INDEX FRESH

SEMINAR

SERIES

Acidification & pH Control with SO_2-Sulfurous Acid Generators

By Terry R. Gong

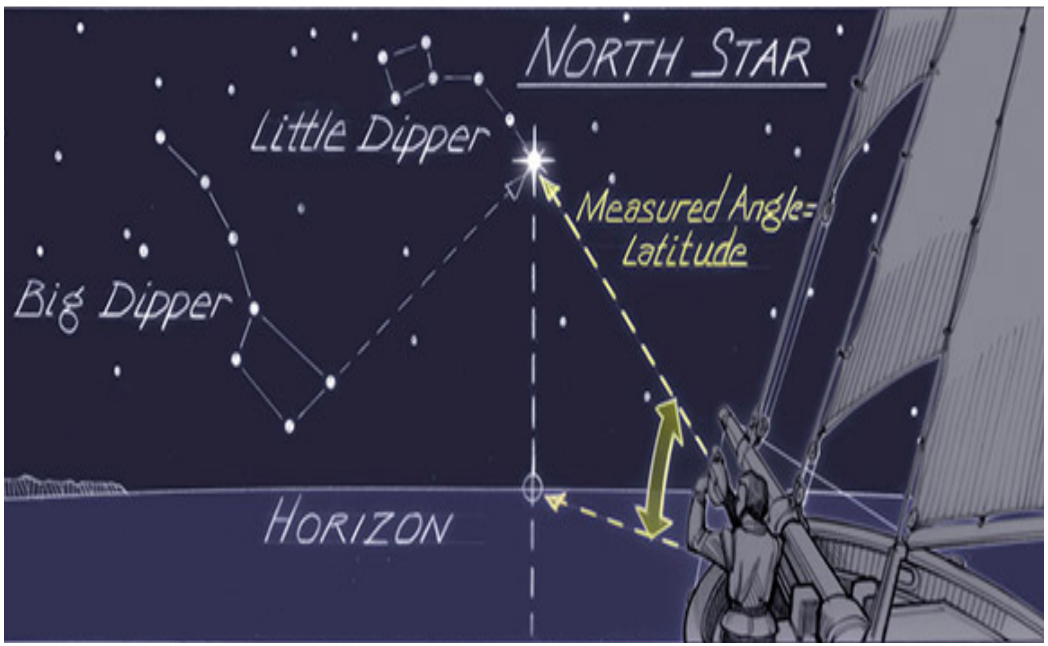
Harmon Systems International, LLC

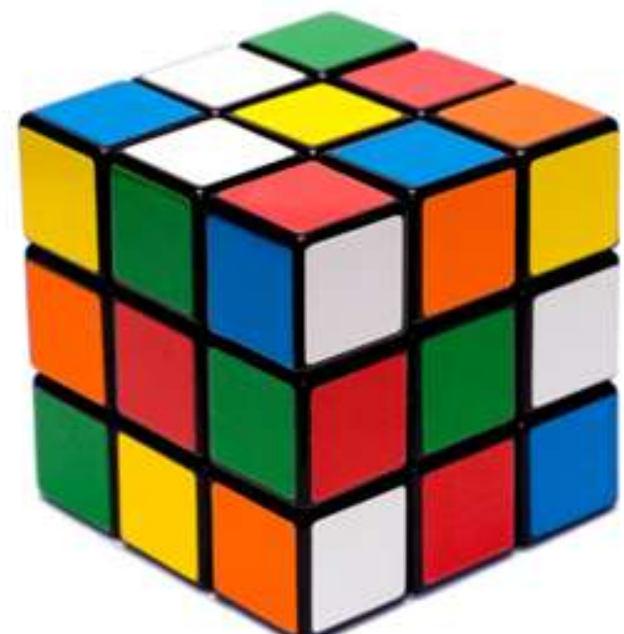
We provide solutions that benefit the world

Presentation Agenda

1. Illustrate how *nature* controls pH.
2. The Importance of pH in Agriculture.
3. Explain what causes our irrigated farmland to become salt affected.
4. Explain why Harmon SO_2-Sulfurous Acid Generator is the most cost effective way to amend/control pH.
5. Questions.

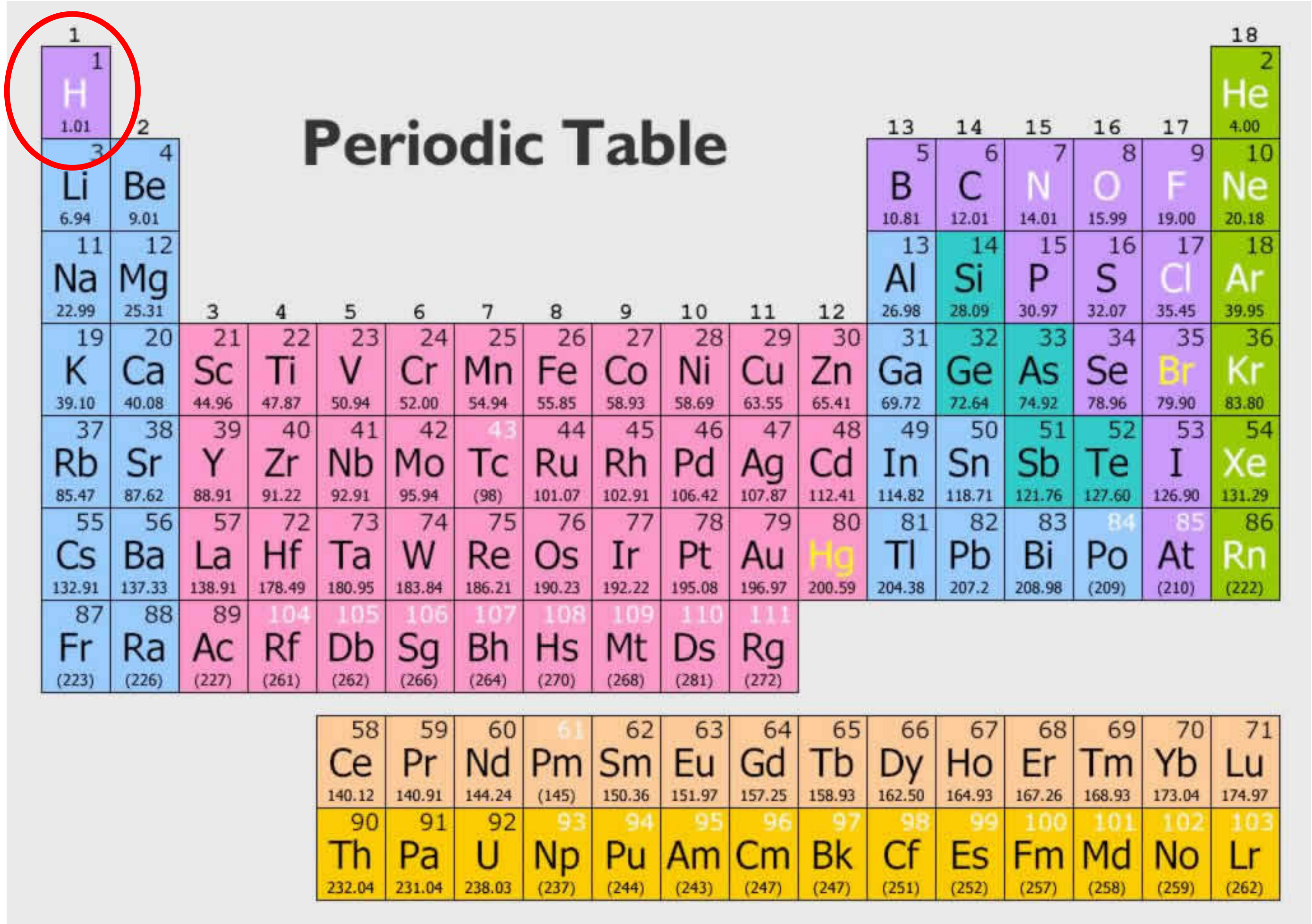
When trying to improve agronomic conditions, what should we use as a reference or starting point?





