

Neutralizing Excess Bicarbonates From Irrigation Water¹

Gerald Kidder and E. A. Hanlon, Jr.²

Many sources of irrigation water in Florida contain dissolved bicarbonates, which are bases and are thus liming materials. Irrigation with such water can decrease the lime requirement for plant production and can cause adverse plant growth by excessively raising the pH of the soil or potting media. The magnitude of the effect depends on the concentration of the bicarbonates in the water, the amount of the water applied, the buffering capacity of the soil or potting media, and the sensitivity of the plants being grown.

This publication addresses this important water quality problem and suggests management practices to minimize adverse effects on plant production.

THE PROBLEM

1. Where in Florida is the problem most likely to occur?

The problem of high dissolved bicarbonates is likely to occur wherever water comes from a limestone aquifer, such as the Floridan or Biscayne, or from lakes or canals that cut into limestone. Thus, this is a potential problem in most of Florida.

2. How can I find out if I have high-bicarbonate water?

A water test is the surest means of determining if a problem exists. Interpretation of the test should include an evaluation of the liming potential of your water. This is best determined directly by titration of the water with an acid to the methyl orange end point. An indirect method which uses the calcium (Ca) and magnesium (Mg) analyses may also be used but may result in over-estimation of liming potential. Such an estimate assumes that all of the Ca and Mg are present as bicarbonates, which is not always the case (c.f., Question 4).

The IFAS Extension Soil Testing Laboratory in Gainesville offers a water test to the public for \$10.00 per sample. The form with instructions is available through all county Extension offices and off the web at <http://hammock.ifas.ufl.edu/pdf/files/ss/ss18400.pdf>.

3. Isn't it sufficient to just measure the water's pH?

If the pH of your irrigation water is below 7.0, then we may safely assume that it will not be a significant source of liming materials. However, if

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 2. Gerald Kidder, professor emeritus; E. A. Hanlon, Jr., Professor and Director, Southwest Florida Research and Education Center; Soil and Water Science Department and Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL 32611-0290.

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the pH is above 7.0, we know that the water contains bases but we don't know how much. For example, one water source may have a relatively high pH of 8.4 and yet contain a very low level of bicarbonates. Another water source, with the same pH, may have a very high bicarbonate level.

4. How are Ca and Mg analyses useful?

Multiplication of parts per million (ppm) Ca by 0.05 and ppm Mg by 0.083, and summing the two products, will give the milliequivalents of those cations per liter (me/L) of water (see Equation 1 in Appendix). In many cases, Ca and Mg will be associated with bicarbonate and carbonate salts. Under those conditions the me/L of Ca plus Mg will be a good estimate of the me/L of associated bases. However, if other non-basic ions such as sulfate are present, the calculation would overestimate the base content of the water. Thus, Ca and Mg analyses may be useful in estimating base content but should be used with caution.

$$\frac{1.0 \text{ g Ca}}{1 \times 10^6 \text{ g water}} \times \frac{1 \times 10^3 \text{ g water}}{\text{L water}} \times \frac{1.0 \text{ me Ca}}{20 \text{ mg Ca}} \times \frac{10^3 \text{ mg}}{\text{g}} = 0.05 \times \frac{\text{me Ca}}{\text{L water}}$$

$$\frac{1 \text{ g Mg}}{1 \times 10^6 \text{ g water}} \times \frac{1 \times 10^3 \text{ g water}}{\text{L water}} \times \frac{1.0 \text{ me Mg}}{12 \text{ mg Mg}} \times \frac{10^3 \text{ mg}}{\text{g}} = 0.083 \times \frac{\text{me Mg}}{\text{L water}}$$

Equation 1.

