ACID INJECTION SYSTEMS
FOR
CORRECTING SOIL PROBLEMS

FOREWORD:

Recently there has been a big push to get injection systems in place on golf courses to correct soil problems and imbalances. Most of this push has come from the suppliers of these systems, and, to some degree more than a few courses may have been exploited with these injection systems.

It is unfortunate when people begin to get exploited just when there is a surge of interest in soils, soil problems, and soil limitations.

Largely these injection systems are built around the concept of injecting an acid or acids designed to correct the soil pH and all sorts of other wondrous things into the ittigation water. It all sounds so simple and so good.

These systems are not cheap, and the material costs to operate the systems is far from inexpensive. I hear cost figures that run from $1,200 to $1,500 per month to operate these systems. To be sure, such costs certainly dictate that we explore the real facts before this kind of expenditure is made.

DEFINITIONS AND SOIL FACTS

Before I write a check for an injection system and before I begin to order expensive supplies to operate this system, I really feel the need to review some basic facts about soil and chemistry.

Everything seems to revolve around the pH of the soil so we need to define pH.

DEFINITION OF pH: "pH is a function of the negative logarithm of the hydrogen (H^+) ion concentration in any solution."

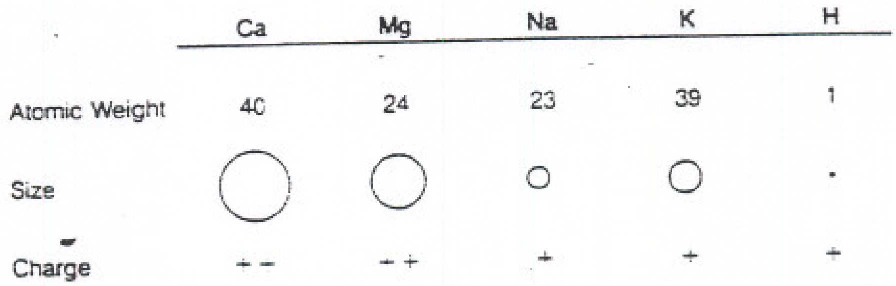
- The above technical definition applies to any and all solutions.
- The definition means that the more H^+ you get into a solution, the more acid it will become and the more acid it becomes, the lower the pH.
- This also means that calcium is only indirectly involved with pH. We tend to think of it as being directly involved in pH because we lime to raise pH (more later).

SOIL ACIDITY:

Hydrogen ions in the soil may be found either dissolved in the soil solution or adsorbed to the soils cation exchange system. Those hydrogen ions found in the soil solution are called active acidity. The active acidity is usually only a very small part of the total soil acidity. Hydrogen ions found on the surface of clay or organic matter particles are called reserve acidity. THESE HYDROGEN IONS ARE EASILY REPLACED BY OTHER CATIONS. In most soils they make a very large contribution to the total soil acidity.

The chart below gives a very good idea of how all the EXCHANGEABLE CATIONS stack up as far as atomic weight, valence (change), and size. In the chemical world, as in the rest of the world, BIG MOVES LITTLE EVERY TIME.

COMPARISON OF CATIONS



In case you missed it, there is only a small speck on the paper underneath hydrogen on the chart. The small dot represents the relative size of hydrogen (H^+). It should be obvious that hydrogen is not going to move anything off the soil colloid.

THE SUMMARY OF FACTS WOULD DEFINITELY INDICATE THE FOLLOWING:

1) Any unadsorbed hydrogen, or free acidity, found in the soil solution must either adsorb onto the soil colloid or be flushed (ionized) out through the soil solution.
2) When colloid saturation is reached (i.e., actual % of total CEC = 100) and little, if any hydrogen is adsorbed onto the soil colloid, there is not much place for the hydrogen infused into the soil to operate (i.e., create a change).

NOTE: Attached please find copy of a soil report that needs a lower pH. This report is from Calmar Dairy at Chandler, AZ. Let's use this report for illustrative purposes at this time.

The Calmar Dairy Soil Report yields the following information.

