Chemigation Uniformity Critical Through Microirrigation System

If done properly, injected chemical application will be as uniform as the water application.

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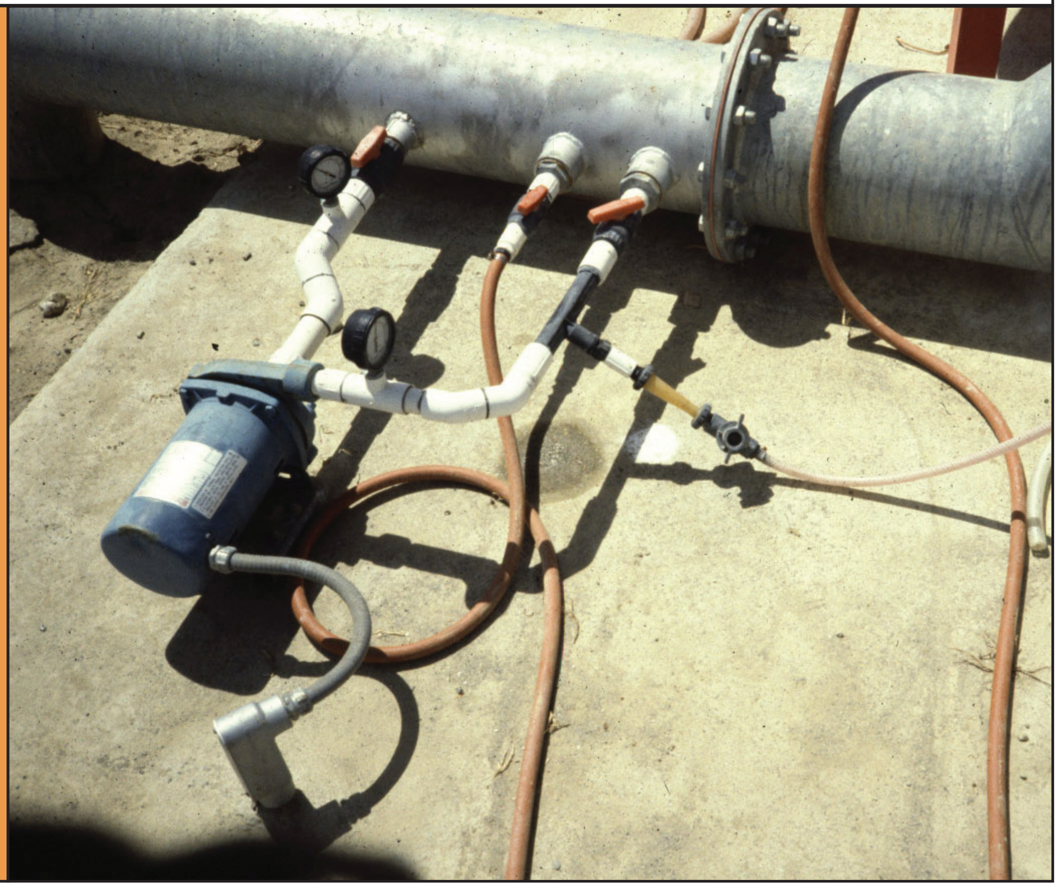
Summary: *While a wide variety of materials are now injected through microirrigation systems, all of them should be applied with as great an application uniformity as possible. This requires a highly uniform microirrigation system and a high quality injection system that is managed properly. Very important to good management of the injection system is selecting the correct injection time and the appropriate post-injection clean water irrigation period. Both the injection time and the post-injection clean water application should be as long or longer than the travel time of chemical moving from the injector to the farthest point hydraulically in the microirrigation system. If this is done, the injected chemical application will be as uniform as the water application.*



Chemigation through microirrigation systems (drip and microsprinklers) is becoming commonplace as microirrigation systems gain in popularity. The most commonly injected chemicals are fertilizers but other products, such as herbicides, pesticides, nematicides, and even microirrigation system maintenance chemicals such as chlorine and acids, are injected. Common to all chemigation practices is the need to apply the chemical as uniformly as possible.

