
11

System Maintenance

Trickle irrigation systems may become plugged from algae, growths of bacterial slimes due to the presence of iron and sulphur or the formation of chemical precipitates such as calcium carbonate and ferric oxide. These problems can be held in check with various forms of chemical treatment. Most irrigation water supplies do not require continuous treatment with chemicals. Spot treatments are suggested and should be initiated as problems begin to occur. An emitter that is completely plugged cannot usually be cleaned by chemical treatment.

This chapter provides information on determining the type of chemical treatment program that should be used and the injection rate of the chemical.

11.1 System Monitoring and Maintenance

System monitoring is important to determine what type of maintenance program is needed.

The following monitoring process is suggested:

- The zone flow rates should be monitored during the irrigation season with a flow meter. A reduction in the zone flow rate would indicate that the emitters are starting to plug.
- If a flow rate reduction is noticed, first check to make sure the filtration system is operating properly. Secondly check the emitters closely for the buildup of organics or chemical precipitates. The emitters at the ends of the lines should be checked closely as this is where the plugging usually starts first.
- Flush the lateral lines at the beginning and end of the irrigation season. When inspecting the emitters flush one lateral to observe the amount of debris that has accumulated. If the water runs dirty for 5 seconds or more all the laterals should be flushed.
- If algae growth in the emitters or laterals seems apparent, chlorine treatment may be required. Most forms of algae can be controlled by injecting chlorine into the irrigation water. Copper sulphate can be used if the algae treatment is to be applied to a storage reservoir.
- Acid injection may be required to treat chemical precipitates.

11.2 Algae Control

Material from Rain Bird's Low Volume Irrigation System Maintenance Manual has been used as a reference to prepare portions of Sections 11.2 through to 11.5.

Organic matter consists of algae, weeds, leaves, bacterial slimes or any other material that is or was alive at one time. The filtration system should prevent most aquatic plants and other organic material from entering the trickle irrigation system, but algae can pass through the filtration system and continue to grow in the laterals and emitters. Algae can also support the growth of other micro-organisms within the trickle system. Various methods are available for controlling algae in trickle irrigation systems.

Copper Sulphate

Copper sulphate is often used to control algae growth in ponds and reservoirs. However, copper sulphate is very toxic to fish and some plants. A maximum level of 1 to 2 mg/L in the upper 2 meters of the reservoir is suggested. To achieve this 1 kg of copper sulphate should be added for every million litres that the reservoir stores.

Algaecides and Biocides

Off the shelf products are available for use with trickle irrigation systems to control algae. The use of these products may be regulated in many jurisdictions and could require licensed individuals to apply them. Design considerations for injection systems used to apply these chemicals is discussed in Chapter 14.

Light Exposure

Since algae needs light to grow, limiting the amount of light that can enter components of the trickle system will reduce algae growth. Irrigation pipes and other components that may be transparent should be painted to reduce light infiltration.

Chlorination

Algae often grows at the emitter orifice. Chlorinating the water as required to kill the algae is the best treatment method. See Section 11.5 on chlorination to determine proper application rates to kill algae.



Figure 11.1

Algae Growth in Surface Water

11.3 Bacteria and Bacterial Slimes

Bacteria and bacterial slimes can cause filamentous material to grow and attach to trickle system components. Bacterial slimes bind and glue together all types of suspended sediments to form large clusters of debris that can clog laterals and emitters. There are various sources for these bacteria and slimes. The treatment method is to use a combination of chlorination and pH control with an acid. See Sections 11.5 and 11.6.

Iron and Manganese Precipitation

Iron bacteria have their name derived from the fact that these organisms flourish in the presence of iron precipitates. Iron bacteria oxidize soluble ferrous oxide into insoluble ferric oxide, forming a reddish filamentous slime. There are many types of bacterium that can form this clogging mass with iron or manganese.

Iron (Fe) in association with bacteria can become a problem at concentrations as low as 0.1 mg/L.

Sulphur

Sulphur bacteria may produce white cottony balls of slime which can completely block emitter orifices. If a steel screen is used as a filter, interaction between iron and sulphur (S) can cause iron sulphide precipitates. Sulphur bacteria can be active at sulphur concentrations as low as 0.1 mg/L. Concentrations of sulphur greater than 0.5 mg/L can be expected to require treatment.

Fertilizers

Slimes form more readily in laterals that have been warmed by the sun and where fertilizers have been applied through the trickle system.

Vacuum Ingestion

During system shutdown, a vacuum can be created around emitters as the water is drained out of the lower sections of the zone. The vacuum can cause water and soil containing bacteria located close to the emitter to be drawn back into the lateral. Subsequent drying inside the lateral may allow bacteria to multiply rapidly.

11.4 Precipitates

The precipitants or solids which are the main sources of problems for trickle irrigation systems are:

- calcium and magnesium carbonate
- iron and manganese sulfides
- iron and manganese oxides

As is the case with all irrigation systems, a water sample analysis should be conducted if there are any doubts whether the water quality will have any detrimental effects on the soil or crop. Although most water supplies in B.C. are considered to be of good or excellent irrigation quality as far as the crop or soil are concerned, some will require treatment to be compatible with a trickle irrigation system. A water sample analysis should include the elements shown in Table 11.1. The concentrations for which these elements are considered to be low or high hazard is also shown.

