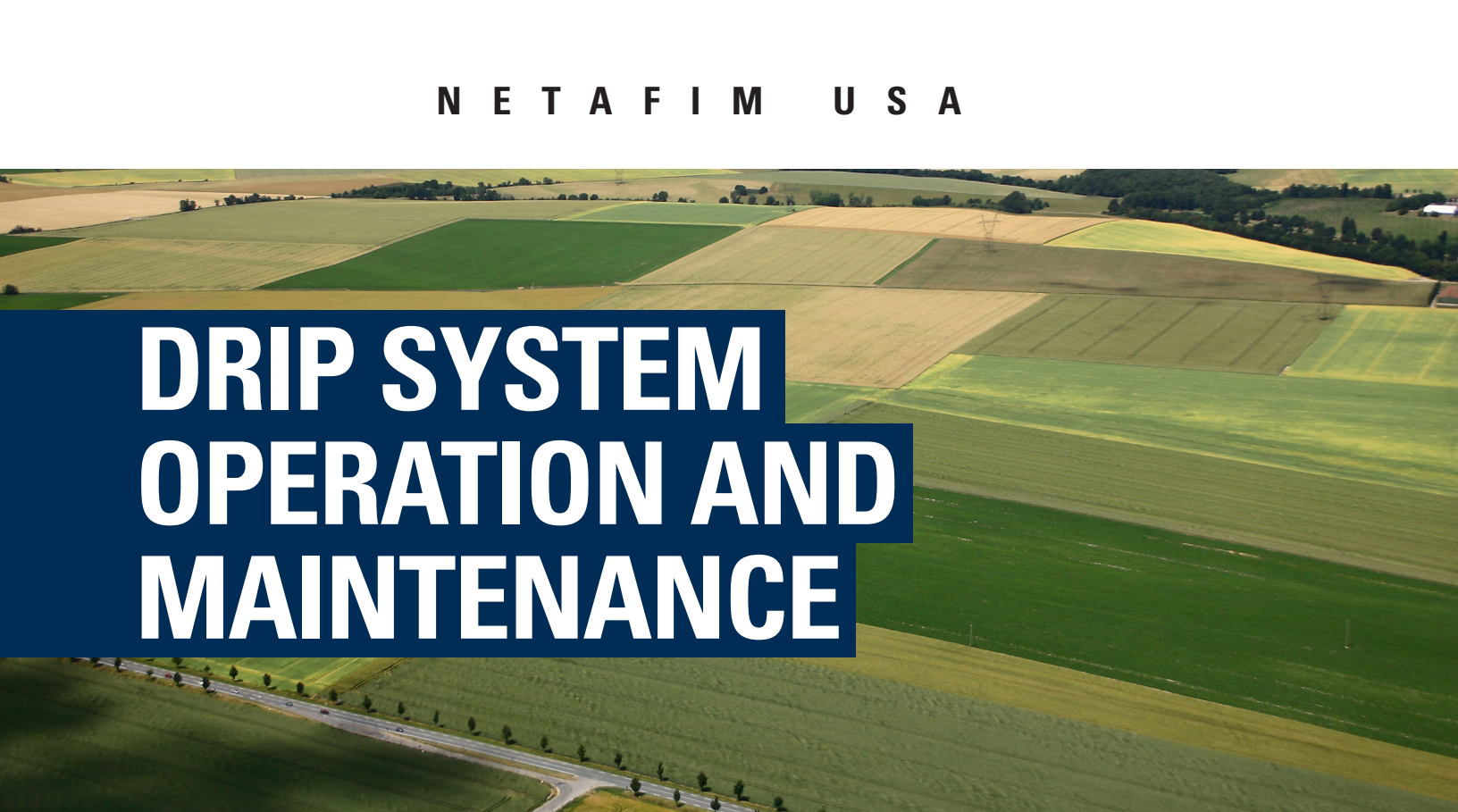


NETAFIM USA



DRIP SYSTEM OPERATION AND MAINTENANCE

RECOMMENDED PROCEDURES FOR A DRIP IRRIGATION SYSTEM

OVERVIEW

Subsurface Drip Irrigation (SDI) is a drip irrigation system where the dripline is permanently buried below the soil surface, supplying water directly to the roots. SDI is more than an irrigation system, it is a root zone management tool. Fertilizer can be applied to the root zone in a quantity when it will be most beneficial - resulting in greater use efficiencies and better crop performance. A number of crop protection chemicals are also available (labelled accordingly) for application through the drip system making it a powerful crop protection tool.

The longevity of the system will depend on factors such as initial water quality, proper operation, regular maintenance and the quality of the dripline. Netafim has sub-surface drip irrigation systems with more than 20 years of continuous operation. This publication details the procedures Netafim recommends to ensure the longest possible life for your SDI system.

BASIC SYSTEM LAYOUT

Figure 1 is a schematic layout of the components which make up an SDI system:

- Dripline - the heart of the system (depending upon the field conditions) can be either pressure compensating (hilly terrain) or non-pressure compensating (flat terrain).
- Filters (typically a disc or media filtration system) is the best choice to protect the dripline.
- Fertilizer Injector - injects fertilizer chemicals into the system for maximum crop performance and to maintain the dripline over the long term.
- Pipeline headers, control and air release vents complete the system.

Our intent is not to describe the process of system design in detail. Your Netafim USA Dealer is trained to design and install quality SDI systems. It is important to understand how the system is put together and why certain design elements are specified.

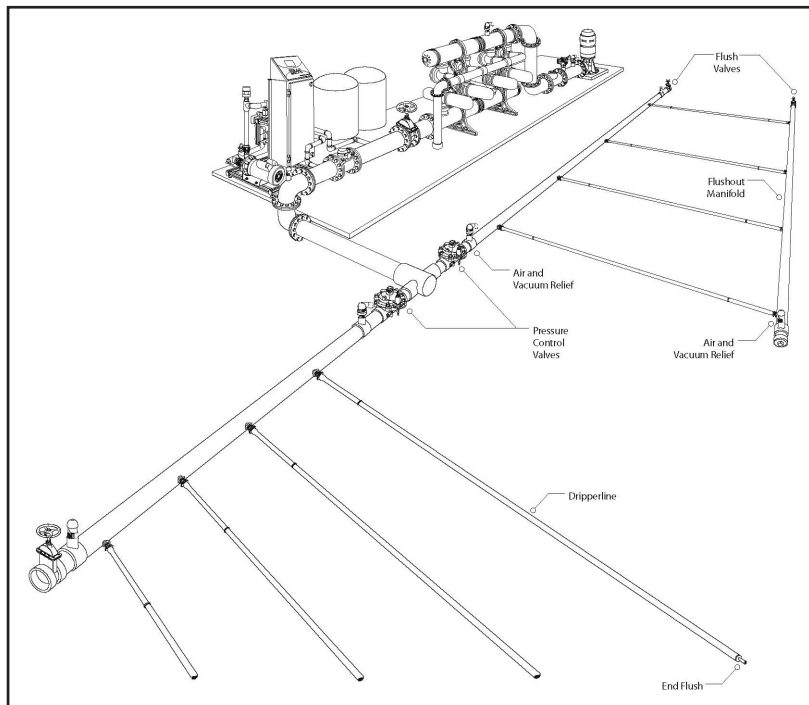


Figure 1. Schematic layout of drip system components

DRIPLINE SPECIFICATIONS

The following dripline recommendations are meant as guidelines only - soil type, topography and water quality will affect the final design. Your Netafim USA Dealer is familiar with the local conditions and will recommend a dripline that is appropriate for your area. The dripline should be installed with a GPS where possible so that its position can be determined as necessary. Depending upon local conditions the dripline can either have pressure compensating (Netafim DripNet PC or UniRam) or non-compensating drippers (Netafim Typhoon or Streamline). Factors such as length of run, topography, zone size and water quality play an important role in choosing the right dripper. Regardless of the type of dripper used there are several basic guidelines to follow:

1. The distance between driplines is determined by the crop. For corn crops with rows every 40" the typical spacing between

rows of driplines is 80", with the dripline located in the furrow and one dripline in every other row. With this layout one dripline irrigates two rows of corn with one irrigated row followed by a dry row. This arrangement has implications for measuring the moisture content of the soil. The measurement should never be taken in the dry row. Some growers have been increasing the density of their corn plantings by moving to 20" rows and in this case the dripline is placed on 40" centers. In all cases the water application rate is set by design to meet the crop needs given the water availability.

2. Driplines are generally buried at a depth of 12" to 18". The crop being grown, the soil texture and the presence of rodents are the main considerations for determining the burial depth of the dripline. Sandy soils generally require a more shallow burial. In areas with a large rodent population deeper burial of the dripline is less likely to cross paths with rodent's teeth. In general rodents are not fond of sandy soil so the shallower depth is not a concern. However, deeper placement may make it difficult to germinate the crop with the drip system unless there is sufficient residual moisture in the soil. The following should be taken into consideration when designing the SDI system:
 - The distance between drippers and the dripper flow rate - selected to achieve the appropriate application rate given the water availability.
 - Dripline wall thickness - 13 to 35 mil is usually recommended, with 15 to 25 mil most commonly used.

PUMP REQUIREMENTS

The volume output of the pumping station dictates the amount of area that can be irrigated. A simple formula has been derived converting the maximum required evapotranspiration rate (ET) in inches of water per day per acre into gallons per minute per acre.

$$\text{ET (inches/day/acre)} * 18.86 \text{ (conversion factor)} = \text{GPM/acre}$$

Using this formula - an ET of 0.25 inches per 24 hours per acre would require 4.72 GPM/acre. This calculation is for a pump running 24 hours. More commonly as a safety factor, systems are sized for 20 hours of operation. To accomplish this use the following formula:

$$24 \text{ (hours in a day)} / (\text{number of hours desired for irrigation}) \times (\text{GPM/acre}) \\ 24/20 \times 4.72 = 5.66 \text{ GPM/acre}$$

On flat land the pressure output required of the pump stations is mainly dictated by the flushing requirements of the filters and pipes. On hilly terrain the pressure required to lift water to the highest point must also be considered. Most automatic filters require a minimum of 30 psi to self-clean properly. This is generally the pump's minimum operating pressure to operate a drip system.

FILTRATION

The filter system protects the drip system from sand and other small particles which can plug the dripline's drippers. A well designed filter system maximizes the performance and longevity of your SDI system. Two types of filters are recommended:

1. Sand media filters
2. Netafim disc filters (Figure 2)

In general, screen filters are suitable only for very clean water sources. Sand media and disc filters which utilize depth filtration are most effective at removing suspended particles from the water. The filter system should be setup to automatically clean when the pressure differential across the media is too large. A pressure differential switch in combination with a flushing controller is a common approach for automation of filter cleaning.



Figure 2. Example of a Netafim Apollo Disc-Kleen Filter



PRESSURE REGULATING VALVES

Pressure control valves (Figure 3) are recommended for non-pressure compensated dripline to achieve the correct working pressure in the drip system. Pressure regulating valves must be adjustable to accommodate higher pressures required during flushing.

AIR VENTS

Air vacuum vents (Figure 3) prevent soil suction into the drippers at system shut-down. For every 50 laterals there should be one anti-vacuum vent at the highest elevation and one mounted on the flushing manifold's highest elevation. A double-purpose automatic air vent must be installed at the pump and is usually required in the mainline.

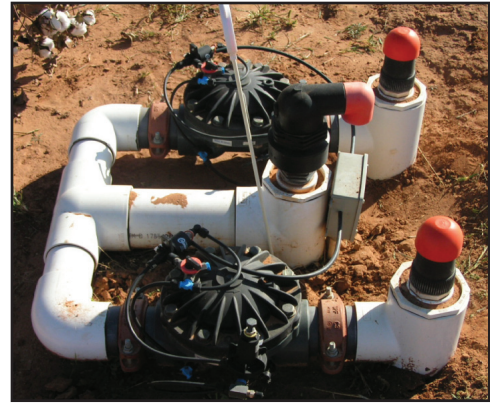


Figure 3. Example of a field installation of pressure regulating valves and air vents

FERTILIZER INJECTION SYSTEM

The system (Figure 4) is designed to supply fertilizer to all irrigation blocks using either an automated system or a simple injection pump. Please consult a Netafim USA Dealer to determine which fertilizers may be safely applied through the drip system.

WATER METERS

It is essential to monitor flow in order to monitor the operation of your system and crop's water use. Your SDI system is designed to produce a specific flow rate at a given pressure. Changes in the flow rate may indicate leaks in the system, improperly set pressure regulating valves or even changes in the well and pumping plant. On the following pages, use of a water meter and a pressure gauge to determine system problems is detailed.



Figure 4. Fertilizer Injection system

PRESSURE GAUGES

Use pressure gauges to ensure that the drip system, filter system and pump operate at the correct pressure. Pressure gauges are also critical to assess potential problems with the system.

FLUSH MANIFOLDS

Most permanent SDI systems use flush manifolds to flush entire zones at a single time. A manifold at the end of the field also improves system uniformity. The use of flush manifolds is highly recommended to reduce the labor required to properly maintain the system.

SYSTEM STARTUP

Whether you have just installed a new system or are starting the system up after sitting through the off season, these simple steps, taken before irrigation will help to ensure optimum system performance.

1. Flush the well before operation through the filter. A new well or one that has been sitting during the off-season, may discharge sand at startup. This "plug" of particles can overwhelm the filtration system causing it to repeatedly trigger an unproductive backflush cycle. If the well discharges sand on a regular basis it may be necessary to install a sand separator before the regular filtration system. Consult your Netafim USA Dealer for more information on sand separators.
2. Thoroughly flush the laterals and mains before system operation. In new systems, during installation, it is possible that dirt and PVC pieces accumulated in the system - these need to be flushed out properly. During the season, systems need to be flushed on a regular basis. Filters do not filter 100% of particles, often fine silt enters. This will settle in lines and must be flushed especially from the driplines. Debris also can get into the lines after a break has occurred and should be flushed after any repairs.
3. Check for leaks in dripline laterals. Laterals are occasionally damaged during installation. System start-up is the right time to check for leaks, before the crop canopy expands making repairs difficult.

