in parallel. Screen filters provide two-dimensional or single plane filtration and maximum and flow rates of 40 to 100 gpm per square foot of total screen are common when the water source is relatively clean (USDA-NRCS, 2013). Sand media filters provide three-dimensional filtration and are typically sized for flowrates of 20 gpm per square foot of the media bed (USDA-NRCS, 2013). Disk filters also are considered to provide three-dimensional filtration and are typically sized for flowrates of 5 to 80 gpm per square foot of surface area depending on the water quality (Van der Gulik, 1999.) These sizing values are just estimates, individual manufacturers will have sizing specifications and guidelines for their own products. As the contaminant load in the water source increases, the flowrate per unit area of filtration is decreased and the physical size or number of filter units (banks) must increase.

Figure 3. The sizing of the filtration system can be accomplished by either using filtration units with greater area of filtration or through usage of multiple filtration units in parallel (bank of filters). For this filtration system for microirrigation in the Canary Islands using wastewater, both techniques for sizing were employed. For scale, these sand media tanks are approximately 12 feet in height. (Photo courtesy of Freddie Lamm, Kansas State University)

Clogging hazards for SDI systems, regardless of the water source, fall into three general categories: physical, chemical, and biological.

Physical clogging hazards

Physical clogging hazards can include a wide variety of materials, ranging from organic material (e.g., living organisms such as bacteria, slimes or algae and dead plant material) to inorganic particulates of sand, silt, and clay. Older or improperly screened groundwater wells may produce sands that pose a threat of physical clogging of the emitters. Since sand has a specific gravity that is much greater than water, cyclonic filters (Figure 2) can be used to remove these sand particles before the source water enters the primary filtration system. With the aforementioned exception, physical clogging hazards from groundwater wells are typically not excessive and can usually be removed with screen filters (Figure 2). Since screen filtration only provides two-dimensional filtration through a single plane, provisions for automatic or manual backflushing need to be part of routine operational schemes. Typically screen filters should be cleaned (backflushed) when the pressure drop across the filter increases by 3 to 5 psi, or as recommended by the manufacturer. Automatic backflushing is available as an option on most filtration systems and is preferable when manual backflushing requirements become frequent. The automatic backflushing can be programmed to occur at set intervals, at a set pressure differential across the filter, or a combination of both backflushing criteria. Continuous self-cleaning capabilities are also available for some screen filters where a vortex flow within the filter is used to “spin off” particles to a location at the bottom of the filter unit. A small amount of water is continuously pushing the filtered particles out of the filtration system to waste.

Other steps may be required for physical clogging hazards with surface water (e.g., reservoirs, streams, and canals). For water with a large silt concentration, a settling basin may be required to remove the silt. Pre-screening of the source water may be required to remove larger debris such as stalks, leaves, and other plant residue. When surface water is used for SDI, more complex filtration systems, such as sand media or disk filters may be desirable due to the greater contaminant loading.

Biological clogging hazards

Biological clogging hazards are often closely associated with surface water sources but can occur in groundwater supply wells that have become contaminated with bacteria.

Sand media filters (Figure 2) are commonly used to filter surface water with high organic material loads, although disk filters, when properly sized, can also address this water source. In addition, fixed or self-cleaning pre-filters in the stream, canal, lagoon, or reservoir might be used in advance of the filtration system. Particle size of the sand media is selected according to the desired degree of filtration (Table 3). Generally, sand media filters should be backflushed when the pressure drop reaches about 10 psi, or as recommended by the filtration system manufacturer. Additionally, it may be advantageous to incorporate a maximum interval (e.g., 2 hours) setting into the automatic backflushing program to lessen the chances for “rat-holing” where a preferential flow path occurs in the sand bed allowing excessive water flow without increasing the pressure differential. In a practical sense, a bank of two or more sand media filters operating in parallel is always required, so that backflushing can occur with filtered water and so that the SDI system can continue operating during the backflush cycle. Backflushing flow rates depend on the media size; lower flow rates should be used for finer filter media. Automatic flushing is generally required on sand media filtration systems. Some manufacturers and designers recommend the use of a screen filter after the sand media filter to reduce the hazard of runaway media clogging the SDI system should a catastrophic failure of the media filtration system occur.

Table 3. Sand media sizes and screen mesh equivalents. After Van der Gulik, 1999.