Element	Hazard Level		
	Low	Medium	High
pH	7.0	7.0 - 8.0	> 8.0
Ca	< 10 mg/L	10 - 50 mg/L	> 50 mg/L
Mg	< 10 mg/L	10 - 50 mg/L	> 50 mg/L
Na	< 5 mg/L	5 - 20 mg/L	> 20 mg/L
K	< 1 mg/L	1 - 5 mg/L	> 5 mg/L
HCO ₃	< 30 mg/L	30 - 120 mg/L	> 120 mg/L
Mn	< 0.1 mg/L	0.1 - 1.5 mg/L	> 1.5 mg/L
Fe	< 0.1 mg/L	0.1 - 1.5 mg/L	> 1.5 mg/L
HSO ₄	< 0.2 mg/L	0.1 - 2.0 mg/L	> 2.0 mg/L

1 mg/L = 1 ppm

Care should be taken in using Table 11.1. In the case of Ca, Mg, Na, K, and HCO₃ it is the combination of the concentrations and the pH level that ultimately determines the degree of hazard. The following section on calcium and magnesium carbonate has a methodology for determining the degree of hazard that takes all of these elements into consideration.

Calcium and Magnesium Carbonate

Precipitation of calcium carbonate (CaCO₃) or magnesium carbonate (MgCO₃) in lateral lines and emitters will reduce the trickle system flow rate over time. Whether these precipitates will actually form depends on:

- The concentration of bicarbonate (HCO₃).
- The pH level of the water supply. If the pH level exceeds 8.0, calcium and magnesium carbonates will precipitate more readily.
- The calcium, magnesium, sodium and potassium concentrations.

Bicarbonate (HCO₃), calcium (Ca) and magnesium (Mg) ions are present in many irrigation waters. The level of concentrations of each determines whether there will be enough precipitate to cause a problem. Calcium and magnesium bicarbonates exist only in solution, not as a solid such as sodium or potassium bicarbonate. Upon evaporation they are readily converted into the insoluble calcium and magnesium carbonates. These precipitates usually form around the emitter orifices or other sections of the trickle system that are exposed to the air. Calcium carbonate can be identified as a white lime like deposit near the emitter outlet.

The following conditions cause CaCO₃ and MgCO₃ to form where sufficient concentrations of the chemicals are present.

Exposure to the Atmosphere

As the water around the emitter starts to evaporate, the calcium bicarbonate in the irrigation water undergoes a change as follows:



The carbon dioxide goes off into the air as the calcium carbonate (calcite) precipitates.

Water pH

Calcium carbonate plugging is usually only a problem if the pH level is above 8.0. The addition of fertilizers such as ammonia to the irrigation water may cause the pH level in the water to rise. Fertilizers or chemicals which raise the pH level should be avoided.

Temperature

Calcium carbonate forms faster in warmer water. Laterals that are buried or shaded will tend to clog slower than laterals that are exposed to the sun.

System Pressure

If water contains dissolved carbon dioxide, calcium carbonate can also form in the system where there is a pressure drop. This will usually occur at the filtration station during a backwash cycle, when the filter is open to atmospheric pressure through the backflush line.



Figure 11.2

Calcium Carbonate Precipitate on Emitter and Lateral

Determining Potential for Formation of Calcium and Magnesium Carbonate

In the planning stages of the trickle irrigation system, the water source should be sampled and analyzed. A field test can provide an indication of whether a carbonate precipitate can form. Laboratory analysis and the determination of a saturation index is another recommended method.

Field Test

1. Fill two bottles with the irrigation water
2. Add aqua ammonia to one of the bottles. Ensure that there is sufficient ammonia to produce a strong smell. The pH should be above 9.5.
3. Leave the bottles sit for at least 12 hours.
4. Check for precipitates on the bottom of the bottle. Using a strong light beam in a dark room may make it easier to see if the bottle containing the ammonia solution looks any different than the other bottle.

Saturation Index

A saturation index (Equation 11.1) can be used to determine whether the irrigation water will precipitate or has the capacity to dissolve CaCO₃ or MgCO₃. A positive saturation index indicates calcium carbonates may precipitate.

Equation 11.1 **Saturation index = pH - pHc**

where: pH = actual measurement taken from water supply
 pHc = $p(\text{Ca} + \text{Mg} + \text{Na} + \text{K}) + p(\text{Ca} + \text{Mg}) + p(\text{CO}_3 + \text{HCO}_3)$
 (Table 11.3)

To determine the saturation index a water sample should be analyzed for Ca, Mg, K, Na, HCO₃, CO₃ and pH. All units except for pH must be expressed in meq/L (milliequivalents per litre). Table 11.2 can be used to convert mg/L into meq/L. The pHc terms can be determined from Table 11.3.