Hydrogen

From the Greek words **hydro** and **genes**, which together mean "water forming" and estimated to be: 93% of all the atoms in the universe.



1. ***Sulfur*** is a base element that when burned, oxidizes into ***sulfur dioxide***.

2. When ***sulfur dioxide*** contacts water, it forms ***sulfurous acid*** and causes the molecular bonds of water to immediately break apart into free ***hydrogen*** and ***bisulfite***.

$$S + O \longrightarrow SO_2 \quad + \quad H_2O \rightarrow H_2SO_3$$

$$H_2SO_3 \rightarrow H^+ + HSO_3^-$$

3. Free ***hydrogen*** is acid and it reacts with ***bicarbonates*** in water which transforms and recycles it into ***water*** and ***carbon dioxide***

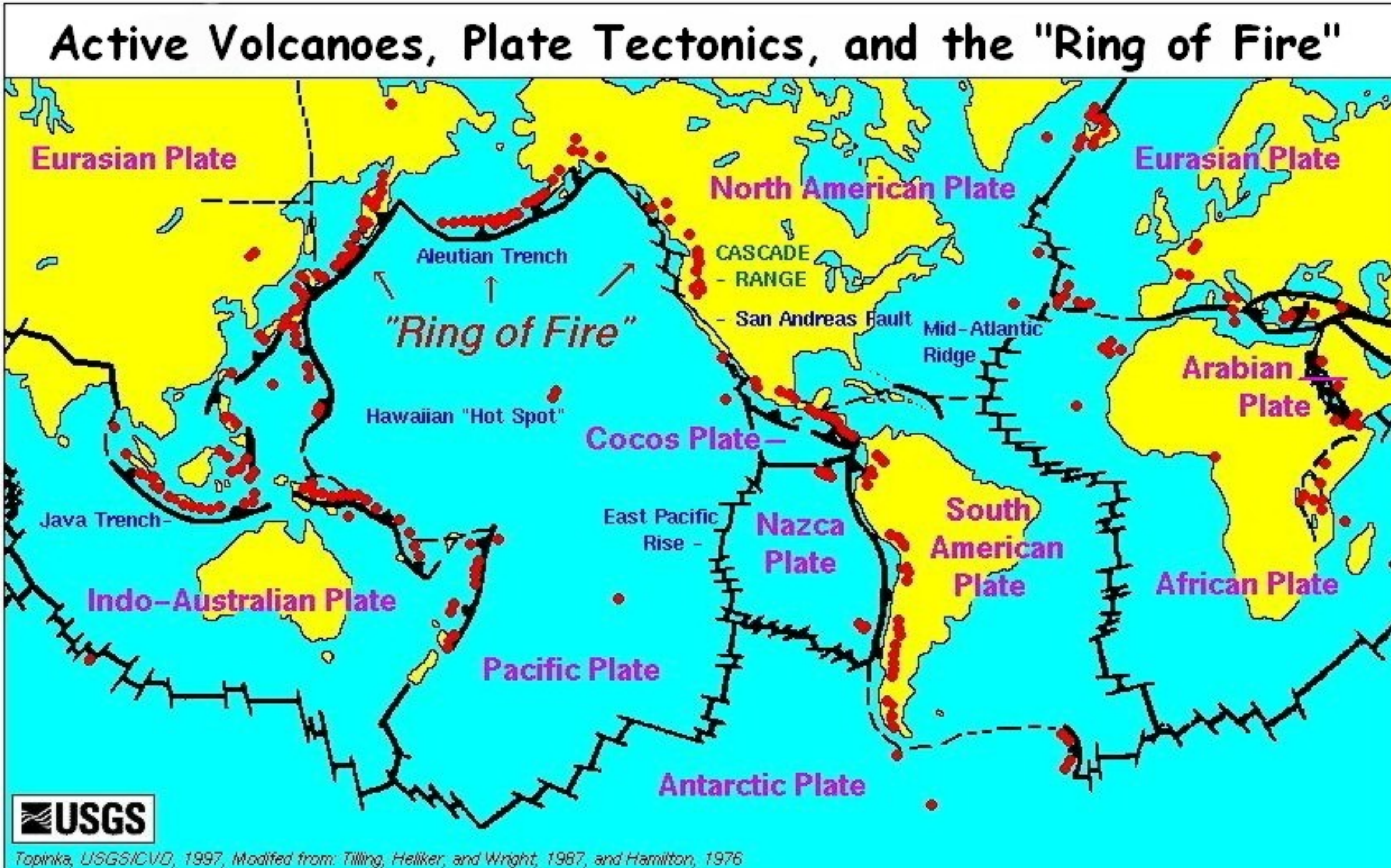
$$H^+ + HCO_3^- \rightarrow H_2O + CO_2\uparrow$$

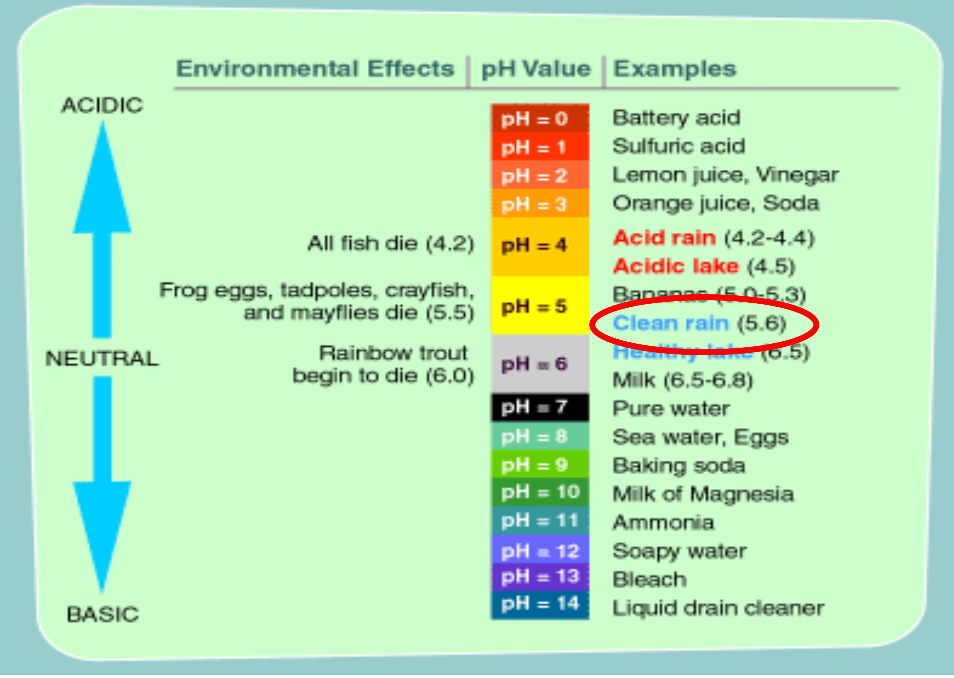
4. The other ***hydrogen*** then releases after the ***bisulfite*** reacts with dissolved ***oxygen*** or is oxidized by sulfur feeding bacteria which transforms it into free ***hydrogen*** and ***sulfate*** to neutralize additional ***bicarbonates*** in water to form more ***water*** and ***carbon dioxide***

