FS035E

Calculating Chemigation Injection Rates

R. Troy Peters, Ph.D., P.E., Washington State University, Prosser, WA
W. Howard Neibling, Ph.D., P.E., University of Idaho, Twin Falls, ID
Tom Hoffmann, Washington State Department of Agriculture, Moses Lake, WA

Chemigation is the application of agricultural chemicals (e.g., fertilizers, pesticides, and soil conditioners or amendments) into or through an irrigation system with the applied irrigation water. It is an efficient and cost effective method of applying chemicals.

This fact sheet describes how to calculate injection rates for chemigation. English units are used exclusively. Many of the equations can be solved with the irrigation calculators provided at http://irrigation.wsu.edu.

Pesticide Labels

The pesticide label is a legal and binding document and must be read carefully, understood, and adhered to. In the event of discrepancies between the pesticide label and information contained in this publication, follow the pesticide label. A pesticide must be specifically labeled for chemigation to be legally used for this purpose. Application rates that exceed the labeled rate are not only unlawful, but will result in higher costs for chemicals than necessary, potentially illegal pesticide residue levels, and possible damage to the crop, irrigation system, and/or the environment. Application rates that are too low may not achieve the desired results. Therefore, it is in a grower's interest to comply with label instructions, correctly calculate injection rates, and properly set up and maintain irrigation and chemigation systems. It is also important to follow state laws and rules, local ordinances, and safety precautions for chemigation. Antipollution devices and safety precautions are listed on the label.

Injection Rates by Fluid Volume

The basic method of calculating injection rates by fluid volume uses the following equation:

$$I_c = \frac{Vol}{T} \qquad \text{(Equation 1)}$$

where:
I_c = Chemical injection rate (gallons per hour)
Vol = Total volume of chemical to inject (gallons)
T = Injection time (hours)

Example: 350 gallons of chemical needs to be applied in 22 hours. The application rate is 350 ÷ 22 = 15.9 gallons/hour.

The *total volume of chemical* (*Vol*) needed is calculated by multiplying the desired application rate (Q_v, in gallons per acre) by the area covered (*A*, in acres) by the irrigation system during the chemigation application, or:

$$Vol = Q_v \times A \qquad \text{(Equation 2)}$$

where:
A = Area (acres)
Q_v = Quantity of chemical to apply per acre by volume (gallons per acre)

Example: A boron supplement is being applied at 3.2 gallons per acre onto a 125-acre center pivot field. The total volume of applied chemical is 2.2 × 125 = 275 gallons of chemical.

Note: It is important to track and to use the correct computational units. For example, if injection time (*T*) in minutes is used, then the chemical injection rate (I_c) result will come out in gallons per minute instead of gallons per hour. If the application rate (Q_v) is reported on the label in quarts per acre, divide the answer by 4 to get *Vol* in gallons. If the labeled application rate (Q_v) is specified in pints per acre, divide the answer by 8 to get *Vol* in gallons. See Table 1 for other common unit conversions.

To simplify, Equations 1 and 2 can be combined into the following equation:

$$I_c = \frac{Q_v \times A}{T} \qquad \text{(Equation 3)}$$

Example: A fungicide is to be applied at 2 pints per acre to a 125-acre center pivot of potatoes. It takes 21 hours for the pivot to make a complete revolution. Since Equation 3 requires the units to be in gallons per acre, 2 pints per acre must be divided by 8, or 0.25 gallons per acre. Now calculate the injection rate using Equation 3:

$$\frac{0.25 \times 125}{21} = 1.5 \text{ gallons of product per hour}$$

This injection rate is far below what most pumps can accurately inject at. Consequently, water should be added to the tank to dilute the chemical. To determine how much water to add and what the new injection rate should be, see the section Diluting Chemical Concentrations to Match Inflexible Injection Rates.

Injection Rates by Mass

Sometimes, instead of fluid volume per acre (Q_v, in gallons per acre), the application rate is specified in weight or mass per unit area (Q_m) such as pounds per acre. This is common when applying fertilizers (fertigation). However, since chemicals are injected in a liquid form, the specified mass (Q_m) must be converted to volume per acre (Q_v). This is accomplished by dividing the desired application rate of the product by the concentration of the injected solution (C) in pounds/gallon. The concentration (C) is an inherent property of the fertilizer or pesticide, and can be found on the label.

$$Q_v = \frac{Q_m}{C} \qquad \text{(Equation 4)}$$

where:
Q_m = Quantity of chemical to be applied by mass (pounds per acre)
C = Concentration (e.g., active ingredient) of injected solution (pounds per gallon)

If the concentration (C) is given in ounces per gallon, then divide the answer (Q_v) by 16 to convert the value to pounds per gallon.