Element	mg/L per 1 meq/L
Ca	20
mg	12
K	39
Na	23
CO ₃	30
HCO ₃	61

meq/L	p(Ca+Mg+Na+K)	meq/L	p(Ca+Mg)	meq/L	p(CO ₃ +HCO ₃)
0.5	2.11	.05	4.60	.05	4.30
0.7	2.12	.10	4.30	.10	4.00
0.9	2.13	.15	4.12	.15	3.82
1.2	2.14	.20	4.00	.20	3.70
1.6	2.15	.25	3.90	.25	3.60
1.9	2.16	.32	3.80	.31	3.51
2.4	2.17	.39	3.70	.40	3.40
2.8	2.18	.50	3.60	.50	3.30
3.3	2.19	.63	3.50	.63	3.20
3.9	2.20	.79	3.40	.79	3.10
4.5	2.21	1.0	3.30	.99	3.00
5.1	2.22	1.25	3.20	1.25	2.90
5.8	2.23	1.58	3.10	1.57	2.80
6.6	2.24	1.98	3.00	1.98	2.70
7.4	2.25	2.49	2.90	2.49	2.60
8.3	2.26	3.14	2.80	3.13	2.50
9.2	2.27	3.90	2.70	4.0	2.40
11	2.28	4.97	2.60	5.0	2.30
13	2.30	6.30	2.50	6.3	2.20
14	2.32	7.90	2.40	7.9	2.10
18	2.34	10.00	2.30	9.9	2.00
22	2.36	12.50	2.20	12.5	1.90
25	2.38	15.80	2.10	15.7	1.80
29	2.40	19.80	2.00	19.8	1.70

From: "Ideas in Soil and Plant Nutrition" (Joe Traynor).

Example 11.1 Determining Whether Calcium Carbonate Precipitate Will Form

The water source for a trickle system is from a well in the Fairview Irrigation District. The water supply from the well has no organic content and inorganic suspended solids of less than 5 mg/L. The water analysis for this district is as shown below. Using Table 11.2 the concentrations of each element are converted to meq.

Water sample:

pH	=	8.1	
Ca ⁺²	=	110 mg/L	= 5.5 meq/L
Mg ⁺²	=	48 mg/L	= 4.0 meq/L
Na ⁺¹	=	26 mg/L	= 1.13 meq/L
K ⁺	=	3 mg/L	= 0.08 meq/L
CO ₃ ⁻²	=	none	= none
HCO ₃ ⁻	=	280 mg/L	= 4.6 meq/L

The pHc terms are derived by adding the meq for each element as follows:

i)	(Ca + Mg + K + Na)	=	5.5 + 4.0 + 0.08 + 1.13	=	10.7 meq/L
ii)	(Ca + Mg)	=	5.5 + 4.0	=	9.5 meq/L
iii)	(CO ₃ + HCO ₃)	=	0 + 4.6	=	4.6 meq/L

From Table 11.3

i)	p (Ca + Mg + K + Na)	=	p (10.7)	=	2.28
ii)	p (Ca + Mg)	=	p (9.5)	=	2.32
iii)	p (CO ₃ + HCO ₃)	=	p (4.6)	=	2.34

$$\text{pHc} = 2.28 + 2.32 + 2.34 = 6.94$$

$$\text{Saturation Index} = \text{pH} - \text{pHc} = 8.1 - 6.94 = 1.16$$

The positive value indicates that CaCO₃ and MgCO₃ will precipitate.

Iron and Manganese

For the most part, iron is more of a problem than manganese. The concentrations of manganese required to cause a plugging concern are at a level that may be toxic to certain crops. Concentrations of iron greater than 0.1 mg/L may create plugging problems.

Chemical precipitation of iron usually occurs when water is pumped from an aquifer, where conditions that favour the solubility of iron, into the irrigation system where the change in environment favours precipitation. Pressure, temperature and pH are the most important variables determining iron solubility.

Iron and Manganese Sulfides

Sulfide levels greater than 0.5 mg/L can cause severe plugging problems. Dissolved iron or manganese when combined with sulfides can form a black precipitate that is very difficult to treat and remove from an irrigation system. Normally sufficient levels of sulfides to cause a problem are not found in surface waters.

Note: Hydrogen sulfide reacts readily with chlorine to form a precipitation of elemental sulphur.

Iron and Manganese Oxides

Two forms of iron oxides are common:

Ferrous oxide – this form is soluble and is the dissolved form of iron found in solution. Ferrous oxide reacts with oxygen to readily form ferric oxide.

Ferric oxide – is commonly known as rust and is not very soluble in water. Plugging of emitters and laterals is common with ferric oxide.



Figure 11.3

Water Source with a High Iron Content

Most iron or manganese problems occur from groundwater sources. However there are surface water sources that do contain levels of iron high enough to cause iron bacterial growths. See Figure 11.3.

Iron and manganese oxides can be treated to prevent plugging of trickle systems. Since the reduction into ferric oxide occurs quite readily, the precipitates can be removed before they enter into the irrigation system. The two treatment methods used are aeration and settling or chlorination and filtration.