Chemigating uniformly means that all areas of the field serviced by the microirrigation system receive the same amount of chemical during an injection event. While there may be times when we want to intentionally apply different amounts of chemical to various portions of the field, it takes a very sophisticated microirrigation injection system to achieve that. In the vast majority of cases, our goal is to apply the injected chemical uniformly as the water is applied.

High chemigation uniformity requires: (1) an irrigation system with high application uniformity, and (2) an injection system that facilitates high chemigation uniformity. Well-designed and well-maintained microirrigation systems should have high irrigation application uniformity. Achieving excellent irrigation application uniformity is why growers pay substantial money for microirrigation systems.

The injection system, especially the injector, is a critical piece of hardware necessary to achieve high chemigation uniformity. In the following section, the various injection systems will be discussed, including their advantages and disadvantages.

Later in this article, the importance of injection system management to maximize the chemigation uniformity will be discussed.

Injection Equipment

A variety of injection equipment is available in a wide range of cost and capability. The simplest injector systems include batch tanks, while the most sophisticated include electrical, gasoline, or water-driven positive displacement pumps. Which injection system to use depends on injector capabilities, reliability, and cost.

Batch tanks. Some of the earliest injector systems used batch tanks (Figure 1). These relatively inexpensive and simple systems consist of a tank that is plumbed into the irrigation system so that a portion of the irrigation water flows through it. The tank must be able to withstand the operating pressure of the irrigation system. Since there is often pressure loss as water flows through the batch tank system, the tank must be plumbed across a pressure differential so that the batch tank inlet is at a higher pressure than the tank outlet. Examples

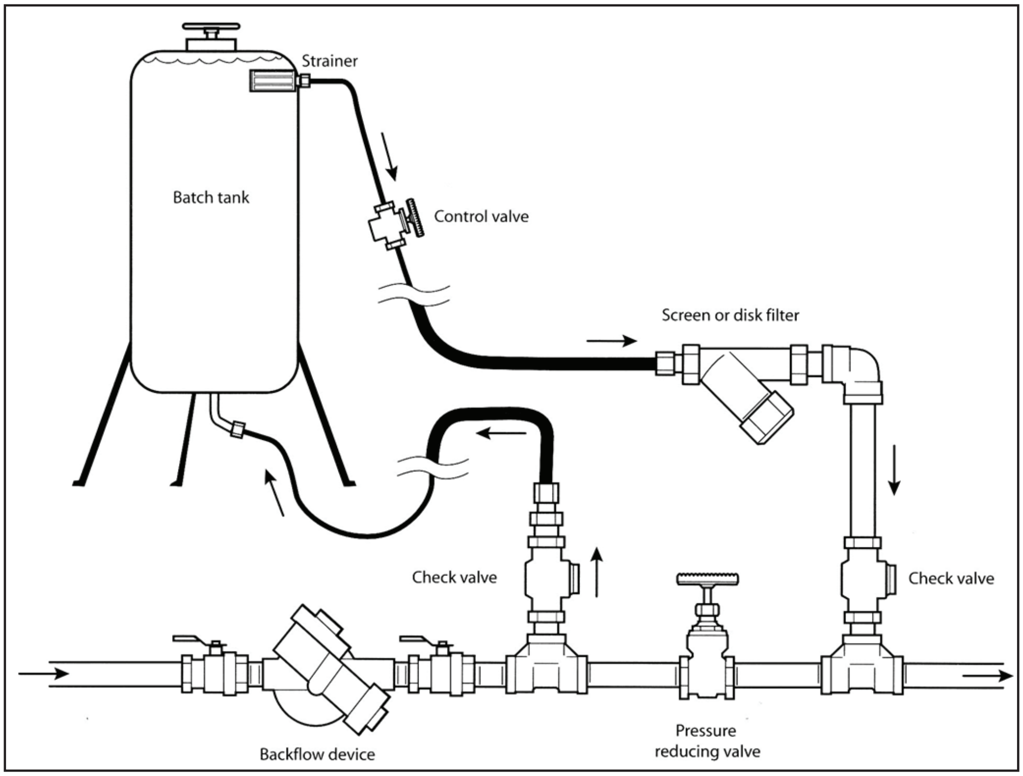


Figure 1. Batch tank.