For simplicity, Equations 3 and 4 can be combined into the following equation:

$$I_c = \frac{Q_m \times A}{C \times T} \qquad \text{(Equation 5)}$$

Example: Based on a leaf petiole analysis, 9 pounds per acre of nitrogen is recommended. A grower plans to apply this using 32% urea-ammonium nitrate (UAN 32; Solution 32) fertilizer. There are 3.54 pounds of nitrogen in a gallon of 32% UAN. The fertilizer will be applied through a drip irrigation system to 45 acres during the last 6 hours of the irrigation set. (Remember to leave time to flush out the system.) The injection pump should be set to:

$$\frac{9 \times 45}{3.54 \times 6} = 19.07 \text{ gallons per hour}$$

Injection Rates for Water Chemistry Control

In certain circumstances it is desirable to inject chemicals to adjust water chemistry. This is common in drip irrigation to prevent the formation of mineral precipitates (iron, calcium, or manganese), to manage algal or bacterial growth, or to prevent or mitigate root intrusion. In these cases instead of gallons per acre or pounds per acre, the goal is a chemical concentration in the water (C_w), usually specified in parts per million (ppm). The injection rate may be determined using Equation 6:

$$I_c = \frac{0.006 \times Flow \times C_w}{P_{cnt}} \qquad \text{(Equation 6)}$$

where:
I_c = Chemical injection rate (gallons per hour; gal/hr)
Flow = Flow rate of the irrigation water (gallons per minute; gpm)
C_w = Desired chemical concentration (parts per million; ppm)
P_{cnt} = Percentage of chemical in solution (%)

Example: Sodium hypochlorite (12.5% solution) is to be injected to control algae and bacteria growth in drip lines. The desired concentration is 3 ppm and the flow rate at the injection site is 460 gpm. The injection rate using Equation 6 would be:

$$\frac{0.006 \times 460 \times 3}{12.5} = 0.66 \text{ gallons per hour}$$

Maximum Concentration

Sometimes a pesticide label will specify a *maximum* chemical concentration in the irrigation application system, specified as a percent (%). Once the proposed chemical injection rate (I_c) is calculated as shown above, the concentration can be checked to ensure it is below the maximum. The percent concentration is calculated as:

$$C_s = \frac{I_c \times 100}{60 \times Flow} \qquad \text{(Equation 7)}$$

where:

C_s = Solution concentration in the irrigation lines (%)

I_c = Chemical injection rate (gallons per hour; gph)

Flow = Irrigation water flow rate (gallons per minute; gpm)

Example: The calculated injection rate is 1.73 gph, and the flow rate is 350 gpm. The label-specified maximum concentration in the irrigation water lines is 2%. The maximum line concentration using Equation 6 is:

$$\frac{1.73 \times 100}{60 \times 350} = 0.008\%$$

This is far less than the 2% maximum, so the injection rate is fine.

Mixing Dry Chemicals

Although less common, sometimes dry fertilizers or dry pesticide formulations (e.g., dry flowable, soluble powder, or wettable powder) are mixed with water so that they can be used in a chemigation application. When applying chemicals this way, two main questions must be solved: 1) how much dry chemical will be needed and 2) how much water should it be mixed with to ensure the chemical's suspension? The total dry chemical to be applied can be calculated as:

$$W_t = \frac{A \times Q_m}{P_{cnt}} \qquad \text{(Equation 8)}$$

where:

W_t = Mass (weight) of the chemical to be applied (lbs)

A = Area (acres)

Q_m = Rate to apply by mass (pounds per acre; lb/acre)

P_{cnt} = Percent concentration in mix (expressed as a decimal), such as the percent of elemental nitrogen in calcium ammonium nitrate (CAN-17; 17-0-0-8.8Ca)

The minimum volume of water required for mixing dry chemicals can be calculated as:

$$Vol_{\min} = \frac{W_t}{S} \qquad \text{(Equation 9)}$$

where:

Vol_{min} = Minimum volume (gal)

W_t = Weight of chemical to be applied (pounds; lbs)

S = Solubility of chemical (pounds per gallon; lb/gal), which is obtained from the pesticide label or fertilizer solution charts. Note: Solubility is a function of solution temperature.