Aeration and Settling for Iron or Manganese Oxide Control

Where a high level of iron or manganese are present and the flow rate of the irrigation system is quite high the use of chlorine for iron control can be quite expensive. Aeration and settling may prove to be the best option for these situations. Aeration and settling is also the best option to use with manganese oxide as the oxidation reaction is much slower than iron. Injection of chlorine into the irrigation line to oxidize manganese is not effective as the precipitates take too long to form.

To aerate the water properly, the source water is usually sprayed into the air and allowed to fall into the reservoir or run over a series of baffles which enhance the mixing of the water with the oxygen in the air. Sufficient aeration is required to have the manganese or ferrous oxide precipitate. Once precipitated the settling basin must be large enough to allow enough time for the precipitate to settle out prior to the water being pumped into the irrigation system.

Chlorine Treatment and Filtration to Remove Iron Oxide

Chlorine reacts very quickly with insoluble iron to form soluble iron as long as there is sufficient turbulence in the lines to create mixing. The iron precipitate is then removed from the water by a sand media filter. It is important that the precipitation process has been completed prior to the water passing through the sand filter, as any precipitation after the filter will cause emitter plugging. To treat iron oxide chlorine must be applied on a continuous basis.

The oxidation reaction for manganese is much slower than that for iron. It is likely that most of the oxidation and precipitation will occur downstream of the sand filter, causing plugging problems. Since manganese is also toxic to some plants care should be taken when dealing with this element. Chlorination is not recommended for manganese oxide.

The amount of chlorine that is required to control iron is 1.4 mg/L of chlorine for every 1.0 mg/L of iron (Fe) in the water. This converts to:

3.8 lbs of chlorine / acre-foot for every mg/L of Fe

or

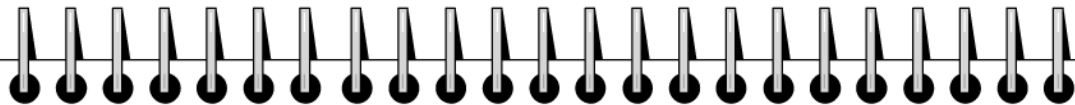
1.4 kg of chlorine / 1000 m³ for every mg/L of Fe

Equation 11.2 can be used to determine the amount of chlorine to be added to treat iron in an irrigation system.

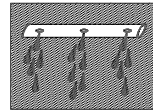
$$\text{Equation 11.2} \quad \text{Cl}_g = \frac{\text{Fe}_{\text{mg/L}} \times Q}{3.15}$$

where: Cl_g = the amount of chlorine to add in g / hr
 $\text{Fe}_{\text{mg/L}}$ = the concentration of Fe in the water supply in mg/L
 Q = the irrigation system flow rate in gpm

Equation 11.3 in Section 11.5 provides another method for calculating the injection rate for a chlorine solution.



Example 11.2 Chlorine Requirement for Iron Oxide Control



The linear tape system draws water from a well that has an iron content of 0.85 mg/L. The irrigation system flow rate is 28 gpm. Chlorine is to be added to the water source to precipitate iron oxide prior to the water entering the irrigation filtration system. How many grams of chlorine per hour are required to treat the iron?

Using Equation 11.2:

$$\begin{aligned} Q &= 28 \text{ gpm} \\ \text{Fe}_{\text{mg/L}} &= 0.85 \text{ mg/L} \end{aligned}$$

$$\text{Cl}_g = \frac{0.85 \times 28}{3.15} = 7.6 \text{ g/hr}$$

Note that this amount of chlorine put into the water supply will create a chlorine concentration of 1.20 mg/L (1.4 times the iron concentration of 0.85 mg/L).

11.5 Chlorination

Chlorine is effective in controlling algae and bacterial growths as well as oxidizing iron in irrigation water supplies. Chlorine can exist in several forms in solution. To be effective to control algae the amount of available or free chlorine in solution is key. The amount of free chlorine in solution depends on whether the treatment method is continuous, intermittent or a high rate super-chlorination. Water containing iron, manganese or hydrogen sulfide will tie up some of the chlorine in chemical reactions. Organic matter in the water can tie up some chlorine through absorption. Free chlorine is the amount left in solution after these other needs have been met.

The addition of chlorine to water results in the following hydrolysis reaction:



The hydrochlorous acid (HOCl) undergoes further reaction as:



Hydrochlorous acid (HOCl) and hypochlorite (OCl⁻) are together referred to as the “free available chlorine” and coexist in an equilibrium which is effected by temperature and pH. In low pH conditions the free available chlorine is mainly in the form of HOCl. In basic or high pH conditions the free available chlorine is in the form of OCl⁻. Hypochlorous acid (HOCl) is a much more potent algae control agent than hypochlorite (OCl⁻). (Approximately 40 times). It is therefore important to keep the ratio of HOCl to OCl⁻ high. This can be done by keeping the pH level low. At a pH level of 6.0, nearly 90% of the free chlorine is in the HOCl form. At a pH level of 8.5 only 10-15% is HOCl.

To control the growth of algae and slimes there must be some free chlorine left in solution. The chlorine residual should be tested near the end of the lateral furthest from the chlorine injection point. A free chlorine residual of 1.0 mg/L (1.0 ppm) should be left in the water at this furthest point.