5. In which crop situations am I likely to have a problem with high pH water?

Crops which are particularly sensitive to high pH soil are usually the first to show ill effects of high bicarbonate water. Blueberries, azaleas, and pine seedlings are well-known for their sensitivity to pH-induced iron deficiencies. However, just about any crop may be affected given the right conditions. Bermudagrass turf has shown manganese deficiencies when the soil pH has been raised by heavy or prolonged use of "hard" water (i.e., water with lots of Ca and Mg bicarbonates).

6. Which irrigation situations are most problematic?

Heavy or frequent irrigations applied to soils or media of low buffering capacity will present the most problems to sensitive crops. Such situations are commonly found in nursery and field situations where plants are being established. Nursery plants are

usually grown in potting media of low water holding capacity and are sometimes irrigated two or three times each day. Propagation houses also employ irrigation rates which far exceed the water taken up by the plants.

Drip irrigation on sand soil is another problematic situation. Water does not move very far laterally in sands, so the typical wetting pattern under a dripper is that of a 15 to 20 inch diameter cylinder. Thus, a relatively small output per emitter can amount to a very high rate per area wetted. For example, assume a typical fine sand soil with a water holding capacity of 13% water by volume and a "wetting circle" of 20 inches is irrigated with 4 gallons of water. The soil under that emitter would experience an irrigation rate of 3.0 acre inches and would be wet down to 23 inches in the profile. Such a high irrigation rate can rapidly raise the pH of the soil within the irrigated "cylinder". Data presented in Table 1 illustrate this point.

7. What can I do to minimize the adverse effects of high-bicarbonate water?

1. Be careful not to over-irrigate. Know the water holding capacity of your soil or media and apply only enough water to slightly exceed the root zone water-holding capacity. Over-irrigation is costly in many ways -- the cost of pumping, of leached nutrients, of wasted water resources and, in this case, of accelerating the increase in soil pH. Avoid these with good irrigation management.
2. Apply acids or acid-forming materials to the soil to counteract the bases applied in the water.
3. Neutralize the liming effect of the water by adding acid to the water **before** it is applied to the crop.

SOIL TREATMENT

8. What can be done if the plants are already suffering from water-induced high pH?

Where high levels of bicarbonates in the water have caused soil or potting media pH to be too high for proper plant performance, it may be necessary to lower the soil pH. This may be accomplished by

addition of extra acid in the irrigation water, use of acid-forming fertilizer in certain cases, or application of elemental sulfur to the soil.

It is important to note that the acid-producing effect of sulfur comes from the formation of sulfuric acid when soil bacteria act on the elemental sulfur (ex., flowers of sulfur, dusting sulfur, or wettable sulfur). The sulfate form of sulfur applied in fertilizers such as potassium sulfate, magnesium sulfate, or gypsum (calcium sulfate) does not have the acid-producing effect of elemental sulfur.

Sulfur application rates of 300 to 500 pounds per acre should not be exceeded. This rate is equivalent to between 0.7 and 1.1 lbs/100 square feet of treated surface area. Over-application of sulfur or acid can cause damage to plants, an effect you certainly want to avoid. Monitor changes carefully.

Remember the pH will increase again as you continue to irrigate with high bicarbonate water. Water or soil acidification will be a continuing effort.

9. Can acid-forming fertilizers keep the soil pH from getting too high?

Under many circumstances the quantity of bases that is being supplied in the irrigation water far exceeds the quantity of acid formed by addition of fertilizer. Under those conditions acid-forming fertilizer will not control the problem of increasing soil pH. However, where very high rates of acid-forming fertilizer are applied (e.g., 6000 lb ammonium sulfate per acre per year on bermudagrass turf) it is possible to keep soil pH acidic with the fertilizer (Snyder, *et al.*, Agron. J. 71:603-8). The quantities of bases applied via the irrigation water and the acid-forming potential applied in the fertilizer must be known in order to determine the magnitude of the effects. Table 2 illustrates such calculations

WATER TREATMENT

10. How can I neutralize the bicarbonates in my irrigation water?

Injection of acid into the irrigation water is a direct way of neutralizing the bases present. Acid may be injected in much the same way as fertilizer. You must take precautions to avoid injuring yourself

and your plants and to avoid contamination of the aquifer. These points are discussed below.

