Calculating Chemigation Injection Rates

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Chemigation is an inclusive term referring to the application of an agricultural chemicals (including fertilizers, pesticides, soil conditioners, and amendments) into or through an irrigation system. It is an efficient and cost effective method of application.

This fact sheet covers how to calculate injection rates for chemigation. The various methods of injecting chemicals into the irrigation water, how to calibrate these systems. The system design requirements for chemigation are not covered in this publication. English units are used exclusively. Many of the calculators are implemented online at http://irrigation.wsu.edu.

Follow the Label

The chemical label is a legal and binding document and must be read carefully and followed. In case of differences between the chemical label and material presented in this publication, the chemical label must be followed. A chemical must be labeled for chemigation if it is to be used in chemigation. Application rates that exceed the labeled rate not only are unlawful, but will result in higher costs for chemicals than necessary, result in potentially illegal pesticide residue levels, and can damage 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 financial interests to follow the label, correctly calculate injection rates, and to properly set up the chemigation application. Although not covered in this publication, it is important to follow state laws and rules, local ordinances, and safety precautions for chemigation.

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), and
T = Injection time (hours).

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

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

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

It is important to keep track and use the right units. For example if you use injection time (T) in minutes then the chemical injection rate (I_c) will come out in gallons per minute instead of gallons per hour. If the application (Q_v) is reported on the label in quarts per acre then divide the answer by 4 to get *Vol* in gallons. If the labeled application (Q_v) is specified in pints per acre then divide the answer by 8 to get *Vol* in gallons.

To simplify things, equation 1 and 2 can be combined into the following equation where all terms are defined above:

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

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

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

This is an injection rate that is below what most pumps can accurately inject at. In this case water might be added to the tank to dilute the chemical. For more information on how to determine how much water to add and what the new injection rate should be see the section below "Diluting Chemical Concentrations to Match Inflexible Injection Rates."

Injection Rates by Mass

Often, instead of fluid volume per acre (Q_v), the application rate is specified in weight or mass per unit area (Q_m) such as pounds per acre or ounces per acre. This is common when applying fertilizers (fertigation). 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 by the concentration of the injected solution (C) in lbs/gallon. This value (C) is an inherent property of the fertilizer 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), and

C = Concentration 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 get pounds per gallon.

For simplicity, Equation 3 and 4 can be combined into the following equation, where all terms are defined above:

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

Example: What is the chemical injection rate (I_c) for the following situation? The label for a pesticide requires 8 ounces per acre. The label also states that the chemical contains 4.6 pounds of active ingredient per gallon. This is going to be applied in a drip irrigation system to 45 acres during the last 1 hours of the irrigation set. (Remember to leave time to flush out the system.)

First convert 8 ounces per acre to pounds per acre by dividing by 16 to get 0.5 pounds per acre. The injection rate is calculated using equation 5:

$\frac{0.5 \times 45}{4.6 \times 1} = 4.9$ gallons per hour

Maximum Concentration

Sometimes the label will specify a *maximum* chemical concentration in the irrigation application system, usually specified as a percent (%). This is to protect the irrigation system and/or prevent precipitates forming. Once the proposed chemical injection rate (I_c) is calculated as shown above, the concentration needs to be checked to ensure it is below the maximum. This can be calculated as:

$$C_s = \frac{I_c \times 100}{60 \times Flow} \qquad \text{(Equation 6)}$$

where:

C_s = Solution concentration in the irrigation lines (%),

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

Flow = Water flow rate (gallons per minute; gpm).

Example: Check the line concentration for this situation: The calculated injection rate is 1.73 gallons per hour from the example above, 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 2% so the injection rate is fine.