Continuous Chlorine Treatment

Continuous chlorine treatment is required:

- to precipitate iron or manganese oxides prior to the filtration system
- where organic loading of the water source is very high
- for controlling bacterial and algae growths that are excessive

For continuous chlorination a residual level of 0.5 – 1 mg/L should be sufficient.

Intermittent Chlorine Treatment

In British Columbia continuous chlorination is not often required and since the chlorine is usually applied manually, intermittent treatment is easier. For intermittent treatment the chlorination level should be 10 – 20 mg/L and held for at least one hour. If the free chlorine level at the ends of the laterals during the treatment are well below the original concentration it suggests that more frequent chlorination may be required. If the free chlorine levels at the end of the lateral are close to the concentration at the injection point it is an indication that fewer treatments can be applied over the course of the irrigation season.

Superchlorination

If emitters are totally plugged by organic matter superchlorination may be one method of clearing the problem. The chlorination levels for superchlorination can be from 200 – 500 mg/L. These high chlorine levels should be kept in the system for 24 hours. At the end of the treatment the system should be flushed starting with the mains, submains and then the laterals.

Superchlorination is not always effective. If the organic matter is totally plugging the emitter the chlorine may not be able to come into contact with all of the organic material. On sloping terrain it is also difficult to keep the chlorine in the laterals as it may leak out of lower emitters that are not totally plugged. Toxicity to plants could occur where leakage occurs. The addition of an acid with the chlorine may help in clearing blocked emitters. See Section 11.6.

A recommended chlorination program for British Columbia is as follows:

- The duration of chlorine application is as important as the concentration. Results from the Summerland Research Station indicate that treatments of 10 mg/L for 4 hours may be more effective than 40 mg/L for 2 hours. When the duration of chlorine application exceeds 4 hours there appears to be no further improvement in system performance.
- The maximum chlorine concentration injected should not exceed 40 mg/L. Concentrations exceeding 40 mg/L may enhance the precipitation of calcium or magnesium carbonate.
- Chlorine should not be injected continuously unless specifically used to precipitate ferric oxide. Concentrations of 1 – 2 mg/L should then be sufficient. (1 mg/L of chlorine will treat 0.7 mg/L of iron).
- If plugged emitters cannot be cleared with a chlorination treatment of 40 mg/L for 4 hours, superchlorination, an acid treatment or manual cleaning may be necessary.
- Chlorine must, as should all chemicals, be injected before the filtration system. This is to ensure that any precipitates that are quickly formed will be filtered out. Irrigation water containing manganese requires extra caution, as manganese oxidizes slowly. Manganese precipitates may therefore form after the filtration system.
- Lateral line flushing should always be done in conjunction with chlorination programs. The chlorine will kill living organisms but not dissolve them. Flushing is required to remove the material from the trickle system.

Note: 1 mg/L = 1 ppm

Testing for Chlorine Levels

Swimming pool kits that measure the level of free chlorine can be used as a simple indicator. Kits that measure the levels of total chlorine are not useful for the reasons described in the previous sections. An indicator called “DPD” turns from clear to darker shades of red with an increasing amount of free chlorine. These kits can measure the free chlorine concentration up to 3.0 mg/L.

For concentrations higher than 3.0 mg/L the samples can be diluted to get a reading. For example:

- Using a syringe to accurately withdraw 1.0 ml from a sample and diluting it with 9.0 ml of distilled water will give it a dilution factor of 10.
- Mixing 1.0 ml of the sample with 99 ml of distilled water will have a dilution factor of 100.

The sample can be diluted to the expected range where a reading can be taken with the “DPD” indicator. The chlorine concentration in the original sample will be the “DPD” indicator reading multiplied by the dilution factor used.

Selecting a Source of Chlorine

Chlorine is available in three forms, calcium hypochlorite, sodium hypochlorite and chlorine gas.

Calcium Hypochlorite

Calcium hypochlorite is available in granular tablets or pellets, which are readily soluble in water and stable under the proper storage conditions. The available free chlorine (Cl_2) will range between 60 – 70%. Using calcium hypochlorite as a chlorine source is not recommended for water sources already containing high calcium concentrations and pH values higher than 8.0. Under these conditions acid addition will generally be required to prevent calcium carbonate precipitates from forming.

Sodium Hypochlorite

Sodium hypochlorite is the agent usually found in household bleach. It is available in strengths up to 18% available free chlorine. Sodium hypochlorite is readily decomposed by light and heat and must therefore be stored in a cool, dark location. It is easy to work with and generally recommended for use with a trickle irrigation system.

Chlorine Gas

Chlorine gas is very corrosive and poisonous and is not recommended for use unless a person is qualified to work with this chemical. Gaseous chlorine is usually only used on very large acreages where great amounts of chlorine are required. Chlorine gas may be used when the addition of calcium or sodium is to be avoided. For B.C. conditions sodium hypochlorite or calcium hypochlorite are recommended for use instead of chlorine gas.

Table 11.4 provides a comparison of chlorine sources and the amounts required to achieve a concentration of 1.0 mg/L.