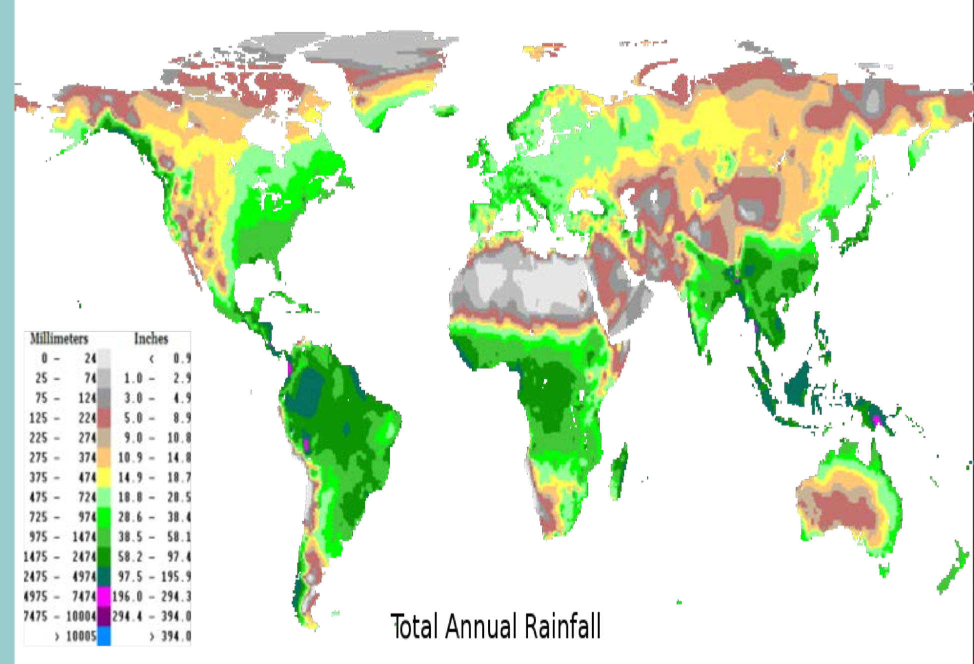
$$HSO_3^- + .5\,O_2 \rightarrow H^+ + SO_4^{=}$$

$$H^+ + HCO_3^- \rightarrow H_2O + CO_2\uparrow$$

Volcanism: Nature's source of SO_2







U.S. EPA pH Chart

PRINCIPAL CONSTITUENTS OF SEAWATER

Chemical Constituent	Content (parts per thousand)
Calcium (Ca)	0.419
Magnesium (Mg)	1.304
Sodium (Na)	10.710
Potassium (K)	0.390
Bicarbonate (HCO_3)	0.146
Sulfate (SO_4)	2.690
Chloride (Cl)	19.350
Bromide (Br)	0.070
Total dissolved solids (salinity)	35.079

COMPARISON BETWEEN OCEAN WATER AND RIVER WATER

Chemical Constituent	Percentage of Total Salt Content: Ocean Water	River Water
Silica (SiO_2)	—	14.51
Iron (Fe)	—	0.74
Calcium (Ca)	1.19	16.62
Magnesium (Mg)	3.72	4.54
Sodium (Na)	30.53	6.98
Potassium (K)	1.11	2.55
Bicarbonate (HCO_3)	0.42	31.90
Sulfate (SO_4)	7.67	12.41
Chloride (Cl)	55.16	8.64
Nitrate (NO_3)	—	1.11
Bromide (Br)	0.20	—
TOTAL	100.00	100.00

Herbert Swenson US Geological Survey Publication

Everything in nature has a purpose…and the role of volcanism is shifting us to adopting a new paradigm.

RESET

It is how earth recycles: hydrogen; sulfur; carbon; oxygen; creates and processes water; deconstructs chemical compounds; resets elements; self-adjusts its pH; feeds bacteria, plants, and animals; and how life on this planet is sustained.

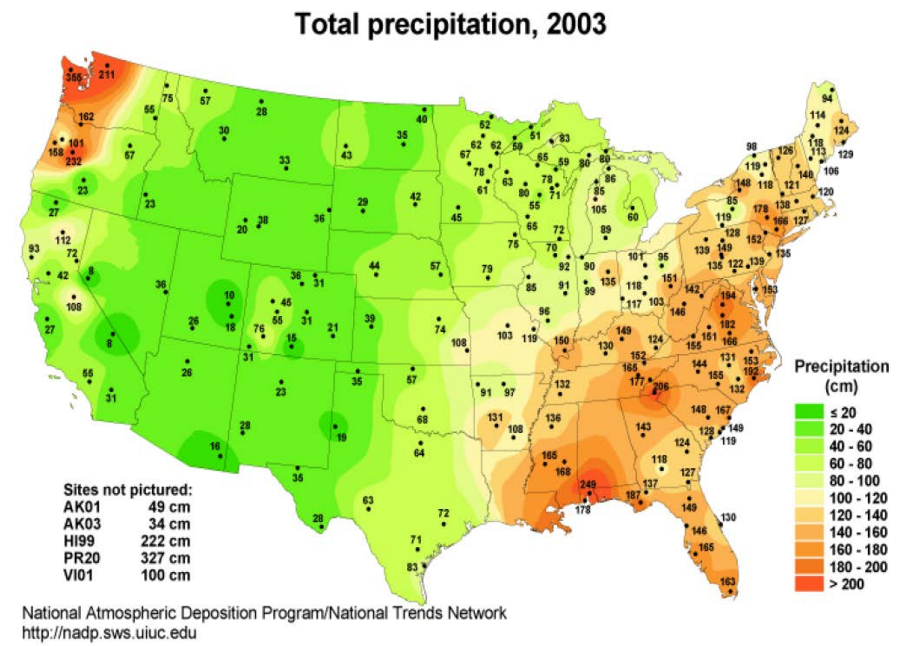
Precipitated salt carbonates near Bonneville, Utah