STARTUP PROCEDURE

1. Open flush manifolds on line ends.
2. If possible, run the pump station for a few minutes with the discharge to waste (not through irrigation system) to flush out any sand.
3. Open mainline flush valves, with submain valves closed, and operate your system until discharge water runs clear for 5 minutes. Check the flow rate and whether and how often the filter system backflushes during operation.
4. Open submain valves with flush manifolds still open to clear the submains of debris.
5. For each submain, open the control valve until discharge water at the end of the lateral runs clear. If the capacity of the water supply is insufficient to flush all laterals simultaneously, then flush a few laterals at a time. Close the submain valve.
6. Close the flush manifolds on lateral ends.
7. Operate the system until it is fully pressurized and all air is discharged.
8. Check system for leaks and repair.
9. Re-flush the lines after leaks are repaired.
10. Check pressure gauges and adjust all pressure regulators, or regulating valves as necessary.
11. Check for proper operation of all system components: pumps, controllers, valves, air vents, pressure regulators, gauges, water meters, filter system and fertilizer injectors.
12. Record readings from all pressure gauges and flow meters and check on the frequency of backflush cycle of your filters. If backflushing is frequent (several times an hour) consult your Netafim USA dealer.

SYSTEM PRESSURE AND FLOW TESTS

Upon initial startup it is best to evaluate the uniformity of your drip system. This is accomplished by:

1. Measuring the pressure in the system at various points and comparing this to the design pressure.
2. Reading the water meter or calculating the system flow and comparing the result to the designed flow rate.

These evaluations should be conducted as part of system startup and as an ongoing part of system maintenance. Consult the maintenance section of this guide for a complete program for system care.

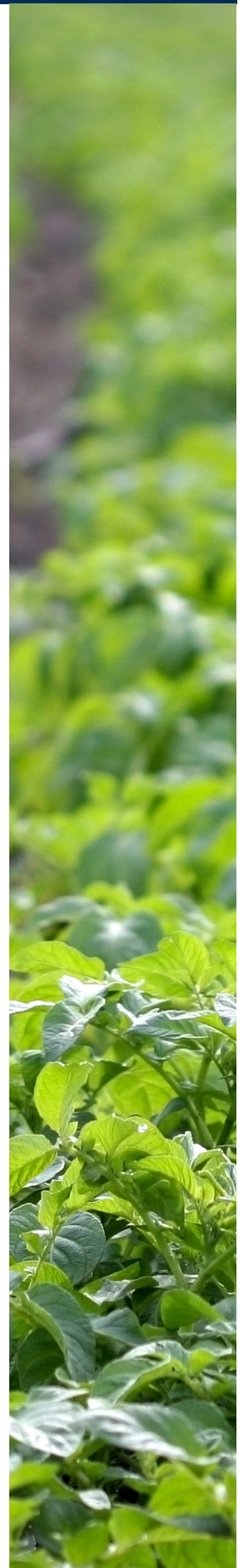
SYSTEM PRESSURE EVALUATION

Drip systems are typically designed to operate between 10 and 15 psi. Measuring the pressure at several points in your drip system is the simplest way to evaluate the performance. A good evaluation will include pressure measurements at a minimum of three points along the header end of the field and three points at the far end of the field. Pressure measurements at more points in the field including along the length of the laterals will give a more complete picture of system uniformity but are usually not necessary if the end pressures are within one psi of the header pressure.

SYSTEM FLOW RATE

A water meter is an important component of every drip system. It gives the operator a quick indication of the operational performance of their system and is used to determine proper water application rates. Every new system should be designed with a water meter. Older systems without water meters should be retrofitted with one. The system design should include an estimated system flow rate and the measured flow rate should be within +/- 5% of the designed rate. To calculate the flow rate expected for each zone use the following formula:

$$\text{Flow rate (GPM)} = (0.2) \times \text{length of dripline (ft)} \times \text{dripper flow rate (GPH)} / \text{dripper spacing (in)}$$



CONVERTING SYSTEM FLOW RATE TO INCHES OF APPLIED WATER

Irrigation schedules are usually based on evapotranspiration (ET) rates which are expressed in inches of water evaporated over a given time period, usually a day or week. It is simple to convert a flow rate in GPM, either read from a meter or calculate as outlined on previous page, to inches of water applied per hour by using the following formula.

$$\text{Inches of water applied per hour} = (0.00221) \times (\text{flow rate, in GPM}) / (\# \text{ acres})$$

For example, a typical SDI system on alfalfa will have 40" spacing between dripline rows with 0.16 GPM drippers spaced at 24 inches. One acre of the above system has 62 rows each, 208 feet long for a total of 12,896 feet. This gives a flow rate of 17.19 GPM.

$$(0.00221) \times 17.19 / 1 = 0.038 \text{ inches per hour which equals } 0.456 \text{ inches in 12 hours}$$

MONITORING YOUR DRIP SYSTEM

To achieve the highest yields and water savings possible with a drip irrigation system, it is necessary to monitor your system and make adjustments. In addition, regular system monitoring may give advance warning of potential problems.

MONITORING SYSTEM PRESSURE AND FLOW RATES

As presented earlier, measurements of system flow and pressure give a good picture of the system's performance. Because of the large number of variables at play in an irrigation system the measured water application rate may not exactly match the predicted rate. Still large differences in calculated versus measured values may indicate a problem with your calculations or a physical system problem such as a broken or clogged line. Over the growing season changes in the flow rate or pressure in your system can be used to diagnose problems with the system. Table 2, details some of the problems that can be diagnosed by monitoring system pressure and flow rate. This is by no means a comprehensive list but is a good place to start.

DRIP SYSTEM MAINTENANCE

The maintenance of your SDI system centers on identification of the factors which can lead to reduction of the performance of your drip system and procedures to mitigate these negative impacts. Factors that can slow or stop flow through the drip system include: suspended material, chemical precipitation, biological growth, root intrusion, soil ingestion and crimping of the dripline. To ensure maximum system life reduce or eliminate the impact of the negative factors (Table 2). This may require water treatment and a systematic program for regular maintenance. In this section we outline the various potential issues that can adversely affect the drip system and offer procedures to mitigate the potential damage.