Table 11.4 Comparison of Chlorine Sources		
Chlorine Source % Chlorine	Amount to Supply 1 kg Cl ₂	Amount per 1000 m ³ to provide 1.0 mg/L
Calcium Hypochlorite		
60-70 %	1.5 kg	1.47 kg
Sodium Hypochlorite		
5%	16.7 Litres	16.5 Litres
10%	8.35 Litres	8.27 Litres
12%	6.96 Litres	6.89 Litres
15%	5.57 Litres	5.52 Litres
16%	5.21 Litres	5.16 Litres
18%	4.64 Litres	4.58 Litres
Chlorine Gas	1 kg	1 kg

Calculating Chlorine Injection Rates

The injection rate of a chlorine solution will depend on the chlorine concentration of the chemical solution, the desired chlorine concentration in the water and the trickle system flow rate.

Commercial sodium hypochlorite (household bleach) usually has 12% available chlorine but is also available in 16% or 18%. Calcium hypochlorite is available as 70% available chlorine but requires pre-mixing since it is in granular form. The concentration of the mixed solution must therefore be determined before an injection rate can be calculated.

Formula 11.3 calculates the chlorine injection rate in gph. The numbers in the equation are conversions to arrive at gph.

$$\text{Equation 11.3} \quad I = Q \times \frac{Cl}{1,000,000} \times 60 \times \frac{100}{(\text{bleach } \%)}$$

where:

- I = chlorine injection rate (gph)
- Q = trickle system flow rate (gpm)
- Cl = desired residual chlorine concentration in the water supply (mg/L) or ppm
- Bleach % = chlorine concentration of solution to be injected (% of available chlorine)

Example 11.3 Chlorine Injection Calculation for Algae Control

A grower wants to apply chlorine intermittently at a rate of 20 mg/L for 2 hrs. The irrigation system zone flow rate to be treated is 50 gpm. A 12% sodium hypochlorite solution is to be used. Calculate the injection rate required and the amount of bleach for the treatment?

$$\begin{aligned} Q &= 50 \text{ gpm} \\ Cl &= 20 \text{ mg/L} \\ \text{Bleach} &= 12\% \end{aligned}$$

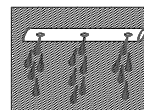
Using Equation 11.3:

$$I = 50 \text{ gpm} \times \frac{20 \text{ mg/L}}{1,000,000} \times 60 \times \frac{100}{12} = 0.5 \text{ gph}$$

The amount of bleach required for the treatment will be:

$$0.5 \text{ gph} \times 2 \text{ hrs} = 1.0 \text{ gallons} \times 3.78 \text{ litres/gallon} = 3.78 \text{ litres}$$

Example 11.4 Chlorine Injection Calculation for Iron Oxide Control



Using the same parameters as in example 11.2, the linear tape system water supply from a well has an iron content of 0.85 mg/L. The irrigation system flow rate is 28 gpm. The system has 8 zones that operate for 2.2 hours each at the peak of the season. A 5% sodium hypochlorite bleach is to be added to the water source to precipitate iron oxide prior to the water entering the irrigation filtration system. What injection rate should be used and how much chemical is required daily during the peak of the season?

The concentration of free chlorine required to oxidize the iron will be:

$$Fe_{\text{mg/l}} \times \frac{1.4 \text{ mg/L (Cl)}}{\text{mg/L (Fe)}} = 0.85 \times 1.4 = 1.2 \text{ mg/L (From Iron and Manganese Oxide Section)}$$

Using Equation 11.3:

$$I = 28 \text{ gpm} \times \frac{1.2 \text{ mg/L}}{1,000,000} \times 60 \times \frac{100}{5} = 0.04 \text{ gph}$$

The daily operating time is 8 zones x 2.2 hrs per zone = 17.6 hours per day.
 The amount of chemical required daily is 0.04 gph x 17.6 hrs = 0.70 gallons
 = 2.7 litres

Equation 11.4 is a metric equivalent of Equation 11.3 and can be used to calculate the chlorine injection rate in litres per hour for trickle system flow rates that are given in litres per second.

$$\text{Equation 11.4} \quad I = Q \times \frac{Cl}{278} \times \frac{100}{(\% \text{ bleach})}$$

I = Chlorine injection rate
(Lph)

Q = Trickle system flow rate
(Litres per second)

Cl = Desired chlorine concentration in the water supply
(mg/L) or (ppm)

Bleach % = Chlorine concentration of solution to be injected
(% available chlorine)

Equation 11.5 can be used to calculate the injection rates for chlorine gas.

NOTE: Chlorine gas is very poisonous and corrosive. Adequate ventilation must be provided at the floor level of storage rooms as chlorine gas is heavier than air.

$$\text{Equation 11.5} \quad I = \frac{Q \times Cl}{2000}$$

I = Chlorine gas injection rate
(lbs / hr)

Q = Trickle system flow rate
(gpm)

Cl = Desired chlorine concentration in the water supply
(mg/L) or (ppm)

11.6 Acid Addition

The addition of acids to a trickle irrigation system water supply has the following benefits:

- Reduces the water supply pH to make chlorination more effective.
- Lowers the level of bicarbonate in the water to reduce plugging of emitters due to calcium and/or magnesium carbonate formation with water evaporation. The acid also breaks up existing precipitates. A pH level of 6.5 lowers the bicarbonate level to half while a pH of 4.5 takes 95% of the bicarbonate out of the water.