11. How much acid should I apply?

The amount of acid that you mix with the irrigation water will depend on the quantity of bases your water contains and on the strength of the acid you use. The base content of the water is determined in the water test and the strength of the acid is given on the container. Table 3 shows the properties of three common acids. Be **sure** of the strength (concentration) of your acid!

One milliequivalent (me) of acid completely neutralizes one milliequivalent of base. For example, if an irrigation water contains 5.2 me of bases per liter, it would take 5.2 me of acid to completely neutralize the liter of water. Neutralization of 80 to 90 percent of the bases in water is a reasonable goal for most irrigation situations.

Use the steps described below to calculate the amount of acid needed to neutralize irrigation water. Alternatively, a computer program that does the calculations is in "Water Management Utilities" (IFAS Microcomputer Software No. 9), available for purchase from UF/IFAS Publications (ph. 800-226-1764).

1. Determine from Table 4 the appropriate factor for your acid. (See Equation 2 in Appendix for derivation of factors.)
2. Multiply the factor by the milliequivalents of base per liter (me/L) which your water contains. This value is determined in the laboratory test of your water or is estimated from its Ca and Mg contents (this calculation is described under Question 4 in this factsheet).
3. The result is the milliliters of your acid which you should apply to each 100 gallons of your water. The factor is calculated to neutralize 80% of the bases in the water. There are 29.6 ml in one U.S. fluid ounce. Divide the number of ml by 29.6 to convert to U.S. fluid ounces.

$$80\% \times \frac{\text{me base}}{\text{L water}} \times \frac{378 \text{ L}}{\text{to be neutralized}} \times \frac{1}{34.7 \text{ N acid}} = 8.7 \times \frac{\text{me base}}{\text{L water}}$$

Equation 2.

NOTE: When calculating your rates for larger volumes, be careful not to round off too soon when making conversions.

12. Why not neutralize 100 percent of the bases?

Some of the reasons for not attempting to neutralize 100% of the bases are:

1. It is not necessary to neutralize all of the bases in order to reduce the problem to insignificant levels. If 80 to 90% of the bases were neutralized, water that would have caused a problem in six months of irrigation might now take up to five years of irrigation at the same rate in order to cause the problem. In most nursery situations, the plants would be moved out long before the problem could occur.
2. Not trying for 100% neutralization allows some room for error in acid application rates, variability in water, etc.
3. The risk of over-acidifying is not worth the benefit of neutralizing the last 10 or 20 % of the bases. It is poor management to spend money and effort creating new problems by over-reacting to the initial problem.

13. In what kind of irrigation system can I practically inject acid?

Neutralization is relatively easy to accomplish in sprinkler, drip, and mist systems but is probably impractical in seepage irrigation systems. The system must allow careful addition of known volumes of acid to known volumes of water. Since acids can be quite corrosive to metals, the system must be able to withstand this possible adverse effect.

NOTE: It is illegal to inject any chemicals into irrigation systems without appropriate safety devices which will automatically prevent the backflow of water and chemicals to the water supply. This is done to protect our water resources. (see, "Backflow Prevention Requirements for Florida Irrigation Systems." Bul 217, by A.G. Smajstrla, *et al.*, 1991).

14. How do I know if my injector is precise enough for acid injection?

Any system precise enough to apply fertilizer through the irrigation lines may be used for neutralizing irrigation water with acid. As in most cases, the way you manage your equipment is more important than the equipment itself. You may use either siphon proportioners or positive-pressure injection systems, provided that you calibrate properly

15. What kind of acid can I use?

The most commonly used acids are sulfuric, hydrochloric, and phosphoric acid. Other acids could be used but cost and availability usually limit the choices to these three. Phosphoric and sulfuric acids may have some nutritional value but this should be a minor consideration in choosing an acid for water neutralization.