INDICATION	POSSIBLE PROBLEM
Gradual decrease in flow rate	Dripper plugging Possible pump wear (check pressure)
Sudden decrease in flow rate	Stuck control valve Water supply failure
Gradual increase in flow rate	Incremental damage to dripperline by pests
Sudden increase in flow rate	Broken lateral, submain, main line Pressure regulator failure
Large pressure drop across filters	Debris buildup in filters Inadequate flushing of filters
Gradual pressure decrease at filter inlet	Pump wear or water supply problems
Sudden pressure decrease at filter outlet	Broken lateral, submain, main line Pressure regulator or water supply failure
Gradual pressure increase at filter outlet	Dripper plugging
Sudden pressure increase at filter outlet	Stuck control valve Other flow restrictions
Sudden pressure decrease at submain	Damaged or broken lateral

Table 2. Problems diagnosed from system flow rates and pressures

WATER QUALITY

The potential for dripper plugging problems will vary with the source of the irrigation water, either surface or ground water. In general, algae and bacterial growth are usually associated with the use of surface water. Whole algae cells and organic residues of algae are often small enough to pass through the filters of an irrigation system. These algae cells can then form aggregates that plug the drippers. Residues of decomposing algae can accumulate in pipes and drippers to support the growth of slime-forming bacteria. Surface water can also contain larger organisms such as moss, fish, snail, seeds and other organic debris that must be adequately filtered to avoid plugging problems. Groundwater, on the other hand, may contain high levels of minerals that can challenge dripper function. Water from shallow wells (less than 100 feet) often will produce plugging problems associated with bacteria. Chemical precipitation is more common with deep wells.

A water quality analysis can give the grower a “heads up” on potential trouble areas for the drip system. This test should be accomplished before the final design of the system to ensure that proper components are installed to address any problem areas. Many laboratories around the United States have Water Quality Analysis services available which are able to conduct a “Drip Irrigation Suitability Test”. The analysis should include testing for pH, dissolved solids, manganese, iron, hydrogen sulfide, carbonate and bicarbonates. Table 3 lists the more common water quality issues that can affect drip irrigation systems. Having a water analysis in the moderate or even severe category does not mean drip irrigation cannot be used but only that special precautions must be applied to prevent problems. Consult your local Netafim USA Dealer for more information on water quality and drip irrigation.

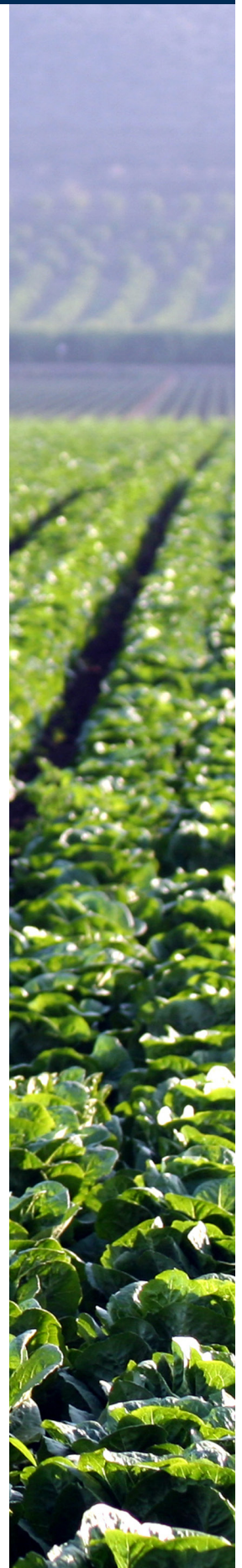
TYPE OF FACTOR	MINOR	MODERATE	SEVERE
SUSPENDED SOLIDS (ppm)			
INORGANIC	<10	10 - 100	>100
ORGANIC	<10		>10
CLOGGING			
IRON (ppm)	0.0 - 0.1	0.1 - 0.4	0.4+
MANGANESE (ppm)	0.0 - 0.2	0.2 - 0.4	0.4+
SULFIDES (ppm)	0.0 - 0.1	0.1 - 0.02	0.2+
CALCIUM CARBONATE	0.0 - 50.0	50.0 - 100.0	150.0+
BIOLOGICAL			
BACTERIA POPULATIONS	10,000	10,000 - 50,000	50,000+

Table 3. Common water quality issues with drip irrigation

SUSPENDED SOLIDS

Suspended solids in the incoming water are the most common stress impinging upon the drip system and the easiest to control. Each and every Netafim dripper has a large filter built into the unit to keep suspended particles from being trapped in the labyrinth. This filter is located at the bottom of dripper and points toward the center of the drip tubing so that it can be cleaned by flushing the dripline. This built-in filter plays an important role in the longevity of the SDI system. Thus, most water used for drip irrigation must be filtered to remove suspended solid particles that can lodge in the drippers and reduce or even stop the flow. These particles can be either organic such as algae or inorganic such as sand. Each manufacturer recommends a filtration level based on the technology of the dripper device. The Netafim drippers commonly require 120 mesh filtration. This is the lowest filtration requirement of any commercial drip irrigation product. That means that the drippers are more reliable ensuring long service even under harsh conditions.

Surface water generally contains a combination of organic and inorganic suspended particles. These include algae, moss, aquatic animals as well as suspended sand, silt and clay particles. Filtering this mix of material is a challenge that is best accomplished using three-dimensional filtration, such as disc or sand media. Well water generally has lower levels of suspended solids which can be handled using disc filtration or in cases of very low contaminant levels screen filters. If large quantities of sand are being generated by the well a sand separator may be installed before other filters. Filters for SDI should automatically clean (backflush) during operation when the contaminant levels get high enough.



CHEMICAL PRECIPITATION

Chemical plugging usually results from precipitation of one or more of the following minerals: calcium, magnesium, iron, or manganese. The minerals precipitate from solution and form encrustations (scale) that may partially or completely block the flow of water through the dripper (see Figure 5). Water containing significant amounts of these minerals and having a pH greater than seven has the potential to plug drippers. Particularly common is the precipitation of calcium carbonates, which is temperature and pH dependent. An increase in either pH or temperature reduces the solubility of calcium in water, and results in precipitation of the mineral.

When groundwater is pumped to the surface and discharged through a micro-irrigation system, the temperature, pressure and pH of the water often changes. This can result in the precipitation of calcium carbonates or other minerals to form scale on the inside surfaces of the irrigation system components. A simple test for identifying calcium scale is to dissolve it with vinegar. Carbonate minerals dissolve and release carbon dioxide gas with a fizzing, hissing effervescence.

Iron is another potential source of mineral deposit that can plug drippers.

Iron is encountered in practically all soils in the form of oxides, and it is often dissolved in groundwater as ferrous bicarbonate. When exposed to air, soluble ferrous bicarbonate oxidizes to the insoluble or colloidal ferric hydroxides and precipitates. The result is commonly referred to as 'red water,' which is sometimes encountered in farm irrigation wells. Manganese will sometimes accompany iron, but usually in lower concentrations.

Hydrogen sulfide is present in many wells. Precipitation problems will generally not occur when hard water, which contains large amounts of hydrogen sulfide, is used. Hydrogen sulfide will minimize the precipitation of calcium carbonate (CaCO_3) because of its acidity.

Fertilizers injected into a drip system may contribute to plugging. This may be the result of a chemical reaction that occurs when different fertilizers are mixed or because the fertilizer in question is not completely soluble. This type of plugging is completely preventable. To determine the potential for plugging problems from fertilizer injection, the following test can be performed:

1. Add drops of the liquid fertilizer to a sample of the irrigation water so that the concentration is equivalent to the diluted fertilizer that would be flowing in the lateral lines.
2. Cover and place the mixture in a dark environment for 12 hours.
3. Direct a light beam at the bottom of the sample container to determine if precipitates have formed. If no apparent precipitation has occurred, the fertilizer source will normally be safe to use in that specific water source.