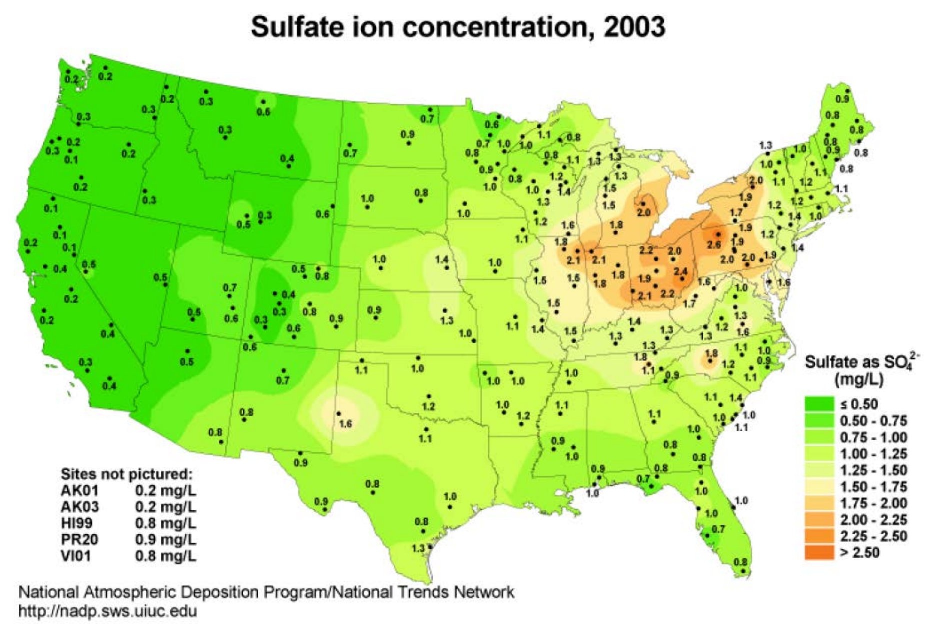
The planet Mars and its surface

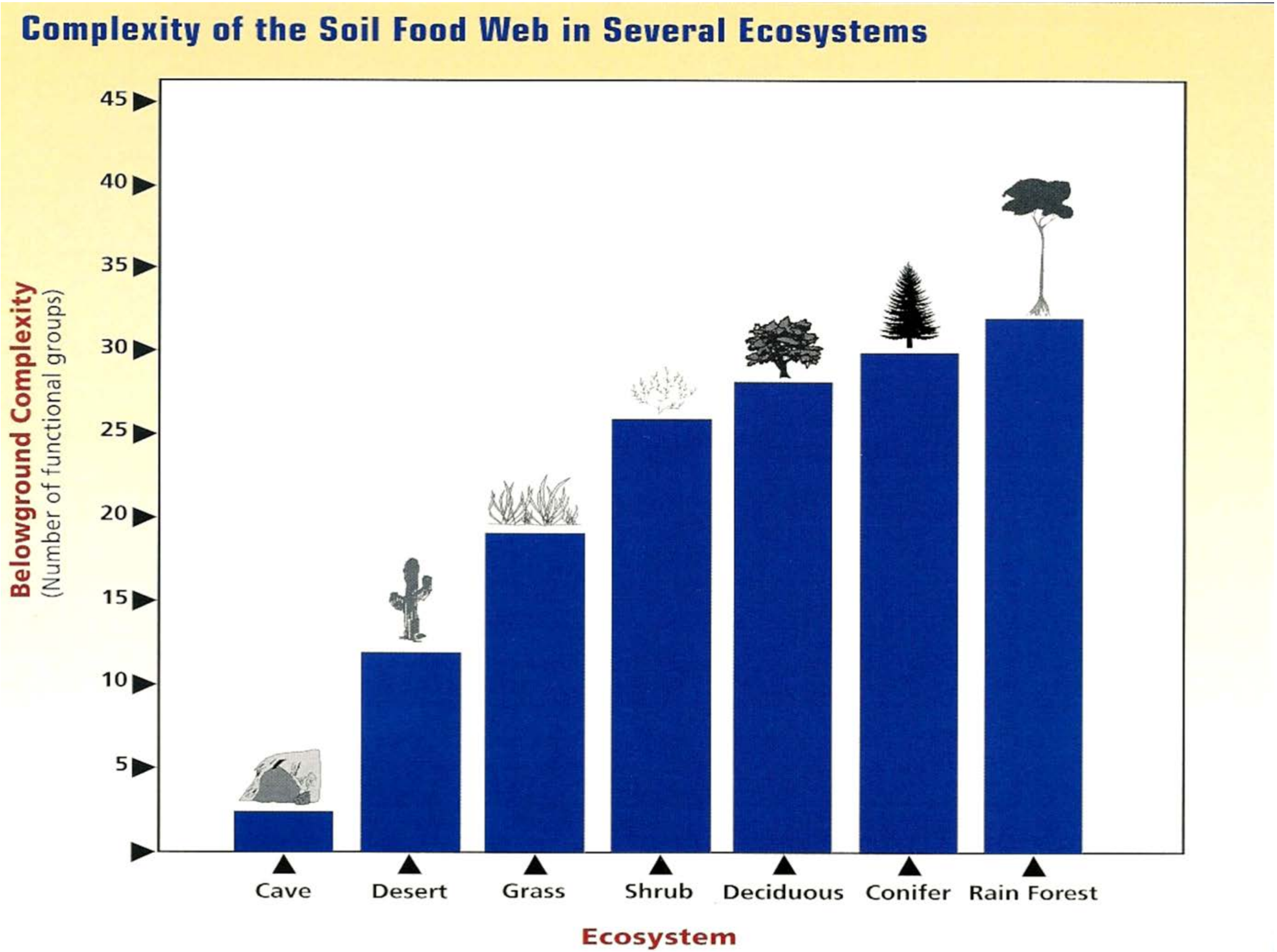
Normal Rain (pH 5.6)

vs.

Acid Rain (pH <5.6)