Water supplies with Calcium (Ca) and Magnesium (Mg) concentrations greater than 50 mg/L and pH values of 8.0 or greater are susceptible to calcium or magnesium carbonate (CaCO_3 and MgCO_3) precipitates forming. Calcium or magnesium carbonates leave a white crusty deposit on the trickle system components when the water evaporates.

The addition of an acid neutralizes the carbonate (CO_3^{2-}) or bicarbonate (HCO_3^-) component leaving the calcium in solution. Carbonate is generally not present unless the pH is greater than 8.3. Bicarbonate is present at pH values below 8.3.



For most situations the buildup of CaCO_3 is very gradual over a long period of time. In these instances a periodic dosage of an acid may be all that is required. Usually lowering the water pH to 6.5 for 24 hours will be sufficient to treat any precipitation buildup that may have occurred. The acid can then be injected before the filtration system.

If a severe CaCO_3 plugging problem exists, a stronger dosage of acid injection may be required. In these situations it is suggested that water acidified to pH 4.5 be left to sit in the lines for one hour. In this case the acid must be **injected after** the filtration system to prevent corrosion of any metallic parts in the filter. The entire system should then be thoroughly flushed until the water runs clear. A check of the emitter flow rates before and after treatment will indicate whether an improvement in flow rate has been achieved.

Note: lowering the pH below 6.5 can be corrosive to metal components of the irrigation system. Use extreme caution.

If the emitters are totally plugged the trickle laterals may have to be removed from the field and dipped in an acid bath with a pH level around 2.

Acid Selection and Application Considerations

The following acids are commonly used to treat trickle irrigation systems.

Hydrochloric Acid

Hydrochloric acid adds chloride to the water which is toxic to plants at high concentrations.

Care should be taken to ensure that chloride levels are not too excessive.

Phosphoric Acid

Phosphoric acid can also be used as a nutrient source for phosphorus.

Sulfuric and Sulfurous Acid

Sulfurous acid (H_2SO_3) is formed by the controlled burning of elemental sulphur. However, sulfurous acid should not be used if chlorination is also needed. Sulfurous acid reacts with hypochlorous chlorine to destroy the usefulness of the chlorine treatment. Sulfuric acid (H_2SO_4) is recommended where chlorination is required, and is more commonly used with trickle systems.

The above acids are available in various degrees of strength and purity. Before using any acid the following points should be kept in mind:

- When injecting acids for durations longer than one hour, the pH level should not be reduced below 6.5. Excessive acidification can be corrosive to pipes, fittings and will eventually harden rubber valve seats.
- All acids are very corrosive when concentrated. Acids must therefore be injected into the irrigation systems at a point that allows suitable dilution with water before contacting metal components of the irrigation system.
- If the water is acidified to a level below pH 4.0, the acid must be injected downstream of any metal components.
- Acid should always be added to water, not vice versa. **An explosion could occur if water is added to an acid.**
- By selecting a mineral acid, such as phosphoric, nitric, etc., some fertilizer benefits can also be achieved. (75% phosphoric acid is 0-52-0 in fertilizer terminology. Phosphoric acid is also the least dangerous acid to handle.)
- Mixing an acid with other fertilizer salts prior to injection can create a very corrosive solution. Premixing these in a large tank of water avoids creating concentrated solutions. Also, by injecting acids and fertilizers separately (but still simultaneously, i.e., two injectors) the mixing will occur in a diluted state and will therefore be less corrosive.

Calculating the Amount of Acid Required

Determining the amount of acid to apply can be achieved by evaluating the water analysis report or performing a titration analysis.

Titration Analysis

A titration analysis is usually performed by a laboratory. Most laboratories can produce a titration analysis if supplied with a sample of the supply water. The laboratory titration curve provides an acid factor to calculate the amount of acid required to adjust the irrigation water to the desired pH. The acid factor

is the milliequivalents (meq) of acid per litre of water required to lower the pH to the desired level. The acid factor can be converted into the amount of acid required per 1000 gallons for different acids. See Table 11.5.

Acid Factor	Amount of Acid Required per 1000 Gallons of Water	
	Sulfuric Acid H ₂ SO ₄ (95%) litres	Hydrochloric Acid HCl (36%) litres
0.5	0.04	0.15
1.0	0.08	0.30
2.0	0.19	0.61
4.0	0.41	1.29
6.0	0.60	1.90
8.0	0.83	2.54
10.0	1.06	3.18
15.0	1.55	4.73

A crude titration analysis can also be done in the field as follows:

- fill a 40 gallon drum with the supply water
- add a small amount of acid (10 ml) and mix thoroughly
- measure the pH level
- continue to add small amounts of acid until the desired pH level is reached
- multiply by 25 to determine the amount of acid that must be added to 1000 gallons

During the 1970's a number of Irrigation Districts in British Columbia suspected of having CaCO₃ precipitate problems were sampled. The values in Table 11.6 were determined over a period of four years. Growers in these districts are still recommended to analyze their own water supply to refine the figures. The acid factors were obtained through a laboratory titration analysis to achieve a final pH level of 6.5.