Sand Media Designation	Effective Sand Size (mm)	Equivalent Mesh Size Range
# 8 crushed granite	1.50	100 - 140
#12 silica sand	1.20	130 - 140
#11 crushed granite	0.78	140 - 180
#16 silica sand	0.70	150 - 200
#20 silica sand	0.47	200 - 250

Disk filters (Figure 2) are also sometimes used with surface water. In some respects they represent a hybrid of screen filters and sand media filters and are considered to provide three-dimensional filtration. The water source flows through small grooves on the disks that trap the contaminants. The grooves on the disk are in opposing directions on the upper and lower sides of each disk. This results in a large number (approximately 12 to 36) of random intersections (Burt and Styles, 2011) and openings of various shapes and sizes for the source water to flow through within the overall stack of disks. Disk filters generally require less backflush water than sand media filters. However, a backflushing pressure as high as 50 psi may be required, which may require the use of a pressure-sustaining valve or booster pump or both. Some automatic disk filters allow a slight separation in the disk stack during backflushing which can allow for a more thorough cleaning of the disks. Disk separation may not be a wise option if an appreciable amount of sand is present, as sand particles can get trapped between disks during separation and prevent thorough closing of the disks for subsequent filtration. Pre-filtering of the water source in advance of the disk filter should also be considered if heavy sand or organic loading is present.

Chemical clogging hazards

Naturally occurring chemical constituents within the source water and/or the addition of agrochemicals to the source water can cause chemical precipitation within the SDI system. The chemical precipitation can be enhanced by a change in water temperature or pressure during the SDI system operation. Water chemistry interactions can be quite complex and the scope of this presentation does not extend to a thorough discussion of this topic. Instead for a more thorough discussion of this topic, the reader is referred to K-State Research and Extension publication MF2575 ***Subsurface Drip Irrigation Systems (SDI) Water Quality Assessment Guidelines*** (electronically at http://www.ksre.k-state.edu/sdi/reports/2003/mf2575.pdf *Note: This 2003 publication is being revised in 2018, so please check for the latest available version*). The two major chemical clogging hazards to SDI systems in the U.S. Great Plains are precipitation of calcium carbonate (CaCO3 also called lime) and formation of iron ochre (slime).

FLUSHING OF DRIPLINES

As indicated earlier, the typical levels of filtration for SDI systems does not remove all of smaller particles in the source water. Over time these contaminants will begin to accumulate in the dripline and additionally can provide a nutrient source for biological growth. Chemical precipitation and biological growth within the driplines may also occur and begin to accumulate in the dripline. To prevent the continued accumulation of these materials and to reduce the potential for emitter clogging, the SDI system should be periodically flushed. The overall system flushing procedure should begin with the pipes of the largest size, which would be the mains, followed by the submains, and then the driplines. An appropriately designed SDI system will include a flushline on the distal end of the driplines to allow flushing of all pipeline and system components. Opening the flushline valve allows water to rapidly pass through the driplines, carrying away any accumulated particles (Figure 4). Additionally, since the flushline is interconnected with a group of driplines, if a dripline is damaged or ruptured, positive water pressure on both sides of the leak will limit sediment intrusion. The American Society of Agricultural and Biological Engineers (ASABE) recommends a minimum flushing velocity of 1 ft/s for microirrigation lateral maintenance (ASAE EP-405, 2008). Achieving an acceptable flushing velocity within the driplines can be hydraulically difficult for some SDI systems and pumping plants, so care must be taken in the design of the system and in the development of the flushing procedures. In some locations, government cost-sharing programs may require a greater flushing velocity in the design of SDI systems. This flushing velocity requirement needs to be carefully considered at the design stage and may dictate larger sizes for submains and flushlines to assure that maximum operating pressures for the driplines are not exceeded (Lamm and Camp, 2007). Research at K-State (Puig-Bargués and Lamm, 2013) has concluded that extending the duration of flushing may be a more cost effective means of protecting the driplines than increasing the flushing velocity. The increased duration would allow for more thorough purging of contaminants that may move in wave-like accumulations within the dripline. The frequency of flushing is largely determined by the quality of the irrigation water and, to a degree, the level of filtration. Evaluation of the amount of debris caught in a mesh cloth during a flushing event can be an indicator of whether more frequent flushing is warranted. When only a small amount of debris is found, the flushing interval may be increased. Heavy accumulations of debris, however, mean more frequent flushing is needed. When significant amounts of contaminants are found in the flush water, it would be wise to determine if these materials are physical (inorganic debris, sand, silt, and clay) biological (dead or living organisms, plant debris and bacterial slimes) and/or chemical precipitates. If sand particles are evident, then the filtration system may not be operating properly or may not have been designed properly. Refer to K-State Research and Extension publication MF2575 ***Subsurface Drip Irrigation Systems (SDI) Water Quality Assessment Guidelines*** (at http://www.ksre.k-state.edu/sdi/reports/2003/mf2575.pdf) for identifying the contaminants or send it to a laboratory for analysis.