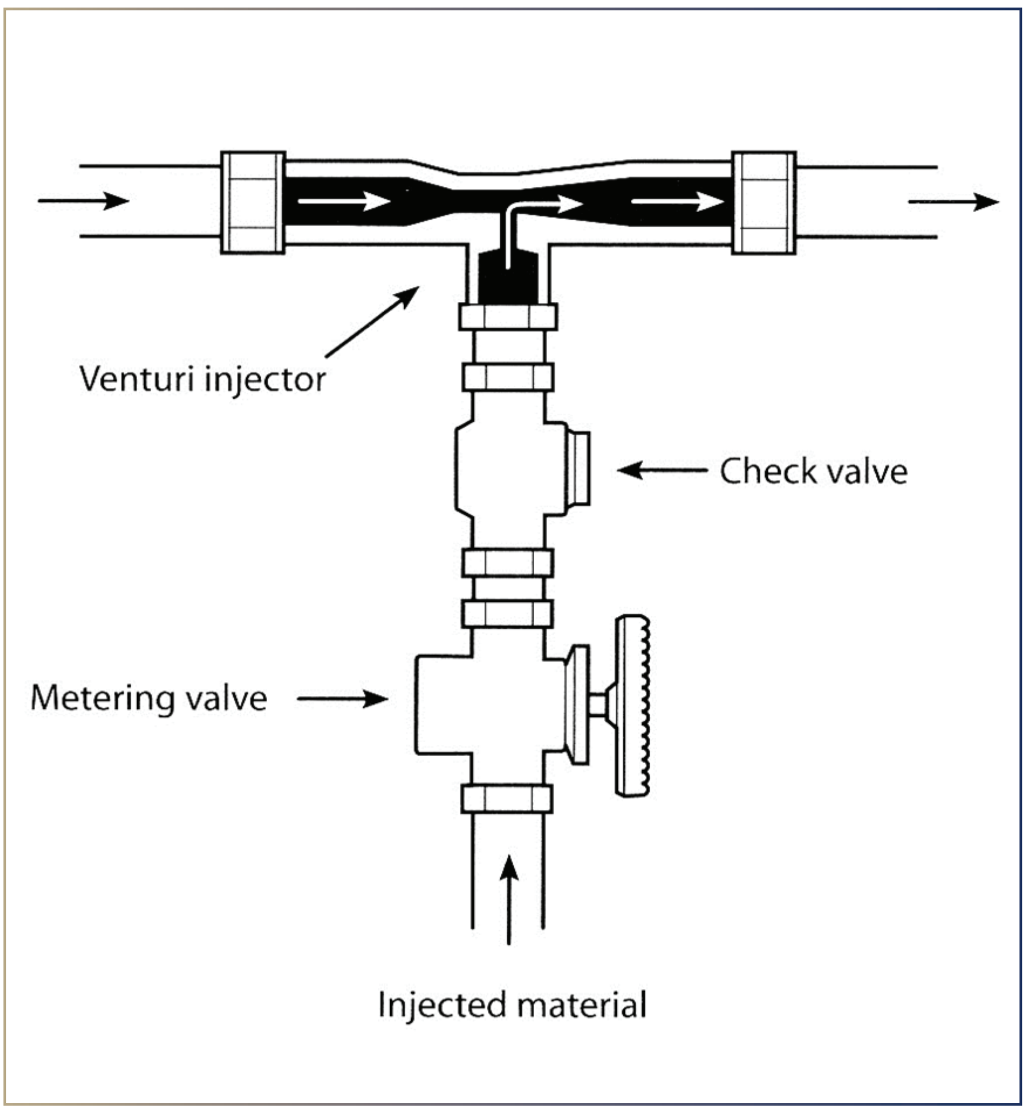


Figure 2. Venturi Injector

of microirrigation system components that can cause a pressure differential are a partially closed valve or a pressure-reducing (pressure regulating) valve. The rate the material is injected is influenced by the flow rate through the tank and the concentration of injection material in the tank at any given time.

The batch tank is filled with the chemical (most frequently, fertilizer) to be applied. During irrigation, water is allowed to flow into the batch tank where it displaces some of the tank's contents, forcing them into the irrigation system. Initially, the liquid leaving the batch tank is of high chemical concentration, but with time, the concentration in the batch tank becomes more diluted as it mixes with water. The chemical injection starts out at a higher concentration and declines in concentration during the injection period. Batch tanks are appropriate if the objective is to inject a total amount of chemical (e.g., fertilizer) during a long injection period. Batch tanks are not appropriate if a constant injection concentration is required.