Example: Urea (46% nitrogen, with a solubility of 7.5 lb/gal) is to be dissolved and applied at 30 pounds of nitrogen/acre to 25 acres. The mass or weight of chemical to apply (refer to Equation 8) is:

$$\frac{25 \times 30}{0.46} = 1630 \text{ pounds}$$

The minimum volume of water required to dissolve the urea is:

$$1630 / 7.5 = 217 \text{ gallons of water}$$

More water can, and probably should be used to ensure that the dry chemical is completely dissolved. The total volume of the mixture then becomes *Vol*, which is used in Equation 1 to calculate the injection rate (I_c).

Batch/Bulk Applications

(Drip, Hand-line, Wheel-lines, Solid Set)

Batch or bulk applications are for set irrigation systems that don't move in the field while irrigation water is being applied. When applying fertilizers, *timing* during the irrigation set is the primary consideration and the injection *rate* is less critical. Therefore, less expensive venturi-type injectors can be used.

The injection rate is set to limit chemical concentration (C_s) in the irrigation line. The injection time (T) is chosen to set the chemical location within the crop canopy or in the soil profile. It is usually best to inject fertilizers towards the end (i.e., during the last half) of the irrigation event or set so that the chemical remains in the upper soil profile where the majority of the plant roots are located and where there is less chance of the chemical being leached out of the root zone by subsequent irrigations. However, injection should be finished in sufficient time before the end of the set to ensure that all of the chemical has been flushed from the lines.

Diluting Chemical Concentrations to Match Inflexible Injection Rates

Sometimes a chemical injection system cannot accurately inject at the low injection rates required, or it has less flexibility in controlling the injection rates – such as with a venturi or another pressure differential type method. In these cases water can be added to the chemical solution (diluted) to achieve the needed application rate. Equation 5 can be solved for the required diluted chemical concentration (C_{dil}):

$$C_{dil} = \frac{Q_m \times A}{I_c \times T} \qquad \text{(Equation 10)}$$

This number is then used to calculate the amount of water to add to the tank mixture (V_{add}) using the following equation:

$$V_{add} = \frac{V_1(C_1 - C_{dil})}{C_{dil}} \qquad \text{(Equation 11)}$$

where:

V_{add} = Amount of clean water to add to the mixture (gallons)

V_1 = Original volume of chemical at concentration C before mixing (gallons)

C_1 = Concentration of the premixed solution (pounds per gallon; lb/gal)

C_{dil} = Concentration of the diluted solution as calculated in Equation 10 (pounds per gallon; lb/gal)

The subsequent total volume of chemical (*Vol*) will be $V_1 + V_{add}$. Obviously the concentration of the solution can be decreased by adding water (diluted), but not increased. If the calculated C_{dil} is greater than C_1, then a different injection system must be used.

<u>Example</u>: 50 lbs of nitrogen per acre is to be applied to a wheel line set of 1.6 acres/set during the last 6 hours of irrigation. A venturi injector is being used that injects at a 50:1 ratio into a pipe line flowing at 150 gpm. Therefore, the inflexible venturi injection rate is 150 gpm/50 = 3 gpm. The required concentration of injected solution (C_{dil} from Equation 10) would be:

$$\frac{50 \times 1.6}{3 \times 6} = 4.4 \text{ pounds per gallon}$$

The injection is from a tank containing 300 gallons of a nitrogen solution with a concentration of 7 pounds per gallon, so the amount of water to add (V_{add} from Equation 11) would be:

$$\frac{300(7 - 4.4)}{4.4} = 177 \text{ gallons}$$

This means a 477 gallon (300 + 177) solution of 4.4 lbs of nitrogen/gallon should be injected with the 50:1 venturi injector.

Table 1: Unit Conversions.

To Convert	to	multiply by
gallons per hour (gph)	gallons per minute (gpm)	0.0167
gallons per hour (gph)	fluid ounces per hour (oz/hr)	128
gallons per hour (gph)	fluid ounces per minute (oz/min)	2.13
gallons per hour (gph)	milliliters per minute (ml/min)	63.1
gallons per hour (gph)	milliliters per second (ml/sec)	1.05
gallons per hour (gph)	ounces per second (ml/sec)	0.0356
gallons per minute (gpm)	gallons per hour (gph)	60
fluid ounces per hour (oz/hr)	gallons per hour (gph)	0.00781
fluid ounces per minute (oz/min)	gallons per hour (gph)	0.469
milliliters per minute (ml/min)	gallons per hour (gph)	0.0159
milliliters per second (ml/sec)	gallons per hour (gph)	0.951
ounces per second (ml/sec)	gallons per hour (gph)	28.1

Unit conversions can also be calculated online at http://irrigation.wsu.edu.