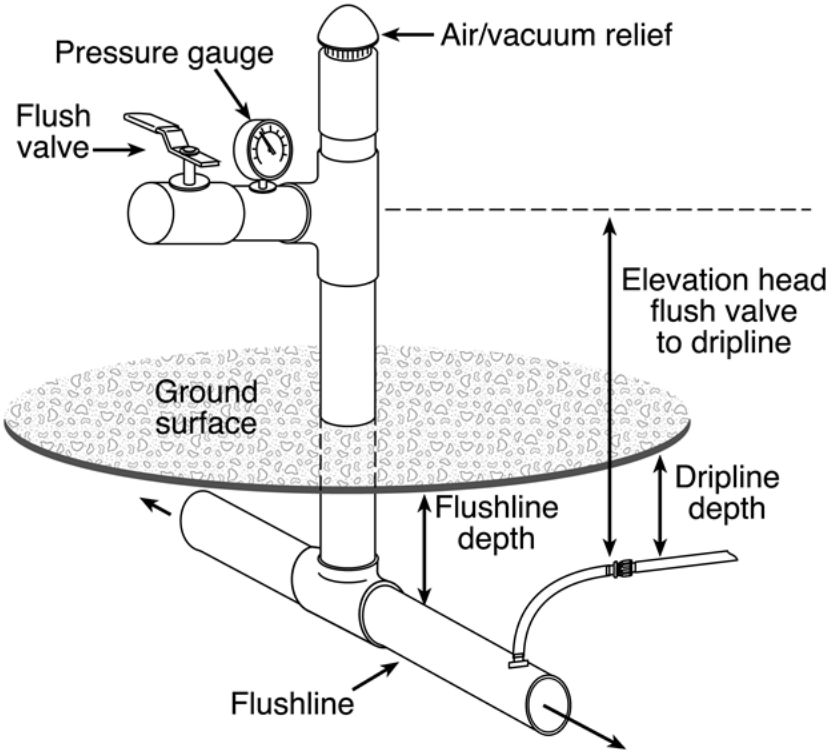

Figure 4. Typical flush valve assembly for a branched flushline. After opening the flushline valve, water can flow rapidly pass through the driplines, carrying away any accumulated particles. (Drawing courtesy of Kansas State University)

Sometimes acid and chlorine treated water may be left in the driplines for an extended period to increase treatment effectiveness. However, after this extended period, the SDI system needs to be thoroughly and completely flushed to remove any residue, sludge, and/or particles. After a long period of non-use, the driplines should be flushed. Flushing should continue until the flush water is clear and remains clear for one to two minutes.

OTHER GENERAL MAINTENANCE CONSIDERATIONS

System Evaluation

The SDI system should be thoroughly evaluated immediately after installation. A similar evaluation should be completed annually, preferably before the main irrigation season. If this is not possible, the evaluation should be conducted before crop growth obstructs the view of the soil surface making it difficult to observe leaks that may have occurred because of off-season rodent damage. Initial and annual evaluation records help to develop an SDI system performance history, which can alert the irrigator of developing problems. Off-season inspection should be performed on all components of the SDI system, including the well and pumping plant.

Well and Pumping Plant Inspection

Inspection for damage, wear, and needed repairs and maintenance on the pumping plant should be completed annually to ensure reliable in-season performance and to prevent costly shutdowns. Records on static and pumping water levels, discharge rate and wellhead pressure should be maintained and are important to determine long-term water supply trends. These records also can be useful to evaluate pumping plant efficiency when combined with fuel use records (See also K-State Research and Extension publication L-885 ***Evaluating Pumping Plant Efficiency Using On-Farm Bills*** or use ***Fuel Cost***, a software tool available at http://www.bae.ksu.edu/mobileirrigationlab/.)

Regular groundwater well treatment using shock chlorination also may be an important preventative maintenance procedure that reduces potential bacterial clogging overload of the filtration system and driplines. Wells that have high iron or manganese concentrations and have known iron bacteria infestations should be treated at least annually. Wells that have severe iron bacteria infestations may need to be treated more often to reduce the bacterial population to an acceptable level. Never pump the treated water from a shock chlorinated well into an SDI filtration system or the driplines (See K–State Research and Extension publication MF-2589, ***Shock Chlorination Treatment for Irrigation Wells*** which is available electronically at *http://www.ksre.k-state.edu/sdi/reports/2003/mf2589.pdf*).