BIOLOGICAL GROWTH

A micro-irrigation system can provide a favorable environment for bacterial growth, resulting in slime buildup. This slime can combine with mineral particles in the water and form aggregates large enough to plug drippers. Certain bacteria can cause enough precipitation of manganese, sulfur and iron compounds to cause dripper plugging. In addition, algae can be transported into the irrigation system from the water source and create conditions that may promote the formation of aggregates.

Dripper plugging problems are common when using water that has high biological activity and high levels of iron and hydrogen sulfide. Soluble ferrous iron is a primary energy source for certain iron-precipitating bacteria. These bacteria can attach to surfaces and oxidize ferrous iron to its insoluble ferric iron form. In this process, the bacteria create a slime that can form aggregates called ochre, which may combine with other materials in the micro-irrigation tubing and cause dripper plugging. Ochre deposits and associated slimes are usually red, yellow or tan.

Sulfur slime is a yellow to white stringy deposit formed by the oxidation of hydrogen sulfide. Hydrogen sulfide (H_2S) accumulation in groundwater is a process typically associated with reduced conditions in anaerobic environments. Sulfide production is common in lakes and marine sediments, flooded soils, and ditches; it can be recognized by the rotten egg odor. Sulfur slime is produced by certain filamentous bacteria that can oxidize hydrogen sulfide and produce insoluble elemental sulfur.

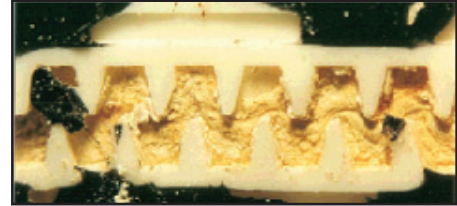


Figure 5. Dripper with calcium precipitate. The black pieces in the picture are pieces of the cut-away plastic dripline and not contaminants.



Figure 6. Filamentous sulfur slime completely clogging a small water meter.

The sulfur bacteria problem can be minimized if there is not air-water contact until water is discharged from the system. Defective valves or pipe fittings on the suction side of the irrigation pump are common causes of sulfur bacteria problems. If a pressure tank is used, the air-water contact in the pressure tank can lead to bacterial growth in the tank, clogging the dripper. The use of an air bladder or diaphragm to separate the air from the water should minimize this problem.

ROOT INTRUSION

Plant roots tend to grow toward soil areas with the highest water content. Because of this tendency, roots can clog subsurface drip systems by growing into the dripper openings. Plant roots tend to “hunt” for water when it is in short supply thus, the problem seems to be more acute when irrigation is not sufficient for the plant needs. This is a particular problem in systems that are left unused for part of the season. Several strategies can be employed to reduce the possibility of root intrusion:

1. Short frequent irrigations keep adequate water in the root zone so the roots have no need to look for water.
2. Acid injection that lowers the pH to less than four will discourage root growth and can be used to clean roots out of drippers with small amounts of root intrusion. High concentrations of chlorine (100 to 400 ppm), N-PHURIC, phosphoric or metam sodium (Vapam) will also destroy roots in the drippers.
3. In areas where it is allowed, trifluralin is an effective inhibitor of root growth and can be used to prevent root intrusion.
4. Seamed dripline encourages roots to grow along the seam and into the dripper. Netafim products are designed without a seam to discourage this intrusion.

SOIL INGESTION

Soil ingestion is not a problem in properly designed SDI systems. Soil injection occurs when soil is sucked into the dripline. When a drip system is shut off the water continues to flow to the low end of the field creating a vacuum at the higher end, sucking saturated soil into the line. A properly designed drip system will minimize this potential problem. The supply manifold must be equipped with vacuum relief vents, these vents allow air to flow into the driplines when the system is shut off. Netafim air/vacuum relief vents will allow sufficient air into the system. Insufficient air will create a vacuum (similar to not using vents). This is not a good place to skimp.

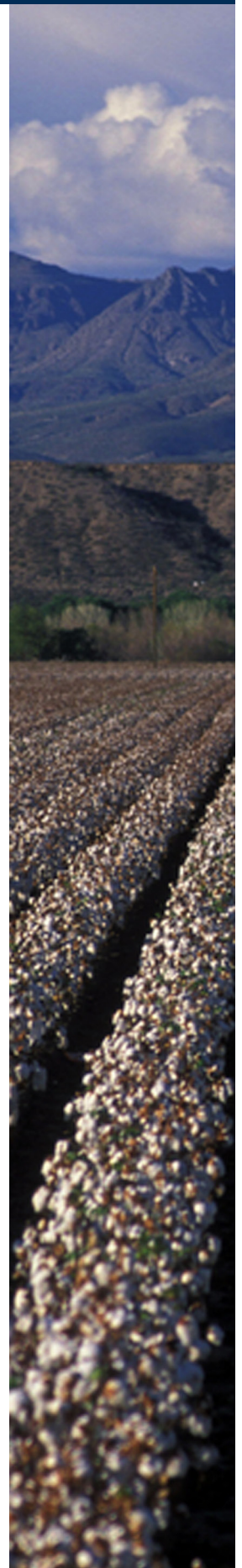
CRIMPING OF THE DRIPLINE

Pinching of the dripline can occur as the result of soil disturbance by equipment or drying out. Because it is difficult to correct crimping in an SDI system many growers are setting up their system so there is minimum traffic on the driplines. The lines are installed using GPS and the field is laid with specific traffic rows.

MAINTENANCE PROCEDURES

Filter Maintenance

Follow the standard instructions for the maintenance of your filter system. Filters are the first line of protection for your drip system and they need regular maintenance to operate at a high level. On a bi-weekly basis observe the system as it completes a backflush cycle. Make sure all pressures are within the system limits before and after backflushing. Check the operation of backflush valves, pressure differential switches and controller. Make sure you clean the command filter. At the end of the season check the media level in media tanks. Scum can build up on disc filters and the discs may need to be cleaned with acid. In areas that experience a freeze, drain all water from the filter, valves and command system.



Dripline Flushing

To minimize sediment build up, regular flushing of drip irrigation pipelines is recommended. The system design should be such that a minimum flush rate of 1.0 ft/sec can be obtained in the lines. Valves large enough to allow sufficient velocity of flow should be installed at the ends of mains, submains and manifolds. Also, allowances for flushing should be made at the ends of lateral lines. Flushing of the drip lateral lines should continue until clean water runs from the flushed line for at least two minutes. A regular maintenance program of inspection and flushing will help significantly in preventing dripper plugging.

Chemical Treatment

Chemical treatment is often required to prevent dripper plugging due to microbial growth and/or mineral precipitation. The attachment of inorganic particles to microbial slime is a significant source of dripper plugging. Chlorination is an effective measure against microbial activity. Use chlorine and all other chemicals only according to label directions. Acid injection can remove scale deposits, reduce or eliminate mineral precipitation and create an environment unsuitable for microbial growth.