- pH = 7.8
- CEC = 31.6
- % Base Saturation

Ca	69.2%	No adsorbed hydrogen therefore no reserve acidity.
Mg	13.5%	
K	13.6%	
Na	3.7%	
Total	100.0%	

There are ample to excessive elements in the soil:

Ca	=	4368 PPM	=	8736 lb/acre
Mg	=	510 PPM	=	1020 lb/acre
K	=	1680 PPM	=	3360 lb/acre
Na	=	270 PPM	=	540 lb/acre

SOME OBVIOUS FACTS:

1) This soil needs more H^+ adsorbed onto the colloid
   a) It needs to be more acid, or lower pH.
   b) Only an increase in H^+ adsorbed onto the colloid can lower pH. (Go back and review pH definition).

2) Obviously this soil is dysfunctional (tied up). How else could the potassium have built to these levels?
   a) Potassium, which is essential and is generally fairly soluble, would be used by the plant if it were not tied up.
   b) If potassium were not tied up in a dysfunctional soil it would be leached out with the irrigation water.

3) We have more evidence of soil tie up (i.e., the soil colloids are not yielding the nutrients adsorbed). This evidence comes from the fact that an otherwise functional calcium base saturation (Mg also), would otherwise almost totally dominate the exchange capacity of the soil when you consider the abundance in the soil itself (8,736 lbs/acre). In other words the Percent Base Saturation Calcium would normally be expected to be higher with these levels in the soil.

NOTE: We are at a point where we must face definite conclusions:

A) The tremendous amounts of calcium in the soil (8736 lb/acre) must be presumed to be insoluble.

   - If the calcium were soluble, it would completely dominate the soil colloid with an extremely high % Base Saturation.

   - If the calcium were this high and soluble in a golf course environment (i.e, with sand content in greens and a subsurface drainage system), calcium, if soluble, would be quickly leached out of the soil solution.

B) Even massive amounts of hydrogen flushed down into the soil is not going to change the soil pH except for a very brief period, and this would be superficial because the only change that can be made is a temporary change in free acidity.

PLEASE REFER BACK TO THE FIRST PARAGRAPH UNDER THE HEADING OF SOIL ACIDITY:

WHY WILL THE ACID INPUT INTO THE SOIL ONLY AFFECT FREE ACIDITY AND THEN ONLY TEMPORARILY?

To answer this question, let's review our situation.

% Base Saturation	
Ca	69.2%
Mg	13.5%
K	13.6%
Na	3.7%
Total	100.0%

COMPARISON OF CATIONS

	Ca	Mg	Na	K	H
Atomic Weight	40	24	23	39	1
Size					
Charge	- -	- -	-	-	-

•WHAT EXACTLY CAN AN ACID DO IN THE ABOVE SITUATION?

a) It will furnish hydrogen that by definition is the essence of acidity.
b) The hydrogen fraction will disassociate from the acid when it mixes with the soil solution.

NOTE: This happens because of the cation size and weight (see comparison chart above) of the H^+ makes it more succeptible to disassociation (extraction) than any other element.

To fully understand the extent of what an injected acid can do, it may be more important to first understand what the acid cannot do.

The acid obviously cannot "bump" anything off the soil colloid because everything already attached to the colloid is heavier by far than is the hydrogen.

There should be one other verse to this song, and that is that hydrogen, which is the real factor in acidity (lowering pH) can only attach to the colloid when "unopposed" since it is the lightest of all elements.

IMPORTANT NOTE: The above situation would not change even if there were already some H^+ on the soil colloid (1 can't push 1). The H^+ can only position itself on the soil colloid when a position is given up by the removal of one of the basic cations (Ca, Mg, Na, K) and the H^+ is attracted (unopposed by any other basic cation).

•What about those who say that there is a desirable plant response when the acid is injected into the soil?

The answer to this is really quite simple and, in many cases, it is quite true. The answer lies in the solubility of essential micronutrients.