Irrigation District	pH	Ca	Mg	Na	K	CO ₃	HCO ₃	Acid Factor to achieve 6.5 pH
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	meq/L
Cawston	7.5	65	12	14	3	-	135	0.98
Fairview Heights	8.07	110	48	26	3	-	280	2.02
Osoyoos	7.8	38	10	10	3	-	140	1.04
Oliver (SOLID)	8.2	35	8	13	3	-	140	0.98
Summerland (Garnet Vy)	8.0	55	8	12	3	-	17	0.20
Lakeview Heights	8.0	35	6	6	2	-	149	1.14
Wood Lake	7.5	80	27	35	7	-	30	0.20

Equations 11.6 and 11.7 can be used to determine the amount of acid required to lower the water supply pH. Use Equation 11.6 if the acid factor is given through a titration analysis or determined from the information in Tables 11.5 and 11.6. Equation 11.6 provides the injection rate that will lower the pH to 6.5. The constants shown in the equation are conversion factors.

Equation 11.6

$$I_a = \frac{A \times Q \times 60}{1000}$$

Where:

- I_a = acid injection rate L/hr
 A = amount of acid (litres) / 1000 gallons of water
 (Table 11.5 if acid factor known)
 Q = trickle irrigation system flow rate (gpm)



Example 11.5 Determining An Acid Injection Rate and Amount of Acid

The water source for a trickle irrigation system is from a well in the Fairview Irrigation District. The water analysis is shown in Table 11.6. The irrigation system flow rate is 50 gpm. The titration analysis indicates that an acid factor of 2.02 meq/l is required to lower the water pH to 6.5. The grower wishes to lower the water pH to 6.5 for a 12-hour period. How much 36% hydrochloric acid is required?

From Table 11.5, for an acid factor of 2.02 meq/L:

$$A = 0.61 \text{ litres/ 1000 gallons of water}$$

The zone flow rate is given as:

$$Q = 50 \text{ gpm}$$

Using Equation 11.6 the injection rate will be:

$$I_a = \frac{0.61 \text{ litres} \times 50 \text{ gpm} \times 60}{1000 \text{ gallons}} = 1.83 \text{ L/hr}$$

To inject for 12 hours will require:

$$1.83 \frac{\text{litres}}{\text{hour}} \times 12 \text{ hours} = 22 \text{ litres of hydrochloric acid}$$

Using Water Analysis and Sulfuric Acid

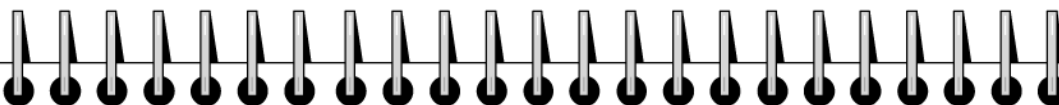
Equation 11.7 can be used if a water analysis provides the level of bicarbonate (HCO_3) in the water supply and sulfuric acid (H_2SO_4) is to be used as the acid source. The level of bicarbonate must be converted into meq/L. The final pH level that will be achieved will be close to 6.0. The value of 287 is a conversion factor.

Equation 11.7

$$L_{\text{H}_2\text{SO}_4} = \frac{\text{HCO}_3 \text{ meq/L} \times Q}{287}$$

Where:

$L_{\text{H}_2\text{SO}_4}$	=	litres of sulfuric acid per hour
$\text{HCO}_3 \text{ meq/L}$	=	amount of HCO_3 in the water supply in meq/L
Q	=	the irrigation zone flow rate in gmp



Example 11.6 Determining An Acid Injection Rate Using Water Analysis

The same conditions as in example 11.5 will be used. The water source for a trickle irrigation system is from a well in the Fairview Irrigation District. The level of bicarbonate in the water is 280 mg/L (from Table 11.6). The irrigation system flow rate is 50 gpm. The grower wishes to lower the water pH to 6.0 for a 12-hour period. How much 95% sulfuric acid is required?

From Table 11.2

$$\text{HCO}_3 \text{ at } 280 \text{ mg/L} \times \frac{1 \text{ meq/L}}{61 \text{ mg/L}} = 4.6 \text{ meq/L}$$

Using Equation 11.7

$$L_{\text{H}_2\text{SO}_4} = \frac{4.6 \text{ meq/L} \times 50 \text{ gpm}}{287} = 0.80 \text{ L/hr}$$

For a 12 hour period the amount required will be:

$$0.80 \text{ L/hr} \times 12 \text{ hours} = 9.6 \text{ litres}$$

Note that the Equations used in this Manual result in a final pH that is slightly different — 6.5 for Example 11.5 using hydrochloric acid and 6.0 for Example 11.6 using sulfuric acid.