CHLORINE INJECTION

Overview

Chlorination is the most common method for treating organic contaminants. Active chlorine is a strong oxidizer and as such, is useful in achieving the following:

- A. Prevent clogging and sedimentation of organic substances.
- B. Destroy and decompose sulfur and iron bacteria, as well as accumulated bacterial slime in the system.
- C. Improve performance of filtration systems while reducing backflush water.
- D. Clean systems of organic sediments. (Chlorine has no effect on scale deposits.)

If the micro-irrigation system water source is not chlorinated, it is a good practice to equip the system to inject chlorine to suppress microbial growth. Since bacteria can grow within filters, chlorine injection should occur prior to filtration.

Liquid sodium hypochlorite (NaOCl)--laundry bleach--is available at several chlorine concentrations. The higher concentrations are often more economical. It is the easiest form of chlorine to handle and is most often used in drip irrigation systems. Powdered calcium hypochlorite (CaCOCl₂), also called High Test Hypochlorite (HTH), is not recommended for injection into micro-irrigation systems since it can produce precipitates that can plug drippers, especially at high pH levels. The following are several possible chlorine injection schemes:

- Inject continuously at a low level to obtain one to two ppm of free chlorine at the ends of the laterals.
- Inject at intervals (once at the end of each irrigation cycle) at concentrations of 20 ppm and for a duration long enough to reach the last dripper in the system.
- Inject a slug treatment in high concentrations (50 ppm) weekly at the end of an irrigation cycle and for a duration sufficient to distribute the chlorine through the entire piping system.

The method used will depend on the growth potential of microbial organisms, the injection method and equipment and the scheduling of injection of other chemicals.

When chlorine is injected, a test kit should be used to check to see that the injection rate is sufficient. Color test kits (D.P.D.) that measure 'free residual' chlorine, which is the primary bactericidal agent, should be used. The orthotolidine-type test kit, which is often used to measure total chlorine content in swimming pools, is not satisfactory for this purpose. D.P.D. test kits can be purchased from irrigation equipment dealers. Check the water at the outlet farthest from the injection pump. There should be a residual chlorine concentration of one to two ppm at that point. Irrigation system flow rates should be closely monitored, and action taken (chlorination) if flow rates decline.

Chlorination for bacterial control is relatively ineffective above pH 7.5, so acid additions may be necessary to lower the pH to increase the biocidal action of chlorine for more alkaline waters. Since sodium hypochlorite can react with emulsifiers, fertilizers, herbicides and insecticides, bulk chemicals should be stored in a secure place according to label directions.

Recipe for Chlorine Injection

WARNING: Active chlorine solutions are dangerous to human beings and animals - **the manufacturers' instructions must be followed very carefully.** When using chlorine, proper protection for the eyes, hands and body parts must be worn, i.e. glasses, gloves, shoes, etc. Chlorine contact with the skin can cause serious burns, contact with the eyes can cause blindness and swallowing may be fatal. Prior to filling any tank with chlorine solution, be sure it is absolutely clean of fertilizer residue. Direct contact between chlorine and fertilizer can create a thermo reaction, which can be explosive. **This is extremely dangerous.** The direct contact of chlorine and fertilizer in the irrigation water after it has been injected into the system is not hazardous.

The contact of free chlorine in water and nitrogenous (ammonium and urea) fertilizer creates the combination of chlor amine which is called "combined chlorine". If possible, avoid any application of ammonium or urea fertilizers together with chlorination.

In the case that chlorination is required, it is recommended to ask your local Farm Extension Service for assistance in the computation and application methods.

Sodium hypochlorite is transported by tanks. It should be stored in a clean tank without any remnants of fertilizers. The tanks should be painted white and placed in a shaded area. In the field, storage should not exceed 20 days. In case of gas chlorine, transportation, storage and general handling should be carried out in accordance with the manufacturers' specific instructions under supervision of the relevant authorities.

CHLORINATION OBJECTIVE	APPLICATION METHOD	REQUIRED CONCENTRATION (PPM = PARTS PER MILLION)	
		SYSTEM HEAD	SYSTEM END
PREVENT SEDIMENTATION	CONTINUOUS CHLORINATION	3 - 5	0.5 - 1
	INTERMITTENT CHORINATION	10	1 - 2
SYSTEM CLEANING	CONTINUOUS CHLORINATION	5 - 10	1 - 2
	INTERMITTENT CHORINATION	15 - 50	4 - 5

CONCENTRATION AND INJECTION POINT

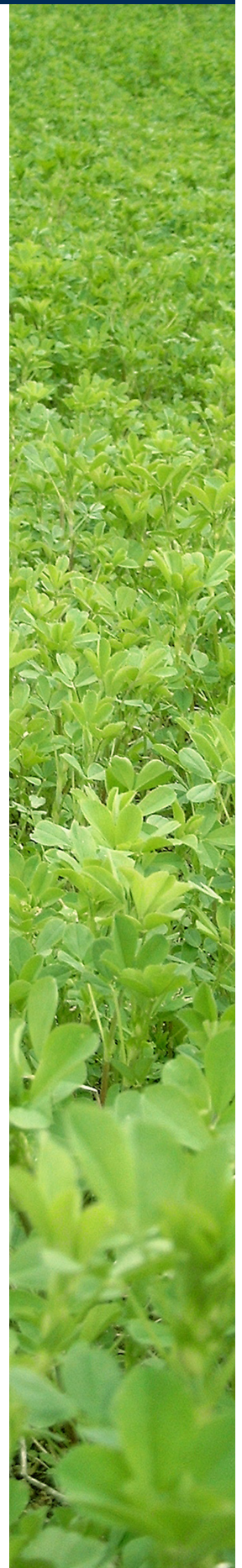
It is important to remember that chlorine concentration decreases as time and distance from the injection point increases. The lowest concentration will always be found furthest from the injection point. The injection point should be as close as possible to the treated system.

The required concentration of active chlorine is a result of the chlorination objective.

When the purpose of chlorination is improving filtration performance, the injection point should be close to the filtration system to assure even distribution throughout the filters. Chlorine concentration downstream of the filter battery should be no less than one to two ppm for constant chlorination and three times more for intermittent chlorination.

For continuous chlorination, the injection should start after pressurizing the system. For intermittent chlorination, the procedure should be as follows:

START	By flushing the system.
INJECTION	Inject required amount over time, preferably at the beginning of the cycle.
CONTACT TIME	Preferably one hour, but not less than thirty minutes.
FLUSH	At the end of the process, open the end of the line, flush out and run fresh water for an hour.



CALCULATIONS - Liquid Chlorine

Use the following worksheets to determine the proper injection rate of chlorine in terms of GPH for liquid and lbs./hr for gas.