1) At a high pH micronutrients such as iron, manganese, zinc, copper, etc. are insoluble and therefore unavailable to the plants.
2) Even though the injected acid cannot do anything for the high pH on an extended basis and do nothing about those cations adsorbed onto the soil colloid, it can furnish H^+ to the soil solution which will temporarily solubilize the micronutrients making them available to the plants/turf for a brief period of time. The plants/turf, being micronutrient deficient, will respond to this temporary availability.

NOTE: This is a decidedly cumbersome and expensive method of getting micronutrients to the plants. Foliar application would be far easier, far more cost effective, and far more predictable than trying to extract from the soil.

•<u>ARE THERE EVER TIMES WHEN THE pH CAN BE LOWERED WITH ACID?</u>

Yes, there are, and if I were selling these systems I would exploit this to the fullest extent because this method will make the system look good, and it is about the only leg they have to stand on.

HOW?

If apply the acid and immediately take a soil sample, this sample may show a dramatic drop in pH.

This drop comes from the fact that the acid puts H^+ or "free acidity" into the soil solution and the test may be made on a solution basis.

WHAT THIS DOES NOT ACCOUNT FOR IS THE FACT THAT IT DOES NOT GIVE A TRUE PICTURE FOR TWO REASONS:

1) There has been no impact on the soil "reserve acidity," which is the only measure that really counts, because,
2) If the H^+ is not adsorbed on the soil colloid, it is going to be flushed or ionized out through the soil at the first watering.

IF WE'RE ARE TALKING ABOUT A GOLF COURSE SITUATION, THE FREQUENT WATERING REQUIRED TELLS THE TALE.

•WHAT ABOUT INJECTING ACID IN THE CASE OF SALINE/SODIC SOILS?

Excessive salts (sodium - Na) will cause an elevated pH because the Na occupies the position on the soil colloid that would ordinarily contain adsorbed H^+. This Na must be removed and flushed before the soil pH can come down. <u>NOTE: YOUR CALPHLEX MANUAL COVERS THIS IN DETAIL.</u>

Many farmers have attempted to address this Na problem by "cutting in" Gypsum or $CaSO_4$,. and it is quite true that injected sulfuric acid H_2SO_4 can convert totally insoluble calcium carbonate ($CaCO_3$) to $CaSO_4$,, which is only slightly more soluble.

Now that we have conversion from the insoluble $CaCO_3$ (Lime) to the Gypsum we are essentially no better off because the $CaSO_4$ is not soluble to any great degree. Remember the truism from New Mexico University that states:

"Any correction of soil sodium problems must eventually involve *soluble* calcium."

The only way you will get substantial amounts of soluble calcium is with CalpHlex, which is what you should have used in the first place.

IMPORTANT NOTE: THE INSTALLATION AND USE OF AN ACID INJECTION SYSTEM DOES NOT PRECLUDE THE USE OF CALPHLEX, IT DEMANDS IT. If you understand two points you can see why this is true.

1) If you understand what the acid itself does (i.e., creates gypsum or calcium sulfate from calcium carbonate).

$$H_2SO_4 + CaCO_3 + H_2O \rightarrow CaSO_4 \bullet H_2O - CO_2\uparrow,$$

2) If you understand the solubility of Gypsum ($CaSO_4$), which is extremely low,

THEN: It should be very apparent to you why CalpHlex needs to be used, even though we have an acid injection system in place.

OTHER THINGS SHOULD BE APPARENT AS WELL:

1) Soil correction demands that water play an essential role in the correction process, (i.e., regardless of whether we are solubilizing or converting elements from one form to another, the end product must be moved down though the soil and out through whatever drainage there is.

CAN YOU SEE THE NEED FOR PERVADE OR CALPHLEX EITHER WITH THE USE OF ACID OR WITHOUT?

CAN YOU SEE HOW YOU CAN DO THE SAME THING WITH PERVADE AND CALPHLEX ALONE?

YES!

- MORE QUICKLY
- FOR LESS MONEY

2) It should also be apparent to you that the growing plants in the area to be corrected must also play an active role in the soil correction scenario (i.e., the plants can do sterling service by being able to use up excessive elements). To accomplish this there is the potential need for many of the FPG Products.