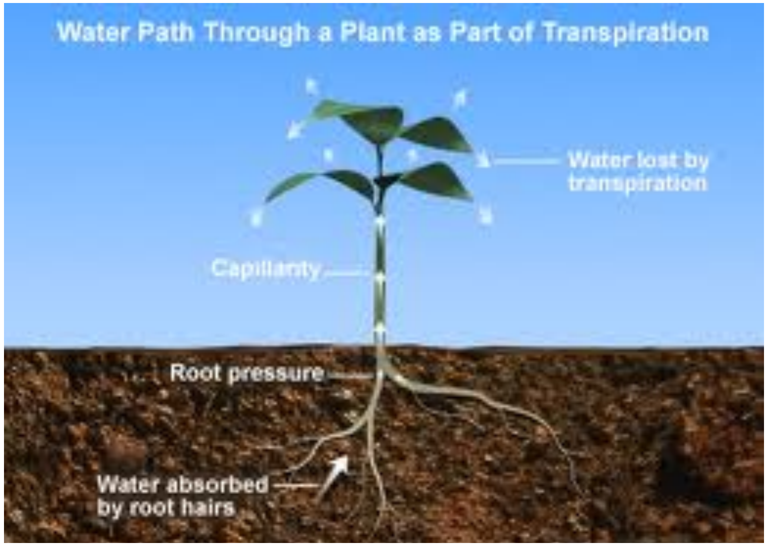


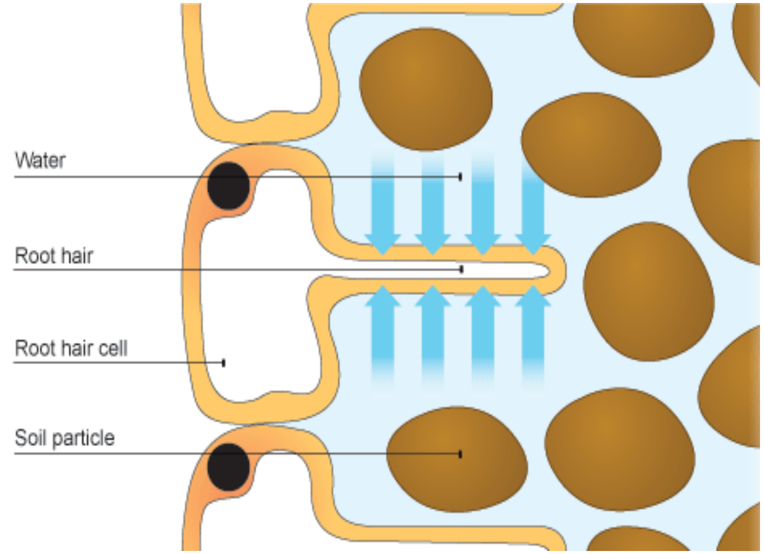


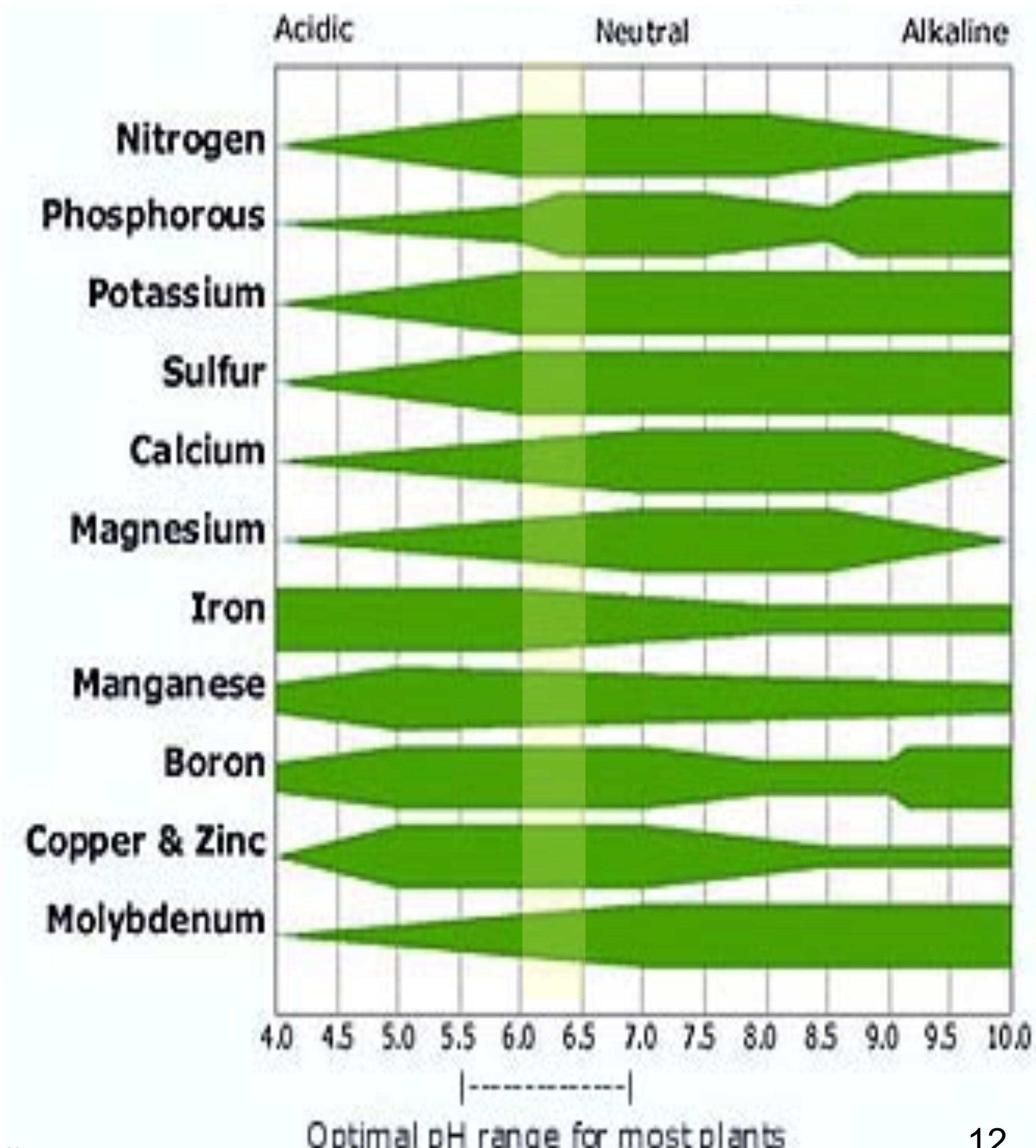


Complexity of the Soil Food Web in Several Ecosystems
Belowground Complexity
(Number of functional groups)
45
40
35
30
25
20
15
10
5
Cave
Desert
Grass
Shrub
Deciduous
Conifer
Rain Forest
Ecosystem

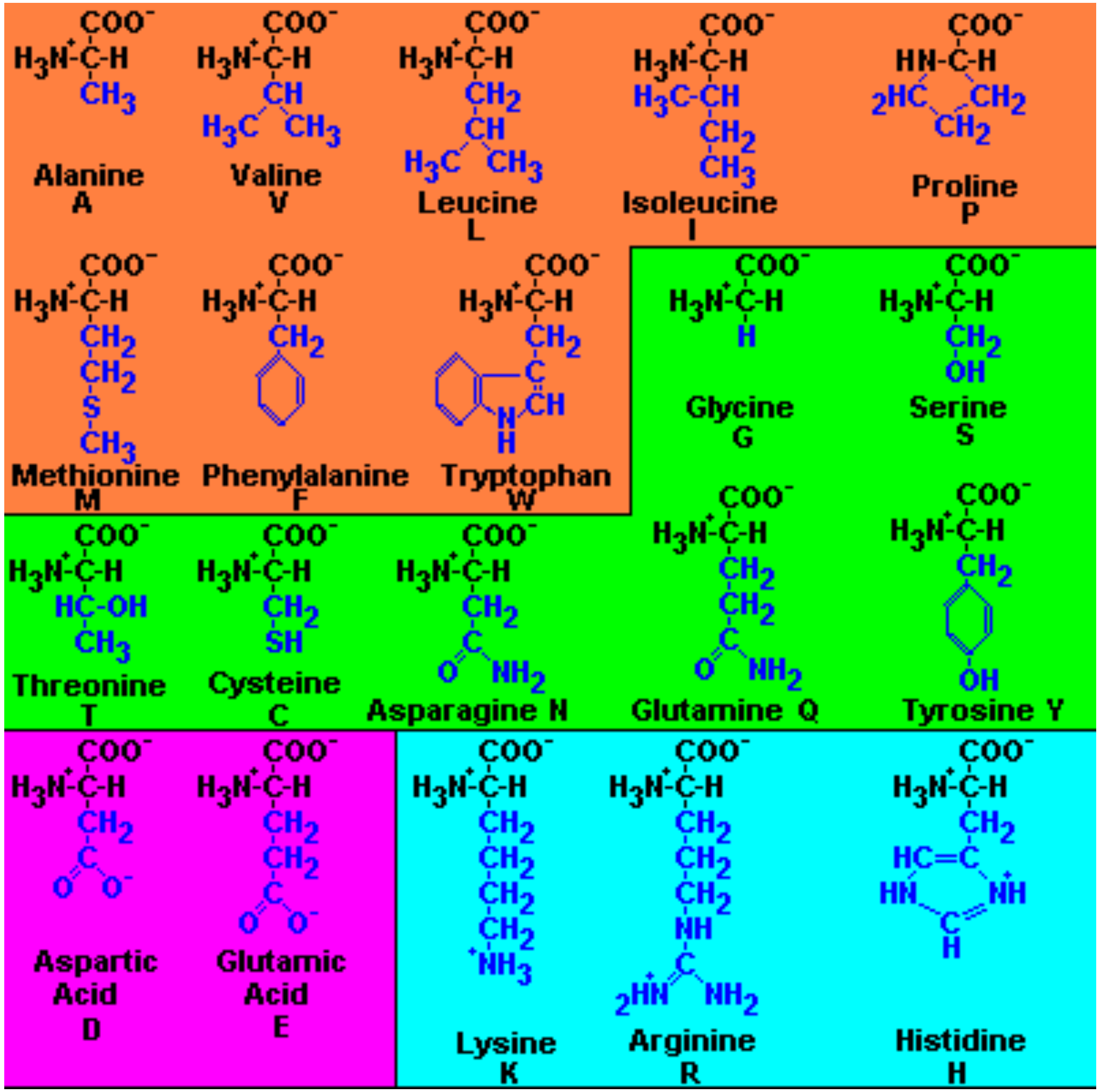
Plant Physiology & Nutrient Availability







Structure of Amino Acids



Sulfur is a Major Plant Nutrient









Sierra snowmelt

Saline and Alkaline water from

CA Aqueduct

Lower Colorado River

Groundwater pumped from deep well aquifers

Recycled Water

Rainwater

The vast majority of the water that we use for irrigation has no acidity and/or provides sulfur in the wrong form.

THE MAJOR CONSTITUENTS IN WATER

Cations:		
Calcium	Ca^{++}	
Magnesium	Mg^{++}	
Sodium	Na^{+}	
Potassium	K^{+}	
Anions:		
Bicarbonate	HCO_3^{-}	**Total**
Carbonate	$CO_3^{=}$	**Alkalinity**
Chloride	Cl^{-}	
Sulfate	$SO_4^{=}$	

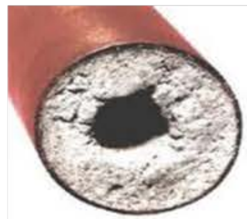
Total Dissolved Solids

The Precipitation of Salts and Mineral Scaling

Calcium + 2 Bicarbonates upon drying Calcium Carbonate + Water + Carbon Dioxide

$$Ca^{++} + (HCO_3^-)_2 \longrightarrow CaCO_3 + H_2O + CO_2 \uparrow$$

lime ($CaCO_3$)



Alkaline/Saline water applied to soil

$CaCO_3$ Ca $CaCO_3$ Ca $CaCO_3$Ca $CaCO_3$ Ca
$CaCO_3$ $CaCO_3$ $CaCO_3$ $CaCO_3CaCO_3CaCO_3CaCO_3$
Ca Ca Ca $CaCO_3$ $CaCO_3$ $CaCO_3$ $CaCO_3CaCO_3$Ca
$CaCO_3$ $CaCO_3$CaCO3CaCaCO3CaCO3 CaCO3Ca

1 Meq./L or 61.02 ppm of bicarbonates approximates 200 lbs. of salt precipitating potential in acre-foot of water.

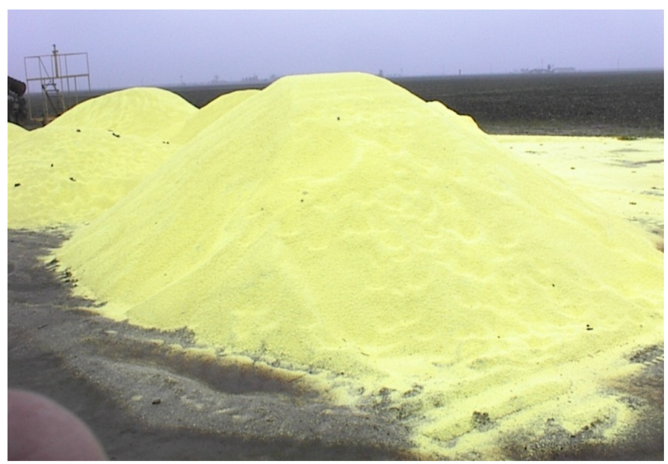





Traditional approaches to the problem:

Home

Agriculture



In 1955, D & J Harmon invented and pioneered the technique of amending irrigation water and soil with SO_2/Sulfurous Acid/Bisulfite Generators.