1. Choose the proper chlorine solution factor:
5% Chlorine Solution: The factor is = 2.00
10% Chlorine Solution: The factor is = 1.00
15% Chlorine Solution: The factor is = 0.67
2. Multiply the solution factor by the treated flow in terms of GPM.
3. Multiply by the desired chlorine concentration in terms of ppm.
4. Multiply by the factor of 0.0006.
5. The result will be the required injection rate of chlorine in terms of GPH

FOR EXAMPLE:

The chlorine solution is 10%. The flow is 100 GPM. The desired chlorine concentration is 10 ppm.

$$\begin{array}{ccccccc} \text{Chlorine} & & \text{Flow} & & \text{Desired Chlorine} & & \text{Chlorine Injection} \\ \text{Solution Factor} & \times & \text{GPM} & \times & \text{concentration (ppm)} & \times & 0.0006 = \text{Rate GPH} \\ 10 & \times & 100 & \times & 10 & \times & 0.0006 = 0.6 \end{array}$$

The injection rate of chlorine solution will be **0.6 GPH**

CALCULATIONS - Chlorine Gas

1. Determine the flow of the treated zone in terms of GPM.
2. Multiply the flow by the desired chlorine concentration in terms of ppm.
3. Multiply it by the factor of 0.0005.
4. The result will be the injection rate of the gas in terms of lbs. per hour.

FOR EXAMPLE:

The flow is 100 GPM. The desired chlorine concentration is 10 ppm.

$$\begin{array}{ccccccc} \text{Flow} & & \text{Desired Chlorine} & & \text{Chlorine Injection} \\ \text{GPM} & \times & \text{Concentration (ppm)} & \times & 0.0005 = \text{Rate (lbs./hr)} \\ 100 & \times & 10 & \times & 0.0005 = 0.5 \end{array}$$

The injection rate of the gas will be **0.5 lbs./hr.**

ACID INJECTION

Overview

Acid can be used to lower the pH of irrigation water to reduce the potential for chemical precipitation and to enhance the effectiveness of the chlorine injection. Sulfuric, hydrochloric and phosphoric acid are all used for this purpose. Acid can be injected in much the same way as fertilizer; however, extreme caution is required. The amount of acid to inject depends on how chemically base (the buffering capacity) the irrigation water is and the concentration of the acid to be injected. One milliequivalent of acid completely neutralizes one milliequivalent of bases.

If acid is injected on a continuous basis to prevent calcium and magnesium precipitates from forming, the injection rate should be adjusted until the pH of the irrigation water is just below 7.0. If the intent of the acid injection is to remove existing scale buildup within the micro-irrigation system, the pH will have to be lowered more. The release of water into the soil should be minimized during this process since plant root damage is possible. An acid slug should be injected into the irrigation system and allowed to remain in the system for several hours, after which the system should be flushed with irrigation water. Acid is most effective at preventing and dissolving alkaline scale. Avoid concentrations that may be harmful to drippers and other system components.

Phosphoric acid, which is also a fertilizer source, can be used for water treatment. Some micro-irrigation system operators use phosphoric acid in their fertilizer mixes. Care should be used with the injection of phosphoric acid into hard water since it may cause the precipitation of calcium carbonate.

For safety, dilute the concentrated acid in a non-metal, acid-resistant mixing tank prior to injection into the irrigation system. When diluting acid, always add acid to water, never water to acid. The acid injection point should be beyond any metal connections or filters to avoid corrosion. Flushing the injection system with water after the acid application is a good practice to avoid deterioration of components in direct contact with the acid.

Acids and chlorine compounds should be stored separately, preferably in epoxy-coated plastic or fiberglass storage tanks. Acid can react with hypochlorite to produce chlorine gas and heat; therefore, the injection of acid should be done at some distance (two feet), prior to the injection of chlorine. This allows proper mixing of the acid with the irrigation water before the acid encounters the chlorine.

Hydrochloric, sulfuric and phosphoric acids are all highly toxic. Always wear goggles and chemical-resistant clothing whenever handling these acids. Acid must be poured into water; never pour water into acid.

Recipe for the Treatment of Drip Irrigation Systems with Acid

SAFETY PRECAUTIONS: Contact of the acid with the skin can cause burns. Contact with the eyes could be extremely dangerous. During treatment and especially when filling containers with acid, wear protective goggles, clothes and boots. Follow the instructions on the Material Safety Data Sheet (M.S.D.S.) attached to the delivered acid.

PROBLEMS OF CORROSION: Polyethylene and PVC tubes are resistant to acid. Aluminum, steel, (with or without inner concrete coating) and asbestos-cement pipes are damaged by corrosion. In every case, resume normal water flow through the system after completion of treatment for at least one hour in order to flush any remaining acid. The importance of flushing cannot be over emphasized when the pipes used are particularly sensitive to corrosion.

METHOD OF OPERATION: Acid can be applied through the drip irrigation system by a fertilizer pump resistant to acids or by conventional control head with a fertilizer tank.

APPLICATION OF ACID BY FERTILIZER PUMP: The goal of acid treatment is to lower the pH level of the water in the irrigation system to values between two to three for a short time (twelve to fifteen minutes). This is achieved by injection of a suitable quantity of acid into the system.

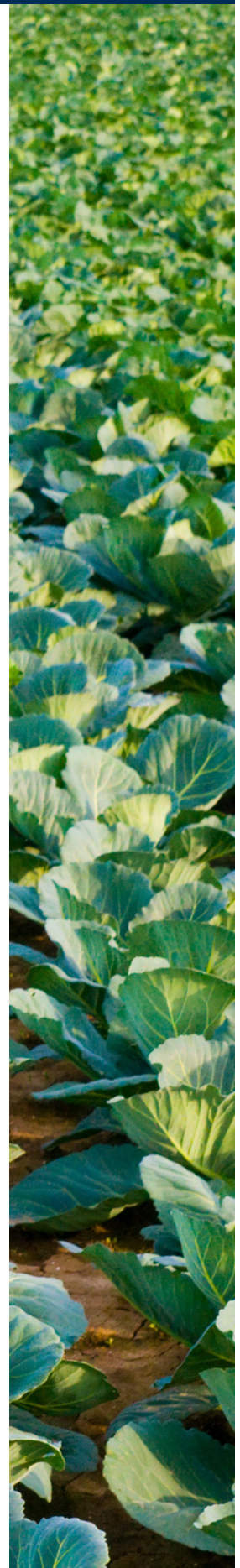
INSTRUCTIONS

1. Clean the filters.
2. Flush the system with clean water as follows: flush the main pipes then the distribution pipes and finally the drip laterals. Use the highest pressure possible for flushing. Deactivate the pressure regulators and flush the laterals, a few at a time. Flushing with clean water will prevent blockages during treatment.
3. Ascertain the discharge of the water from the system through which the acid will be injected, and the discharge of the fertilizer pump.
4. Calculate the required amount of acid that should be injected into the system in order to get 0.6% of acid concentration in the irrigation water.
5. Inject the acid into the system within fifteen minutes only after the system has reached maximum operation pressure.

NOTE: Acids suitable to be injected in 0.6% concentrations are:

Nitric acid	60%
Phosphoric acid	75%- 85%
Sulfuric acid	90%- 96%
Hydrochloric acid	30%- 35%

In many cases the most economical acids are sulfuric acid (battery acid) and hydrochloric acid (swimming pool acid).