16. Where can I get these acids?

Each of these three acids is available in commerce and sources vary locally. Consult the yellow pages of your phone directory under "Chemicals" or "Chemicals-Whol & Mfgr." Here are examples of possible sources. Explore other sources too.

- Suppliers of agricultural or industrial chemicals.
- Fluid fertilizer dealers.
- Construction and swimming pool supply companies. (Hydrochloric acid, frequently called muriatic acid, is used for many purposes such as cleaning bricks following building construction and acidifying the water in swimming pools.)
- Auto supply companies. (Sulfuric acid is the acid used in auto batteries.)

17. What are the dangers of using acids for water neutralization?

Hydrochloric, sulfuric and phosphoric acids are highly toxic materials irritating to the skin, eyes, nose, throat, lungs, and digestive tract. Always wear goggles and chemical resistant (rubber, neoprene,

vinyl, etc.) gloves, apron and boots whenever handling these acids. Acid must be poured into water, never vice versa, and should be done in a well-ventilated area.

Should a spill or splash occur, remove all clothing and shower immediately. Immediately irrigate eyes with large quantities of water. Drink large quantities of water if the acid is ingested but do not induce vomiting. Seek immediate medical attention for all eye, nose, throat, lung, and digestive tract exposures and for skin irritation which persists after showering.

It is generally advisable to dilute concentrated acid in a nonmetal mixing tank prior to injection into the irrigation system, rather than injecting concentrated acid directly. Most metal fittings, tanks, and other parts of the irrigation system will be damaged by acid, even dilute acid, so proper precautions must be taken. Flushing the system after application is frequently sufficient to avoid significant damage.

In addition to the dangers involved with handling strong acids there is also the danger of over-application of acid. Excess acid addition could result in injury to plant parts which come in direct contact with the water, such as leaves in sprinkler irrigation systems. Also, an excessive acidification of the soil or potting media could result in plant injury or death. These problems can be avoided by:

1. determining the proper amount of acid to apply
2. monitoring the irrigation system to ensure that the correct amount is applied.

18. How can I assure that I'm adding the correct amount of acid to my water?

Monitoring the pH of the acid-treated water is one way of checking on a daily operational basis. You can do this with a pH meter or with pH papers (both methods require some experience to give reliable results). Add acid to bring the water pH to between 4.5 and 5.0. Because the neutralization reaction continues slowly over a period of a day or two, the measured pH of the water immediately after acid addition will usually be lower than that measured

once the reaction is complete. Table 5 shows the average pH measured soon after addition of acid and the pH two days later. For monitoring purposes during acid additions, use the pH measured immediately after acid addition as a guide to avoid over-acidifying.

If the pH after treatment is very different from that calculated from the chemical analysis, you may want to have another water sample analyzed and consult with your county Extension agent before continuing.

19. Let's see that all summarized.

1. Have your irrigation water tested.
2. Select an acid of known strength.
3. Determine how much of your acid is needed to neutralize 80% of the bases in your water.
4. Add the calculated amount of acid to your water.
5. Measure the pH of the water as it comes out of the irrigation line.
6. If the pH is not between 4.5 and 5.0, increase or decrease the amount of acid.
7. If the amount of adjustment in Step 6 is more than 15 to 20% of the calculated value, consult a specialist before extended use of the system.
8. Retest the well water and irrigated soil about once a year and keep a record of the test results.

APPENDIX

I. Derivation of factors discussed in Question 4 as shown in Equation 1 .

II. Derivation of factors discussed in Question 11 as shown in Equation 2 . See Table 3 for normalities. Example is for $34.7 \text{ N H}_2\text{SO}_4$.