BAKERSFIELD, CALIF., SUNDAY, SEPTEMBER 12, 1976

THE GOLDEN EMPIRE

Supplement serving Kern County's multi-million dollar agri-business industry.

Tehachapi orchards bearing fruit

sulfur burners effective aid to water quality

department goes metric millimeter by millimeter

"TWO EXTRA TONS OF BEETS PER ACRE"
With
Harmon SO_2 Generator

DAVE FARMER, MERCED AREA GROWER HAS THIS TO SAY ABOUT THE HARMON SO2 GENERATORS: "I started with the 20 lb. Machine and Have Now Purchased both the 30 & 40 lb. Units. My Water Penetration and Retention Has Improved, Plus the Crop Yield has increased TWO EXTRA TONS OF BEETS PER ACRE! THESE SAME BEETS CONTAINED THE BEST SUGAR LEVEL IN THIS AREA."

The picture on the Left Is The Field That WAS NOT TREATED With The SO2. On The Right, Dave Displays A Beet From The Field Just Across the Road Where The SO2 Generator WAS USED.

THE SO2 GENERATOR IS HERE AND IT WORKS . . . FOR IMPROVING QUALITY OF IRRIGATION WATER AND PROBLEM SOILS. POSITIVE PROVEN BENEFITS, SAFE, POLUTION FREE WITH AN UNCONDITIONAL WARRANTY!

(Leasing Program Available)

HARMON SO_2 GENERATORS

Sulfur: Mobile Burners Turn It Into Alkali Killer

From Page F3

in some way from each other.

He got his first patent in 1964 and added a couple of new ones in 1971 and 1972. He has still more pending now.

From the start, Harmon has been operating on the premise that alkali trouble starts with the water and a farmer can have the best of soil chemistry and see it ruined by the character of his water. He started from the base of sulfuric acid being a fine way to counteract alkali but one that was just too expensive. From there he went to work hunting a way to get the power of sulfuric acid into the water with less expense and still have a way of measuring it out in controllable doses.

His burner, which has no moving parts, and does its work by burning the raw sulfur as its fuel and principal ingredient of treatment, operates on gravity feed for the sulfur and uses the rush of flame to accelerate the air intake that gulps in oxygen to turn out sulfur dioxide. Intake and outlet pipelines control the flow of the water to be treated. Handset valves meter the dosage to the need.

"The charm of this system is that it turns the SO2 into sulfurous acid after injection and that then becomes sulfuric acid in the soil after reacting on the insoluble calcium carbonates in the ground." Harmon ... the exchange capacities of the soil."

A fairly typical installation of the Harmon SO2 generator is seen here being checked out by J. D. Walker on the E-A-B ranch. One flexible line carries water to the burner from the well pipe, right foreground, and another carries the treated water back to the line for spreading on the cropland.

Harmon, like others who tried sulfuric acid, found it added at least $2 for every acre-foot of water used in applying it, and water was about $20 an acre-foot.

The straight acid treatment, even using the "spent" acid available as an oil refinery leftover priced at $52 a ton, has its own drawbacks on the safety considerations aside from costs. Any acid is a ... generator, is regarded as quite safe, and there is little handling involved anyway once the burner is filled because of the gravity feed system. Harmon also figures the burner has a 20 to one advantage over raw sulfur used as a soil dressing directly into the soil because 1,000 pounds of mineral would be needed to do the job of 50 pounds as SO2. Gypsum enough to do the job would come to three tons, he figures, using Califor... ing point, about $3.50 an acre-foot, where treating hits the point where it can no longer pay off in higher yields or shortened irrigation time. His sulfur supply, a salvage product from El Segundo and Santa Maria refineries, has risen to $69 a ton.

Ready as he may be to sell his system, Harmon also is quick to point out all farmers will not necessarily gain by its use. He emphasizes it is aimed at ... with each untreated irrigation," he warns. He is convinced the problem has been building by the use of hydrocarbon fuels contaminating our atmosphere where raindrops pick up carbonic acid and thus bombard our soils with new trouble in each rainstorm.

One satisfied customer, who has a solid chunk of experience with Harmon's unique tool, is Clyde Irion, the superintendent of ... tered about the big farming enterprise, having added two new ones just last March. The biggest burns 60 pounds of sulfur hourly.

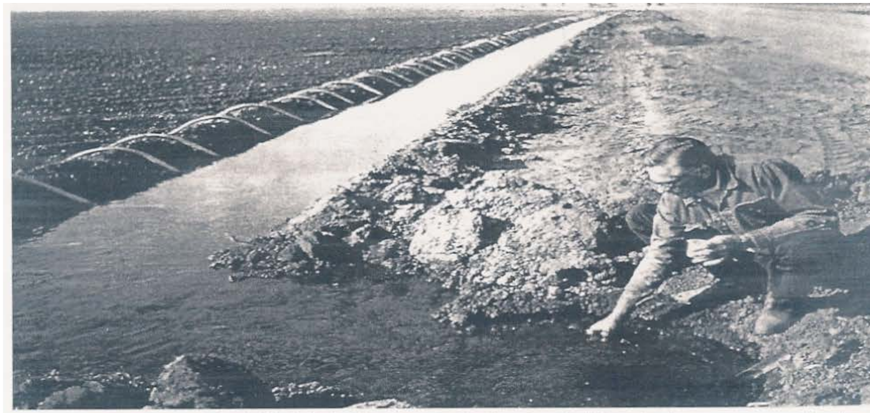
"We like the adaptability of this setup and the more versatile adjustments possible," said Irion. "Tomatoes, onions, sugar beets and garlic got this treatment, and we used it this year for cotton pre-irrigation. It has helped us everywhere we used it. Water is taken up faster by the soil and more water is taken in, so we cut our tail water.

"Our onions got it first, whites grown for the Gilroy dehydrator, and we saw a big yield difference. We used it to irrigate up our seeded tomatoes, but mostly we used it to get as much water as possible into our soil during the winter season."

Harmon remarked that these Fresno County installations are relatively new, most of the units have been concentrated in Kern County, where he maintains his factory at Bakersfield. He has no plans for expanding out of state for some while, prefering to handle the West Side fully first. J. D. Walker, his sales chief in the north end of the valley, says there are 15 burners in this area now.

Open House Will Promote Organics

Two Fresno firms, Or-



Sampling water to test Total Alkalinity in bicarbonates/carbonates to determine how many pounds of sulfur per acre foot of water are needed to bring the pH of the water to 6.5.