SDI System Components

During the off-season, all valves, pressure regulators, pressure gauges, filters, fittings, and other system components should be inspected and if defective, they should be repaired or replaced. Some inspection can only be made during SDI system operation. Short-term system operation during the off-season (such as early to late spring) provides a good opportunity to observe for any dripline leaks. Rodent damage tends to occur more often during idle winter periods, so inspection during this time period can be very helpful. Unfortunately, dripline leaks may not be detectable during a short duration test, so observations should continue throughout the season, especially during irrigation or fertigation events that take place before full crop cover. A wet soil surface typically indicates a leak, particularly if standing or flowing water is observed, since surface wetting is a less common occurrence with SDI systems.

Start-Up Procedure at the Beginning of the Irrigation Season

After static inspection of the system components, start the pumping plant and bring the SDI system to normal operating conditions. A shock chlorination treatment may be beneficial at this time, followed by a complete system flush. This preventative maintenance procedure may help remove any biological growth or chemical reaction precipitates that may have occurred during the off-season. During this treatment, pressure gauge tests and leak inspections also can be conducted.

Root Intrusion

The root hairs of the crop can plug emitters and stop or reduce emitter discharge. In general, well-watered, seasonal (summer grown) crops have not caused emitter plugging in the U.S. Great Plains. However, root intrusion may become a problem for perennial crops, such as alfalfa. Some of this intrusion may occur during the early winter and spring periods when alfalfa root activity may be occurring, but irrigation is not. Root intrusion may be minimized by frequent and non-deficit irrigation. Use of acidic fertilizers may also help to prevent root intrusion. Preventive treatments of acid also can deter root intrusion by lowering the water pH. Some herbicides might also discourage root intrusion, but there are often strict limitations on their usage in the U.S. Great Plains. Dripline with herbicides impregnated in the line can be purchased, but are considerably more expensive than normal driplines.

Soil Ingestion

Soil particles can be sucked into the emitter orifice due to a vacuum effect during SDI system shut-down. This problem should be addressed during the design and installation phase by installing vacuum relief valves at all elevated points of the submains for each irrigation zone. These valves allow air to enter the pipeline system, thus neutralizing the associated vacuum during shutdown and drainage. This can be a difficult design issue to address for fields with undulating topography in a practical and inexpensive manner and this may prevent SDI adoption on these fields.

Rodent Control

Rodent damage to the driplines can be a very frustrating and time-consuming problem, although severe problems have not been a widespread problem occurring for all SDI systems. The driplines can be especially vulnerable immediately following installation before soil reconsolidation occurs and somewhat so during the off-season. SDI has the potential of being ideally suited to no-till systems, because fertilizers could be fed through the SDI system to the root zone. However, removal of overwintering habitat through tillage has been a tool to control rodent population, by reducing shelter and food sources in the field. Control of habitat in adjacent field edges and removal of habitat from around above-ground SDI system appurtenances also may help to reduce rodent pressure. Baiting of field edges, particularly those adjacent to road and railroad easements, irrigation canals, pastures, or other lands with permanent cover may help prevent field infestations.

CONCLUDING STATEMENTS

When using SDI systems, it is important to prevent clogging problems to ensure that the system will last for many years. The best prevention plan includes an effective filtration and water treatment strategy. Depending on the water source and its quality, various combinations of sand separation, screen filtration, sand media or disk filtration, chlorination, and acid injection may be required. Filtration equipment may be the single component of greatest cost when installing the SDI system. One must resist the temptation to *"cut corners."* Good filtration and system maintenance will pay for itself by avoiding labor, or extra effort that may be required to remediate or replace a damaged system that was not adequately maintained.

Profit margins for crops typically grown with SDI in the U.S. Great Plains are not as great as those for fruits and vegetables traditionally grown elsewhere. To make SDI systems in the Great Plains economically viable, they must have a long life. Prevention of emitter clogging and timely and consistent maintenance are therefore critical to the successful and economical use of SDI in the U.S. Great Plains.

OTHER AVAILABLE INFORMATION

Subsurface Drip Irrigation website: www.ksre.ksu.edu/sdi

General Irrigation website: www.ksre.ksu.edu/irrigate

Mobile Irrigation Lab website: http://www.bae.ksu.edu/mobileirrigationlab/

Maintenance of Microirrigation Systems http://micromaintain.ucanr.edu/

ACKNOWLEDGEMENTS

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