Injection Rates for Water Chemistry Control

In certain circumstances it is desirable to inject chemicals to control the water chemistry. This is common in drip irrigation to prevent the formation of mineral (iron, calcium, or manganese) precipitates, algal or bacterial growth, or to mitigate or prevent root intrusion. In these cases instead of gallons per acre or pounds per acre, the goal is a desired chemical concentration in the water (C_w), usually specified in part per million (ppm). The injection rate may be determined using Equation 7:

$$I_c = \frac{0.006 \times Flow \times C_w}{P_{cnt}} \quad \text{(Equation 7)}$$

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

Example: Sulfuric acid (15% acid solution) is to be injected to control algae and bacteria growth in drip lines. The desired concentration is 0.6 ppm and the flow rate at the injection site is 460 gallons per minute. The injection rate using Equation 7, would be:

$$\frac{0.006 \times 460 \times 0.6}{15} = 0.11 \text{ gallons per hour.}$$

Mixing Dry Chemicals

Although less common, sometimes dry fertilizers, powdered chemicals, or dry pesticide formulations are mixed with water so that they can be used in a chemigation application. When applying chemicals this way there are two main questions to be solved: 1) how much dry chemical should be mixed with water, and how much water should it be mixed with. The *total chemical to be applied, or how much dry chemical to mix with water* can be calculated as:

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

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), and
P_{cnt} = Percent concentration in mix (expressed as a decimal), such as the percent of elemental N in Calcium Nitrate.

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

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

where:
Vol_{min} = Minimum volume (gal),
W_t = Weight of chemical to be applied (pounds; lbs), and
S = Solubility of chemical (pounds per gallon; lb/gal), which is obtained from the label. Note that solubility is often a function of temperature.

Example: Urea (46% N; with a solubility of 7.5 lb/gal) is to be dissolved and applied at 70 lbs/acre to 25 acres. The mass of chemical to apply (Equation 8) is:

$$\frac{25 \times 70}{0.46} = 3804 \text{ pounds.}$$

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

$$3804/7.5 = 507 \text{ gallons of water.}$$

More water can, and probably should be used to ensure that the dry chemical is completely dissolved. Once Equations 8 and 9 have been employed, the total volume of the mixture then becomes *Vol* and is used in Equation 1 to calculate the mixed chemical injection rate (I_c).

Batch/Bulk Applications

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

This is for set irrigation systems that don't move in the field while irrigation water is being applied. When applying fertilizers, the injection rate is less critical as long as it is completed before the irrigation event is done. Because less precision is required, less expensive venturi-type injectors can be used. It is usually best to inject fertilizers towards the end of the irrigation event so that the chemicals remain in the upper soil layers where the majority of the most active plant roots are and where there is less chance of the chemical getting washed out of the root zone by subsequent water applied. Therefore injecting during the last few hours of the irrigation set is recommended. However, injection should be finished a sufficient time before the end of the set to assure that all the chemical has moved from the lines and onto the field. The injection rate is set to limit the irrigation line concentration(C_s) and to set the injection time (T) and consequently the chemical location within the soil profile.

Diluting Chemical Concentrations to Match Inflexible Injection Rates

If a chemical injection system is being used that has less flexibility in controlling the injection rates such as with venturi or pressure differential type methods, then the concentration of the injected solution can be decreased (diluted) by adding water to help get the application rate correct. In this case, we solve Equation 5 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), and

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.

Example: We are attempting to apply 50 lbs of N per acre to a wheel line set of 1.6 acres/set during the last 6 hours of irrigation. We are using a venturi injector that injects at a 50:1 ratio. We are injecting into a line that is flowing at 150 gpm. Therefore the fixed injection rate is 3 gpm (e.g. 150gpm/50 since the injection ratio is 50:1). The required concentration of injected solution(C_{dil} from Equation 10) would be:

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

We are injecting from a tank containing 300 gallons of N that has a concentration of 7 pounds per gallon. Therefore the amount of water to add ($V_{add}$from Equation 11) would be:

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

This would give a total volume of 300 + 177 = 477 gallons.

Unit Conversions

Multiply gallons per minute (gpm) by 60 to get gallons per hour (gph). Multiply gallons per minute (gpm) by 60 to get gallons per hour (gph). Multiply gallons per hour (gph) by 128 to get fluid ounces per hour (oz/hr). Multiply gallons per hour (gph) by 2.13 to get fluid ounces per minute (oz/min). Multiply gallons per hour (gph) by 63.1 to get milliliters per minute (ml/min). *Divide* the later number by the given constant to get the former in all of the above. For example, divide milliliters per minute by 63.1 to get gallons per hour.