Venturi injection. Injection devices using the venturi principle (Figure 2) have been used for many years in a wide variety of industrial and agricultural applications. A venturi is a specially shaped constriction in a device's water flow path. As the flow passageway at the venturi section becomes smaller, the velocity of the flowing fluid increases such that a vacuum is formed at the venturi's throat section. An opening located in the venturi's throat allows air or a fluid to be "sucked" in and mixed with the water stream. To create this effect, the inlet pressure to the venturi must be at least 15 to 20 percent greater than the outlet pressure. This is achieved by plumbing the venturi device across a system pressure differential (e.g., a partially closed valve, Figure 3) or using a small pump that draws water from the microirrigation system and forces it through the venturi injector (Figure. 4). The injection rate of a venturi-type injector depends on the size of the venturi section (1/2-inch to 2-inch sizes are available) and on the pressure difference between the inlet and the outlet of the venturi.

The venturi injector delivers a more constant chemical injection rate than does a batch tank. However, the injection rate of a venturi injector can change (or even stop) if the pressure changes upstream or downstream in the microirrigation system. This can occur if irrigation sets (applications) with different flow rates are operated from the same water supply pump. A venturi injector installation in which the venturi is plumbed across a pressure differential (see Figure 3) is particularly sensitive to such changes, and it is often inconvenient to readjust the injector. The injector is usually installed parallel to the microirrigation system pipeline, with valves that can be closed to isolate the injector from the irrigation system when injection is not occurring (see Figures 3 and 4). A venturi injector installation using a small pump in conjunction with the venturi eliminates the need to install the venturi across a pressure drop, and it also minimizes the venturi's sensitivity to irrigation system pressure fluctuations. However, this type of installation requires an electrical or gasoline power source.

Positive displacement pumps have a relatively small capacity and deliver a very constant rate of injection. The pumps can use a cylinder-piston configuration or a flexible diaphragm to inject a liquid at a pressure higher than that of the irrigation system. Electrically-driven, gasoline-engine-driven, and water-driven pump injectors are available. Positive displacement pumps provide the most accurate and constant injection rate, but they are also the most expensive injection devices. They do not need to be installed across a pressure drop since they are externally powered.

Positive displacement pump injectors are available as constant-rate pumps and as proportional pumps. Constant-rate pumps inject at a set rate (often adjustable) no matter what the flow rate is in the irrigation system. Proportional pumps (frequently water-driven) inject at a rate dependent on the flow rate passing through the injector or through the irrigation system. For the electrical or gasoline-driven pumps, the injector is linked to the irrigation system via a flow meter. For example, a proportional positive displacement injector set at 1:250 would inject 1 gallon of material for every 250 gallons of water passing through it. The proportional rate setting can be adjusted, as can the stock tank mixture concentration, to control the injected material's concentration in the irrigation system.

Solutionizer machines. With the relatively recent advent of solutionizer machines, a wide variety of less-soluble solid materials is now being