ASTRON AND PER "4" MAX: Help build root systems. The more roots in number and length, the more elements that will be mined from the soil as they are solubilized. These products also help to maintain the turf/crop until the soil begins to function as a feeding medium. DO THESE PRODUCTS AND CALPHLEX GO HAND IN HAND? YOU BET THEY DO!

MAXIPLEX: Creates better soil tilth. Can you see how better soil tilth will enable CalpHlex and the Biostimulants to work better? I would hope that you could.

RENAISSANCE AND KNIFE: The micronutrients are almost always tied up as a result of a dysfunctional soil, and yet the turf or crop must have these elements to remain strong and healthy. CAN YOU SEE HOW THESE PRODUCTS FIT INTO THE PICTURE? SURELY YOU CAN.

THE BOTTOM LINE

1) If you use an acid injection system you still have a need for the FPG program.
2) Sole dependence on an acid injection program will ultimately lead to soil collapse.

II
Exploring Other Methods Practices

BACKGROUND: Native soils in high rainfall areas are naturally more acidic than arid regions of the Western US. This happens because high rainfall "leaches" (washes) the small fragments of dissolved calcium down through the soil and out of the growing zone. This and other factors tend to make the high rainfall soils more acidic.

NATURAL SOIL ACIDIFICATION IS A RESULT OF ONE OR MORE OF SIX (6) FACTORS:

1) <u>CARBON DIOXIDE AND RAINFALL:</u> CO_2 from decomposing organic matter and root respiration dissolves in water to form a weak carbonic acid.

$$CO_2 + HOH \rightarrow H_2CO_3 \rightarrow HCO_3^- + H^+$$

This weak acid can free up some calcium in the presence of sulfur and, even though this is relatively insoluble $CaSO_4$, it will eventually leach.

OBVIOUSLY: In the desert Southwest there is no decomposition taking place, there is little if any root respiration (no plants), and no rainfall to speak of.

2) <u>CROP REMOVAL:</u> For example, a corn crop removed as corn silage removes considerable amounts of elements, with Ca being one of the dominant ones.

3) <u>AMMONIUM FERTILIZERS:</u> These are oxidized by bacteria (nitro bacters) to form nitrate. Ammonium fertilizer chemically is NH_4^+ and for each cation oxidized $2\ H^+$ results.

$$NH_4^+ + 2\ O_2 \xrightarrow[\text{Bacters}]{\text{Nitro}} NO_3^- + H_2O + 2H^+$$

4) <u>PLANT ROOTS:</u> Plant roots exude hydrogen ions to exchange for other nutritive cations.

5) <u>ACID RAIN:</u> Acid rain is only created when airborne sulfur dioxide (SO_2) and Nitrogen/Nitric Oxide (NO) are combined and form sulfuric acid (H_2SO_4) and Nitric Acid (HNO_3) mostly through oxidation and dissolved rain drops.

6) <u>SULFUR:</u> Often added to the soil in commercial fertilizers and fungicides. Sulfur oxidizes to sulfate and hydrogen ions.

$$2S + 3O_2 + 2\ HOH \rightarrow = 2\ SO_4^{--} + 4H^+$$

NOTE: The sulfate ion itself is not acidic.

NOTE: Many "remedies" have been devised based on the above factors, and, while they may seem very practical on the surface, they fail miserably when put to one single test that is of utmost importance.

THE TEST: Can the method or material being employed be certain to maintain a functional balance within the soil solution itself. The answer to all the methods/products is a resounding NO.

OTHER METHODS/MATERIALS FOR ACIDIFYING SOILS:

Various and sundry materials have been used and continue to be used to acidify soil up to and including iron and aluminum. If you are dealing with golf greens on a thinking level, I probably just got your attention.

Basically the methods and materials employed are beset by two major problems.

1) The reactions created by these products are incomplete and other products such as CalpHlex which likely could have done or at least begun the job in the first place with one heck of a lot of side effects.
2) The massive quantities of these products that will be required to do any correcting is totally impractical, too expensive and will all create some rather unpleasant conditions that would have a potentially low-turf survival.

Of all the materials used from time to time <u>SULFUR</u> is probably the best. It is probably best because you would use less of it.