Table 1. This table shows the striking influence of drip irrigating with high-bicarbonate water (2.1 me/L of bases) on soil pH. The soil texture was sand, so only a small circle (or cylinder, in three dimensions) of soil near the dripper was wetted. The pH of the irrigated soil increased to 7.6 within a year, while the pH of unirrigated soil a few inches away remained at the native soil pH of 5.0. (Data courtesy of L.A. Halsey, Jefferson County Extension Director).

Distance from drip irrigation emitter (inches)	0 to 1	8 to 10	24 to 48	60
pH of top 6 inches of soil	7.6	5.5	5.0	5.0

Table 2. Use this table to determine the approximate amounts of sulfuric acid, elemental sulfur, ammonium sulfate, or ammonium nitrate to neutralize 100% of the calcium carbonate from 20 inches of irrigation water of the indicated concentration of bases (me base/L). Note that the values shown are for each 20 inches of irrigation water. Be sure to increase or decrease to reflect your irrigation rate per acre.

Water quality (me base/L)	Approximate pounds of pure CaCO ₃ added per acre by 20 inches of water	Approximate amount of acid-producing materials per acre to neutralize 100% of the bases from the water			
		93% Sulfuric acid (gallons)	Elemental sulfur (pounds)	Ammonium sulfate (pounds)	Ammonium nitrate (pounds)
1.0	225	15	75	200	375
2.0	450	30	150	400	750
3.0	675	46	225	600	1125
4.0	900	62	300	800	1500
5.0	1125	77	375	1000	1875
6.0	1350	92	450	1200	2250
7.0	1575	108	525	1400	2625
8.0	1800	123	600	1600	3000
9.0	2025	138	675	1800	3375
10.0	2250	154	750	2000	3750

Table 3. Some properties of acids, including a cost comparison.

Acid name and chemical formula	Concentration commonly found in commerce	Approximate normality	Common container sizes (gallons)	Approximate cost* of acid	Approximate cost* of treating 1000 gallons of water containing 4 me base/L
Sulfuric H_2SO_4	93% H_2SO_4 (also sometimes expressed as 66° Baume)	34.7 <u>N</u>	1555	\$75/ drum(\$8.50/ CWT)	\$0.13
	1.265 sp. gr. (battery acid)	9.19 <u>N</u>	115	\$3/gal	\$1.04
Hydrochloric HCl (also called muriatic acid)	20; Baume (has a specific gravity of 1.16 and is 32% HCl)	10.2 <u>N</u>	114	\$2.80/gal\$27/ drum	\$0.88\$0.61
			1555	\$50/ drum(\$9.00/ CWT)	\$0.29
Phosphoric H_3PO_4	85% H_3PO_4	44.1 <u>N</u>	1555	\$320/ drum(\$40.50/ CWT)	\$0.42

*These costs will vary and are presented here for illustrative purposes only. However, they do reflect relative costs of the three acids and differences in sources.

Table 4. Appropriate factor for acid.

Acid name and formula	Acid strength	Factor
Sulfuric H_2SO_4	93%66° Baume 1.265 specific gravity	8.78.7 32.9
Hydrochloric HCl	32%20° Baume 1.16 specific gravity	29.629.6 29.6
Phosphoric H_3PO_4	85%	6.8

Table 5. This table shows the pH changes of seven typical water samples after sulfuric or hydrochloric acid additions. Note that Situation I illustrates the recommended partial neutralization. Situation II illustrates the resulting low pH with 100% neutralization.

Water Sample No.	Initial pH of water	Situation I - pH of water after 80% neutralization		Situation II - pH of water after 100% neutralization	
		Soon after acid addition	Two days later	Soon after acid addition	Two days later
A	8.1	4.1	4.1	3.3	3.3
B	8.3	4.6	5.9	3.3	3.3
C	8.0	4.3	5.4	3.2	3.2
D	8.1	4.6	5.6	3.5	3.6
E	7.6	5.2	6.1	3.6	3.6
F	8.2	4.4	4.5	3.2	3.2
G	9.0	4.4	4.8	3.4	3.4