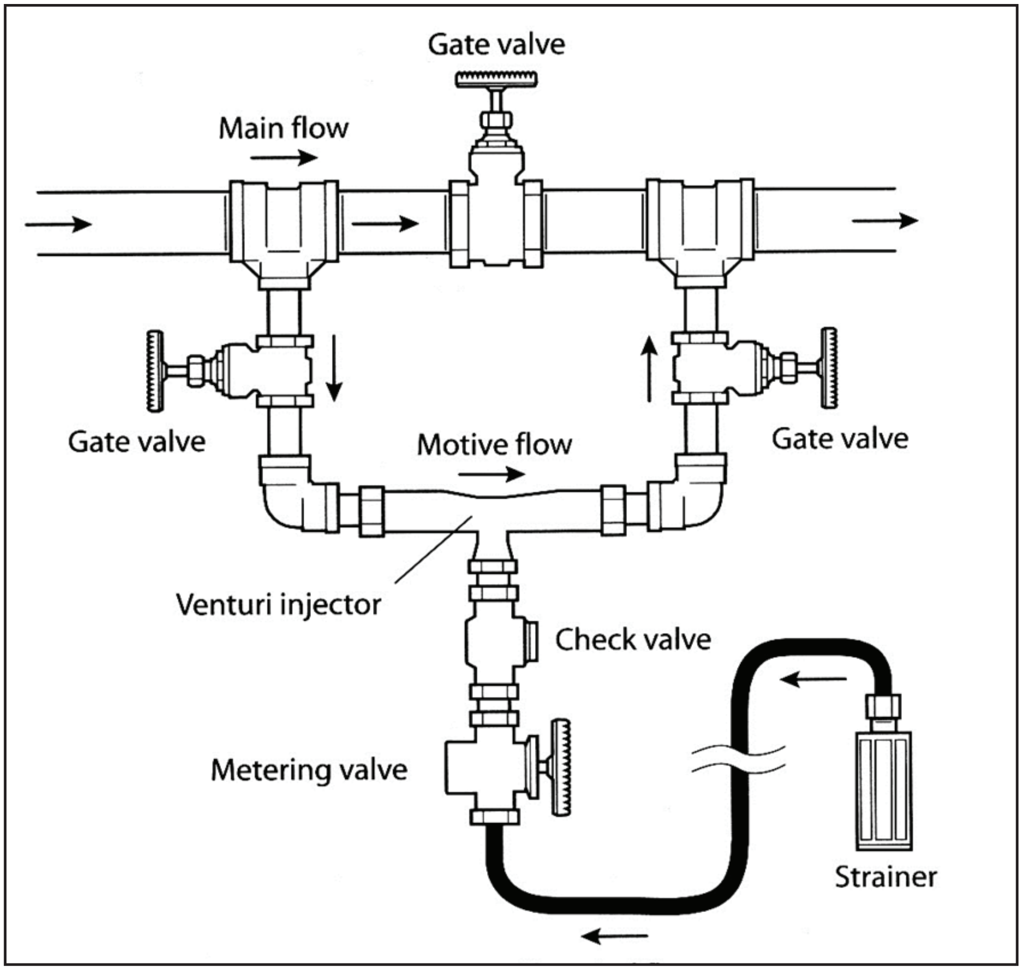


Figure 3. Venturi "across a pressure drop" layout

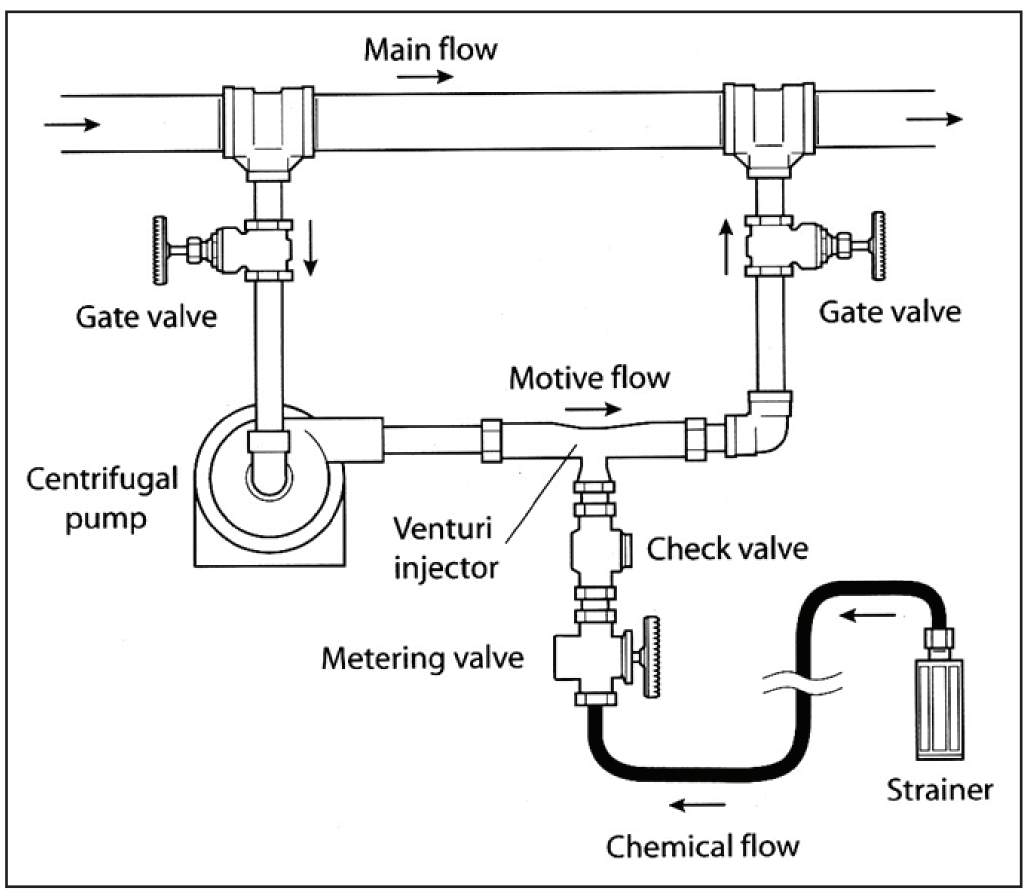


Figure 4. Venturi with a small pump

injected in microirrigation systems. Foremost of these is gypsum, but other materials such as potassium sulfate and other granular fertilizers are also being injected. The injection rate of the solutionizer machine should be adjusted to ensure that the injected material goes into solution prior to reaching any of the emitters. While the use of solutionizer machines has been an advance in chemigation, some caution must be used. Three issues are of concern: chemical precipitation, injected material solubility, and impurities in the injected material.

As with liquid materials, solid materials containing calcium should be injected with caution if the irrigation water contains substantial bicarbonates (greater than 2 meq/1, or 120 parts per million) and the water pH is greater than 7.5. The jar test should be performed before injecting any new product. Remember that gypsum, which is calcium sulfate, is a ready source of calcium.

Some of the materials injected by the solutionizer machine, including gypsum, are not readily soluble in the irrigation water. The concentrations at which these materials are injected should be monitored to ensure that the material is going into solution. In addition, adequate time should be allowed for the materials to go into solution once they are injected into the irrigation system.

Impurities in the injected material are also a major consideration when using a solutionizer machine. Even the "pure," finely ground gypsum materials prepared for use with solutionizer machines contain some impurities. If the material is 95 percent gypsum, 5 percent of it is still "foreign" material. Thus, for every 100 pounds injected, there will be 5 pounds of the foreign material, some of which may not go into solution.

Injecting granular fertilizers using solutionizer machines should be done with even greater caution. Many of these may have been meant to be land-applied, and no particular care was taken in the production to minimize the impurities. Some have oil or wax coatings to prevent water absorption, and introducing insoluble materials such as these into a microirrigation system may lead to emitter clogging.