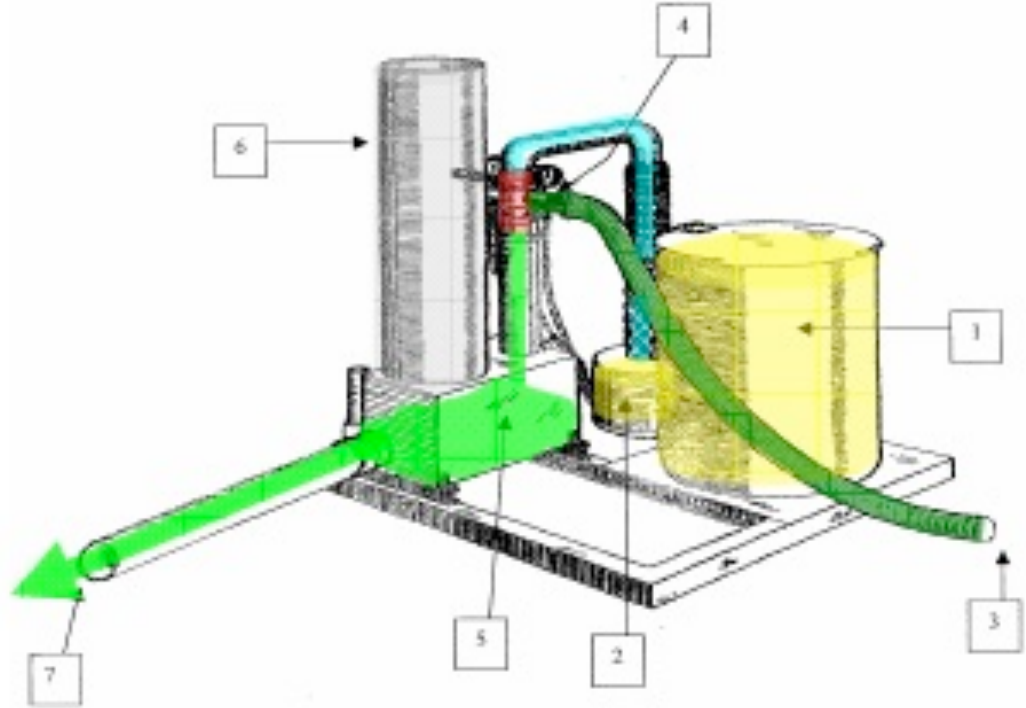
A portable Harmon SO_2/Sulfurous Acid Generator being placed to amend irrigation water for 160 acres of wheat.

Darrell Harmon, inventor and pioneer of the SO_2/Sulfurous Acid Generator, at a 600 acre field in Kern County, CA with problem soil caused with poor water quality.

Well water with high levels of Sodium and Total alkalinity, require SO_2/Sulfurous Acid treatment and Gypsum as noted by this farmer.

Photos are from article titled: Reduced Yields? It Could Be The Water February 1977 issue of Western Hay and Grain Grower Magazine

The Harmon SO_2/Sulfurous Acid Generator:



Elemental Sulfur is stored in the Hopper (1) supplies material thru a channel to Burn Chamber (2) for oxidation. By supplying and regulating a pressurized side-stream of feed water (3) through a device called the Aspirator (4), air can be drafted and the burn rate of the sulfur can be controlled (after it has been ignited by a match, propane trigger torch, or electric heating element, no other fuel or heat source will be necessary). The resulting sulfur dioxide (SO_2) produced is immediately captured to form an aqueous solution of free hydrogen and bisulfite within the Tank (5). The Scrub Tower (6) wet scrubs and washes any fugitive SO_2 into solution to prevent it from escaping into the atmosphere. Nitrogen (N), which is 79% of air, is drafted through the equipment and ventilated through the Scrub Tower. The concentrated aqueous solution of free hydrogen and bisulfite is then pumped from the Tank (7) into a storage vat and used for de-chlorination. Since the fuel source is the sulfur itself, as long as it remains ignited, the production of free hydrogen and bisulfite will be continuous until such time the sulfur material has either been depleted or the flame is extinguished for shut down (turning off the pressurized flow of water and capping off the oxygen supply).

PERFORMANCE TESTING OF A HARMON SO_2 GENERATOR

July 28, 1983

Prepared for

D&J Harmon Company, Inc.
3737 Gilmore Avenue
Bakersfield, California 93308

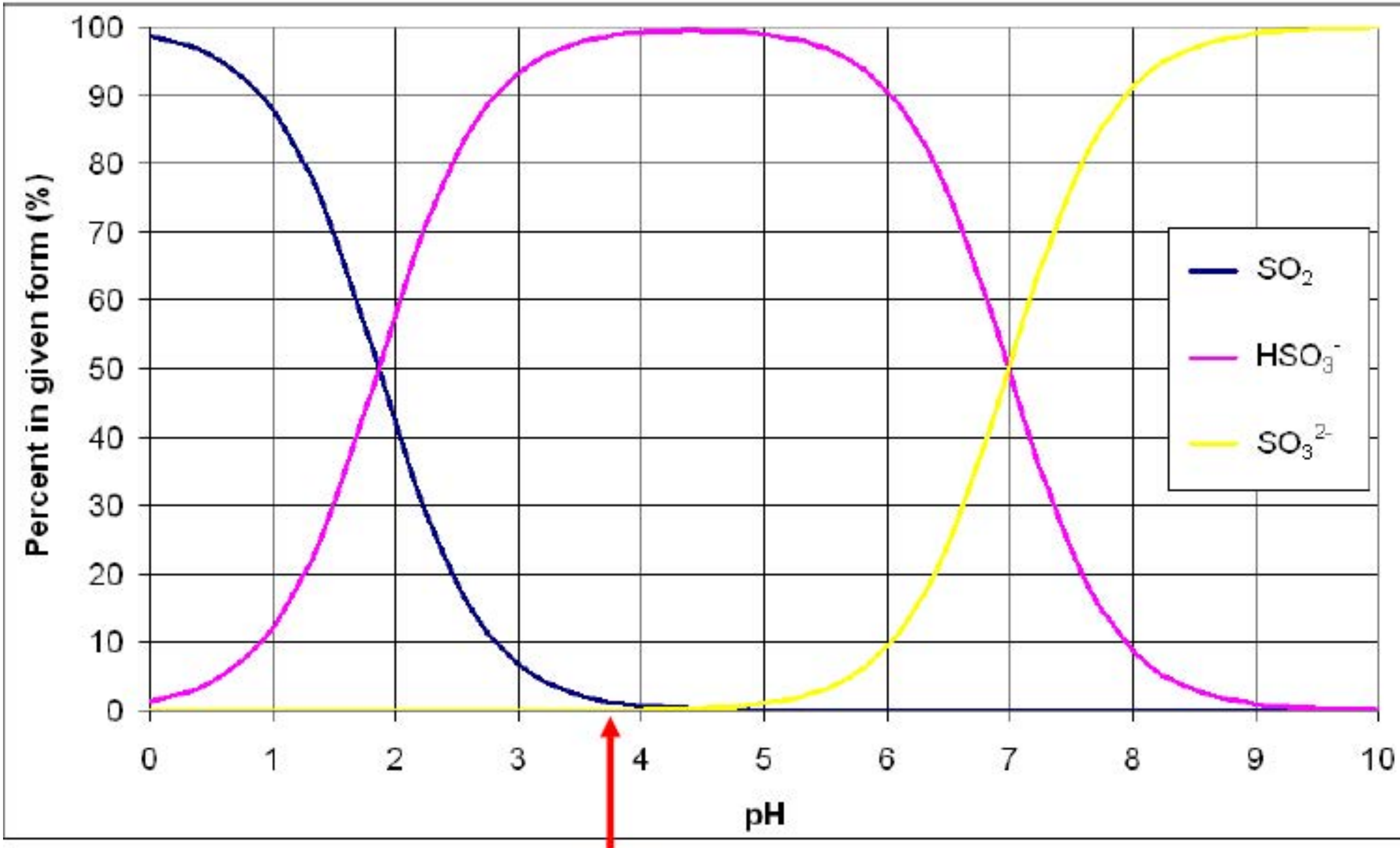
Prepared by

Pape & Steiner Environmental Servic•
5801 Norris Road
Bakersfield, California 93308

Purchase Order No. 1023

Report PS-83-137/Project 5123-83

Table 3-1 summarizes the results of the tests conducted on the SO_2 generator north of Bakersfield. The average SO_2 concentration was 14.24 ppm The average SO_2 emission rate was very low (0.0042 lb/hr) since there are very little combustion products leaving the burner.