Listed below are products that could and have been used. I have done some calculations that give you an idea of how much material must be used to get the desired response.

NOTE: Since sulfur requires the smallest amount of material it has been assigned the number 1.0 in the equivalency chart.

AMENDMENT	EQUIVALENT TO 13 LB SULFUR
Sulfur	1.0 lb
Lime Sulfur Solutions	4.2 lbs
Sulfuric Acid (98%)	3.1 lbs
Iron Sulfate	8.7 lbs
Aluminum Sulfate	6.9 lbs

Now we need to consider the amount of sulfur per acre that would be required to drop the pH (i.e., acidify) one acre of soil.

pH Change Desired	lbs of Sulfur per acre Required to Achieve Change		
	On Sandy Soil	On Loam	On Clay
$8.6 \rightarrow 6.5$	1960 #	2494#	2939#
Increases PPM by	980 ppm	1247ppm	1470 ppm
$7.5 \rightarrow 6.5$	490 #	802 #	1100 #
Increases PPM by	245 ppm	401 ppm	550 ppm

Now let's see what's going to happen

$$2S + 3\,O_2 + 2\,H_2O \rightarrow 2\,H_2SO_4$$

Which is otherwise known as sulfuric acid.

Now, we would reasonably expect the sulfuric acid to go to work in the following manner.

$$\underbrace{H_2SO_4}_{\text{Sulfuric Acid}} + \underbrace{CaCO_3}_{\text{Lime}} \rightarrow \underbrace{CaSO_4}_{\text{Gypsum}} + H_2O = CO_2 \uparrow$$

NOTE: We have taken sulfur from which sulfuric acid is eventually evolved. This acid will eventually react with lime to form Gypsum

* This process is slow.
* This process keeps soil imbalanced with sulfur for a long period of time.
* The end result is not beneficial in and of itself because Gypsum is just not very soluble.

QUESTION: Is CalpHlex required where sulfur is used?
ANSWER: It certainly would be of great benefit.

QUESTION: Would CalpHlex have solved the problem in the first place?
ANSWER: You bet it would.

QUESTION: Which approach (Sulfur or CalpHlex) will create the greatest soil imbalance?
ANSWER: CalpHlex creates no problem whereas sulfur at these rates can create many.

Having looked at the massive numbers required of sulfur we can turn our attention to the other "alternatives"; the list and their numerical relationship to sulfur are reproduced in the following chart.

AMENDMENT	Equivalent to 1.0 lb. Sulfur
Sulfur	1.0 lb
Lime-Sulfur Solutions	4.2 lbs
Sulfuric Acid (98%)	3.1 lbs
Iron Sulfate	8.7 lbs
Aluminum Sulfate	6.9 lbs

LIME SULFUR SOLUTIONS: Do not bear discussion since the ultimate outcome is gypsum from the sulfur fraction itself. In summary we are probably looking at brief elevations of H^+ as free acidity which will be flushed or ionized almost immediately. 0 + 0 = 0.

SULFURIC ACID: Where the adjustment required 1960 pounds of sulfur, the same situation will require 6076 pounds of sulfuric to do the same thing.

IRON SULFATE: Where 1960 lbs of sulfur was required, 17,052 lb of $FeSO_4$ will be required.

$$Fe_2(SO_4)_3 + 6\,H_2O \rightarrow 2\,Fe(OH)_3 + 3\,H_2SO_4$$

- *First of all the amount of 17,052 # is ludicrous.
- *Second, you will never bring this soil back into balance relative to essential micronutrients should this amount of $FeSO_4$ be used.
- *Third, you've still got to deal with Gypsum that will evolve from the 3 H_2SO_4.

ALUMINUM SULFATE: If you used 1960# of sulfur, you would need 13,524 lb of aluminum sulfate.

$$Al_2(SO_4)_3 + 6\,H_2O \rightarrow 2\,Al(OH)_3 + 3\,H_2SO_4$$

SUMMARY

Do yourself and your customer a favor, learn about CalpHlex. SHOW HIM HOW TO SOLVE HIS PROBLEMS.