One option for dealing with suspended impurities is to inject the slurry from the solutionizer machine upstream of the microirrigation system's filter(s). A filter cannot be located on the line from the solutionizer machine since the output from the machine is a slurry, and the injected material (e.g., gypsum) does not go into solution until it is injected into the main irrigation line. Use caution if the microirrigation system has sand media filters, an automatic backflush screen, or disk filter system. Any material injected while the filters are backflushing goes out with the flush water—a potential environmental concern when injecting fertilizers or certain irrigation system maintenance products.

System management

Injection point. The location in the microirrigation system at which material is injected should depend on the type of material being injected. Readily soluble materials, such as fluid fertilizers and chlorine, should be injected downstream of the system's main filters. This will prevent the injected material from being part of the filter backflush water if filter cleaning occurs during injection. Also, a small screen or disk filter should be installed in the line from the storage tank to the injector to catch any impurities that may be in the material or tank. Acidic products for microirrigation system maintenance should not be injected where low water pH may damage metal components (e.g., some sand media filter tanks). Most plastic components will not be affected by low water pH.

Materials injected by solutionizer machine should be injected upstream of the microirrigation system's main filters to remove any impurities in the injected material. Ideally, the injection should not occur while the filters are being cleaned.

To ensure that the injected material and the irrigation water are mixed, materials should be injected into the middle of the water stream rather than at the pipe wall. Commercial devices are available that thread into the pipeline through a fitting and extend into the pipe, allowing injection directly into the fast-moving irrigation stream. It is also possible to make such a device using PVC fittings and pipe.