CALCULATION METHOD

The injection rate of the acid to the treated zone can be calculated as follows:

Injection rate in GPH = (System flow in GPM) X (0.36/acid % in decimal form)

FOR EXAMPLE:

Sulfuric acid 90% and system flow is 100 GPM.

$$100 \times (0.36/0.9) = 40 \text{ GPH}$$

Because the acid is to be injected only 15 minutes the total acid required is 10 gallons

NOTE: Under certain conditions, i.e., hard water with a very high pH, there might be a need to raise the acid concentrate in the system to 1%. Please consult a Netafim USA Representative prior to such a treatment.

IRON CONTROL SYSTEM FOR DRIP IRRIGATION

Overview

Iron deposits create severe clogging problems in drip systems. Iron deposit is described as a filamentous amorphous gelatinous type of brown-reddish slime, that precipitates from water that contains iron. Iron deposits get stuck in drippers and can cause complete plugging of the system.

The problem exists in well water areas where the groundwater aquifers are formed mainly of sandy soils or organic muck soils (very common in Florida) usually with a pH of below 7.0 and in the absence of dissolved oxygen. These waters contain ferrous iron (Fe+2) which is chemically reduced, 100% water soluble and serves as the primary raw material for slime formation.

Iron bacteria, mainly from the filamentous genuses like Gallionella Sp. Leptolhris and ,Sphaerotihus and less from the rod type like Pseudomonas and Enterobacter, when present in the water, react with the ferrous iron (Fe+2) through an oxidation process. This changes the iron form to ferric iron (Fe+3) which is insoluble. The insoluble Ferric iron is surrounded by the filamentous bacteria colonies that create the sticky iron slime gel that is responsible for clogging the dripper.

Concentrations of ferrous iron as low as 0.2 ppm are considered a potential hazard to drip systems (H.W. Ford 1982). Between 0.2-1.5 ppm dripper clogging hazard is moderate. Concentrations above 1.5 ppm are described as severe (Bucks and Nakayama -1980). Practically any water that contains concentrations higher than 0.5 ppm of iron cannot be used in drip systems unless they are treated chemically or otherwise. Experiments in Florida indicate that chlorination successfully controls iron slime when iron concentrations were less than 3.5 ppm and the pH was below 6.5 (Nakayama and Bucks -1986). It is also stated that long term use of water with a high level of iron, may not be suitable for drip irrigation. The literature mentions that water containing more than 4.0 ppm cannot be efficiently chemically treated and it should undergo a pond sedimentation process before pumping it back to a drip system.

Iron Control Methods

There are several ways to control iron slime problems. The common denominator of all treatments is prevention of the formation of slime. Basically there are two preventive treatments:

1. **STABILIZATION (Precipitation Inhibitors)**
Stabilization treatments keep the ferrous iron in solution by chelating it with sequestering agents. Such agents include various poly phosphates and phosphonate.
2. **OXIDATION - SEDIMENTATION - FILTRATION**
This type of treatment oxidizes the soluble "invisible" ferrous iron into the insoluble "visible" ferric iron. It then will precipitate, so it can be physically separated from the water by means of filtration.

The second procedure is generally the less expensive for the severe iron problems in supply water. The various means to oxidize iron include chlorination and aeration. There are also other oxidizers but they are generally more expensive. Chlorine injection for iron control is normally handled in the same manner as continuous chlorine injection outlined above, with residual chlorine levels of one to two ppm. Aeration is most often applied to settling ponds using sprayers or agitators to react the Iron with the air. In this case the pond becomes a pre-filtration component.

Sedimentation - Filtration

A sand media filter is the most appropriate filter for settling down the oxidized iron and filtering it from the water. When designing a filtration system for iron removal it is good practice to oversize the filter units. Larger units with slower water velocity will allow oxidized iron to settle and the resultant water will be easier to filter. This is the same principle as exhibited in settling ponds.

SCALE INHIBITORS

Scale inhibitors, such as chelating and sequestering agents, have long been used by other industries. A number of different chemicals are being marketed for use in micro-irrigation systems to prevent plugging. Many of these products contain some form of inorganic polyphosphate that can reduce or prevent precipitation of certain scale-forming minerals. These inorganic phosphates do not stop mineral precipitation, but keep it in the sub-microscopic range by inhibiting its growth. Probably the most commonly used of these materials is sodium hexametaphosphate - as little as 2 ppm can hold as much as 200 ppm calcium bicarbonate in solution.

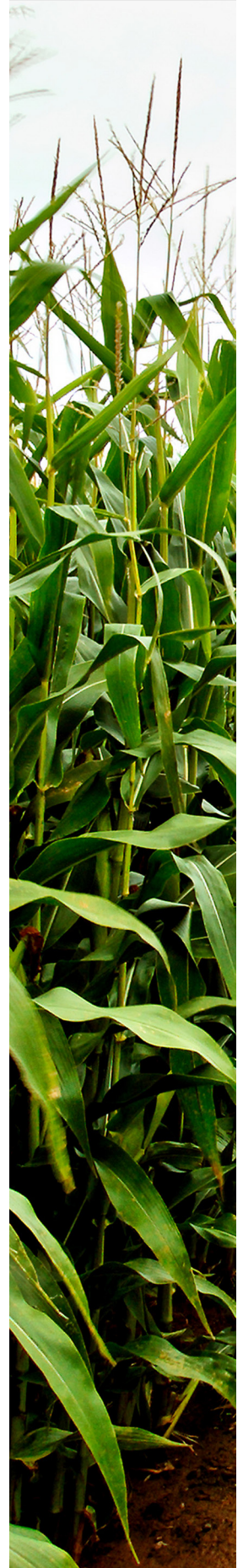
Sodium hexametaphosphate is not only effective against alkaline scale, but also forms complexes with iron and manganese and can prevent depositions of these materials. Although the amount of phosphate required to prevent iron deposits depends on several factors, a general recommendation is two to four ppm phosphate for each ppm of iron or manganese.

These phosphates are relatively inexpensive, readily soluble in water, nontoxic and effective at low injection rates.

POND TREATMENT

Algae problems which often occur with surface water sources such as a pond can be effectively treated with copper sulfate (CuSO_4). Dosages of one to two ppm (1.4 to 2.7 pounds per acre foot) are sufficient and safe to treat algae growth. Copper sulfate should be applied when the pond water temperature is above 60°F. Treatments may be repeated at two to four-week intervals, depending on the nutrient load in the pond. Copper sulfate should be mixed into the pond (i.e., sprinkled into the wake of a boat). The distribution of biocides into surface water must be in compliance with EPA regulations.

Copper sulfate can be harmful to fish if alkalinity, a measure of the water's capacity to neutralize acid, is low. Alkalinity is measured volumetrically by titration with H_2SO_4 and is reported in terms of equivalent CaCO_3 . Repeated use of copper sulfate can result in the buildup to levels toxic for plants.





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