Timing/duration. When injecting materials through a microirrigation system, two objectives should be kept in mind. First, the irrigation amount applied should be correctly determined so that the applied water and injected material remain in the plant's root zone. Applying more irrigation water than the plant's root zone can hold (over-irrigation) causes water to percolate below the root zone. Over-irrigation can also cause the injected material to percolate out of the root zone if the injected material travels through the soil easily with the water (e.g., nitrates). Good irrigation scheduling techniques can minimize this hazard and optimize the efficiency of chemigation. A good time to inject material is in the middle of an irrigation set (assuming that the irrigation set is long enough to allow a choice of when to do the injection). This makes it more likely that the injected material will stay in the root zone if over-irrigation occurs. Second, the duration of injection should provide a uniform application of injected material throughout the microirrigation system. It is important to remember that the injected material does not immediately reach all the emitters as soon as injection begins. A period of time is required for the water and injected material to move through the system to the emitters. This travel time depends on the design and layout of the microirrigation system. In the following discussion of travel times, it should be assumed that injected materials travel through the microirrigation system at the same speed as the irrigation water.

Water travels through a microirrigation system's mainline and submain pipelines quite quickly. These pipelines are typically sized so that the flow velocity is less than 5 feet per second (fps) to minimize frictional pressure losses. Flow velocities of 1 to 3 fps are quite common in mainline and submains. Some pipeline systems are long, so movement of water and injected materials through them may take a while: travel times of 20 to 30 minutes are common, and travel times as long as 65 minutes have been observed (Table 1).

Irrigation water flows slower in microirrigation lateral lines than it does through the mainline and submains. The flow velocity is particularly low at the tail end of the lateral lines. Understanding how water flows in drip lateral lines helps explain this.

At the inlet of a drip lateral, the flow rate is that of all the combined downstream emitter discharges. For example, if 60 1-gallon-per-hour (gph) emitters were installed in the lateral line, the flow rate at the head of the drip lateral would be 60 gph or 1 gpm. For typical drip tubing with a nominal inside diameter of 5/8-inch, the resulting flow velocity would be 60 feet per minute (fpm) or 1 foot per second (fps). The flow velocity in the drip line depends on the flow rate and the tubing size. For the same size drip tubing, the higher the flow rate, the higher the flow velocity. Using the above drip lateral as an example, downstream of the first emitter, the flow rate in the drip tube would be 59 gph; downstream of the second drip emitter, the flow rate would be 58 gph; and so on. Since the flow rate decreases along the drip lateral, so does the flow velocity. The slowest-moving water is between the next-to-last and the last emitter. In our example, the flow rate in this section is only 1 gph. For the same 5/8-inch drip tubing, the flow velocity would be only about 1 fpm in this last drip line section.

The total travel time of water along a drip lateral line therefore depends on four factors:

- The length of the drip lateral
- The number of emitters installed in the lateral line
- The discharge rate of the emitters
- The inside diameter of the drip tubing.

Knowing these factors, the drip lateral line travel times can be calculated. But the easiest way to deter¬mine the travel time is to measure it in the field.

Field measurement. Microirrigation water travel times can be measured by "tracing" the movement of injected chlorine through the system. Injecting chlorine into the irrigation system is a recommended microirrigation system maintenance procedure. The presence of chlorine in the discharge from emitters can be easily monitored using a pool or spa chlorine test kit. The chlorine's passage through the microirrigation system can be readily traced using this technique, and the water travel time easily determined. The recommended procedure is as follows:

Step 1: Start up the microirrigation system and allow it to come to full pressure. If the microirrigation system has not been flushed recently (pipelines and lateral lines), this should be done now. Allow the microirrigation system to return to full pressure after flushing.

Step 2: Begin injecting chlorine so that the chlorine concentration in the irrigation water is approximately 10 to 20 parts per million (ppm). Note the time when chlorine injection begins.

Step 3: Go to the emitter at the head of the lateral farthest (hydraulically) from the injection point. Using the chlorine test kit, monitor the discharge from that emitter and note the time when the chlorine registers on the test kit. The time from the start of the injection to when the chlorine registers on the test kit is the travel time of water through the mainline-submain system.

Step 4: Go to the last emitter at the tail end of the lateral you just monitored (the lateral farthest hydraulically from the injection point). Monitor discharge from this last emitter until chlorine registers on the test kit and note the time this occurs. The time from the start of the injection to when the chlorine registers on the test kit is the travel time of water through the entire microirrigation system.

As part of a field study of microirrigation systems, travel time and chemigation uniformity information on a number of drip systems was collected. Table 1 shows the travel times for these evaluations. This data show that there is no standard water travel time to the far point in a drip irrigation system. Travel time should be measured for each individual microirrigation system, but it only needs to be measured once.

Table 1. Water and chemical travel times through pipelines and drip lateral lines for selected vineyard and orchard field sites.

Site		Mainline and submain pipeline		Lateral line	Total
	Length	Travel time	Length	Travel time	Travel Time
	(ft)	(min)	(ft)	(min)	(min)
1	1,000	22	175	10	32
2	1,500	30	340	10	40
3	5,000	65	340	10	75
4	1,400	15	630	23	38
5	700	8	625	23	31
6	820	17	600	28	45

Post-injection. To ensure chemigation uniformity it is important that irrigation continue following an injection. This accomplishes two things. First, it allows the injected material to be cleared from the microirrigation system. Second, it maximizes the chemigation uniformity, since all emitters will have discharged nearly the same amount of injected material by the time the irrigation stops.

Clearing the microirrigation system of the injected material is often important to minimize emitter clogging. For example, leaving fertilizer in the system may encourage biological growth (e.g., biological slimes), which can lead to emitter clogging. Leaving materials containing calcium (e.g., gypsum or calcium nitrate) in the system may lead to chemical precipitation of calcium carbonate (lime), which may also cause emitter clogging. Time and temperature enhance chemical precipitation. The exception to this recommendation may be the injection of system maintenance products such as chlorine or acid. It may be desirable to leave these products in the system at shutdown to maximize their effects and minimize clogging problems.

Just as it takes time for the injected material to travel through the microirrigation system once injection starts, it takes an equal or greater amount of time for the injected material to clear out of the system. The injected material first clears from the head of the system, and the last point to clear is the emitter hydraulically farthest from the injection point. This is just the opposite of what occurs when injections began, and it balances the amount of injected materials discharged from emitters throughout the microirrigation system. This gives a uniform chemigation application.

Field evaluations have been done on a single drip lateral line to evaluate the impact on chemical application uniformity of varying the injection and post-injection irrigation times. The results of some of these evaluations are shown in Table 2. The lateral line evaluated was a 500-foot drip lateral (16 mm polyethylene tubing) with 1-gph pressure-compensating drip emitters installed every 5 feet. It was determined through field evaluation that the travel time for water and injected chemicals passing through the lateral line was 25 minutes.

Excellent chemical application uniformity was achieved when:

- The injection period was equal to or greater than the water travel time to the end of the drip lateral (25 minutes in the test case)
- The post-injection irrigation time was equal to or greater than the lateral line's water travel time.

The results in Table 2 also show that there are two injection strategies to avoid.

First, avoid injection periods that are less than the microirrigation system's water travel time to the end (hydraulically) of the system.

Second, an injection should always be followed by a period of "clean" water irrigation. This post-injection irrigation should be at least as long as the water travel time to the end of the system.

The worst chemigation uniformity results from too short of an injection period (less than the end-of-system travel time) followed by immediate microirrigation system shutdown. In fact, field measurements and laboratory studies have shown that clearing injected material from a microirrigation system takes even longer than it does to originally move the injected material through the system. Flow velocities at a pipe or tubing wall are very small (theoretically zero), so some of the injected material "hangs up" on the pipe or tubing walls and takes quite a while to clear from the system.

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Table 2. Chemigation uniformity in a drip lateral (500 feet long) with 1-gph drip emitters installed at 5-foot intervals) for various injection times and post-injection clean water irrigations. The water and injected chemical travel time to reach the end of the drip lateral was 25 minutes.

Injection time (min)	Post-injection irrigation time (min)	Relative uniformity (%)
50	50	100
50	25	98
25	25	95
25	50	90
13	25	81
50	0	25
25	0	11
13	0	7