Percent in given form (%)
100
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
5
6
7
8
9
10
pH
SO_2
HSO_3^-
SO_3^{2-}

Synthetic
Strong Acid

Sulfuric

H_2SO_4

$H^+ + HCO_3^- \rightarrow H_2O + CO_2\uparrow$

$H^+ + HCO_3^- \rightarrow H_2O + CO_2\uparrow$

$SO_4^=$

Natural
Weak Acid

SO_2 – Sulfurous

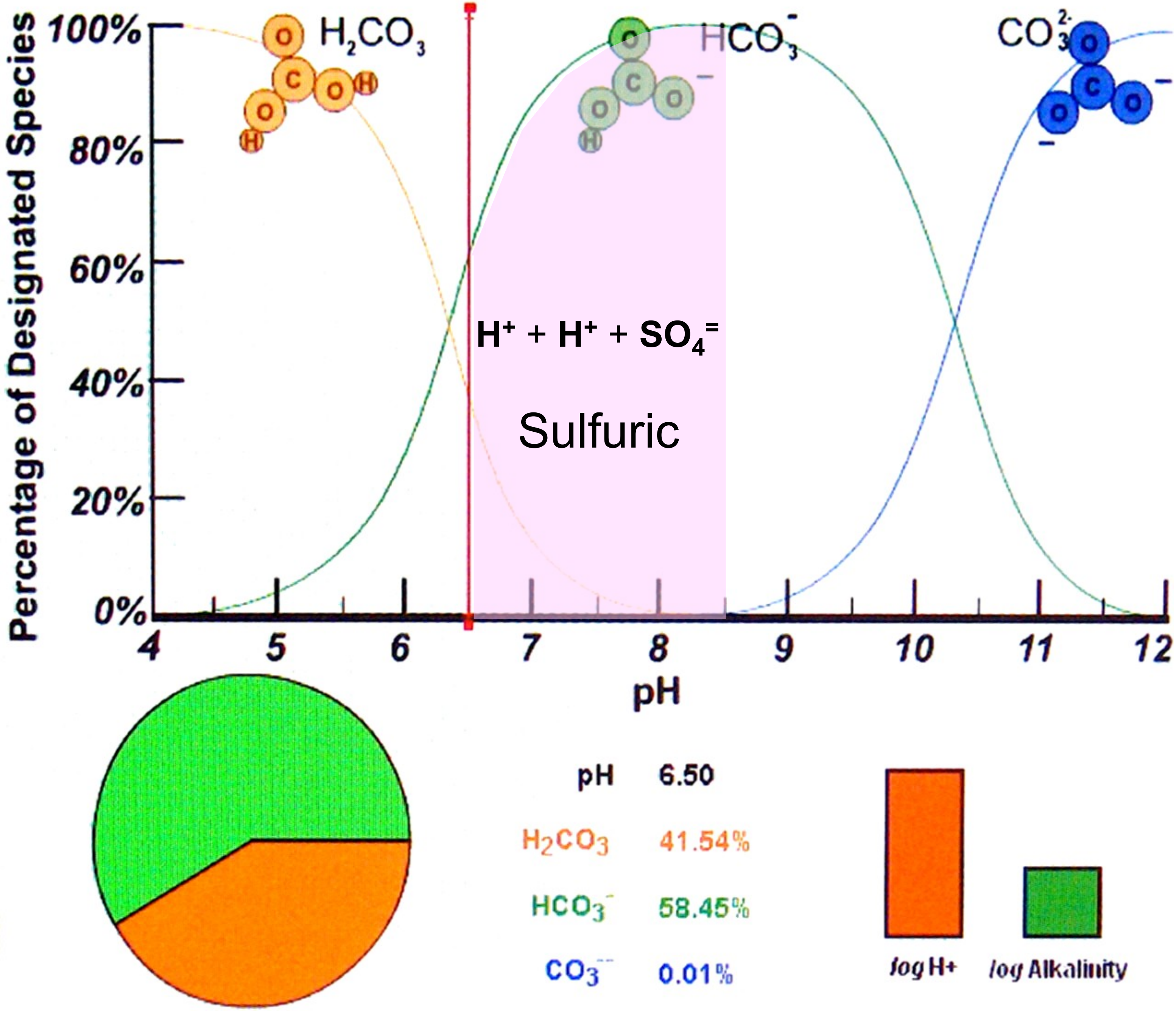
$S + O_2 \longrightarrow SO_2 + H_2O$

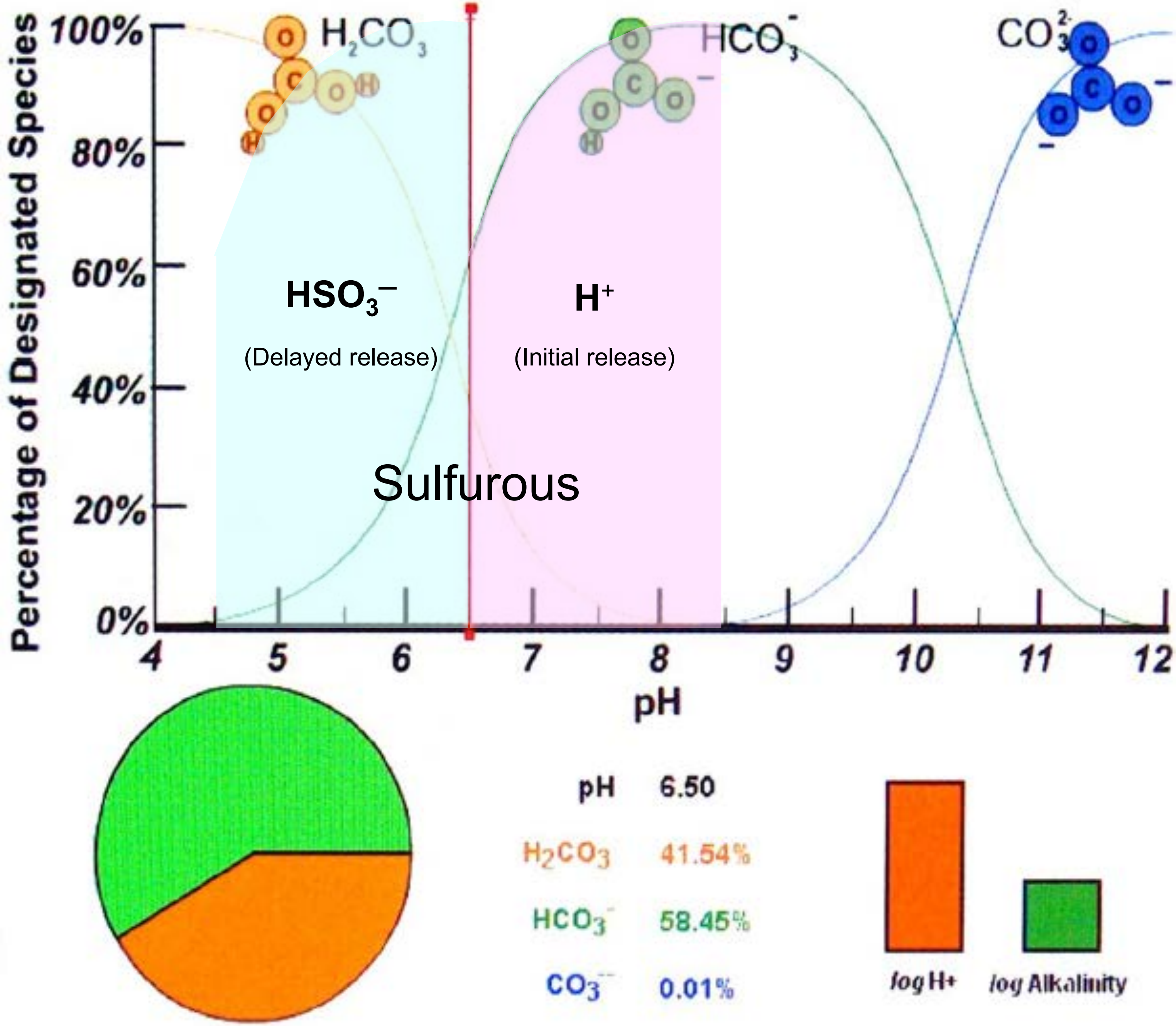
H_2SO_3

$H^+ + HCO_3^- \rightarrow H_2O + CO_2\uparrow$

$HSO_3^- + .5O_2 \rightarrow H^+ + SO_4^=$

$H^+ + HCO_3^- \rightarrow H_2O + CO_2\uparrow$


Percentage of Designated Species
100%
80%
60%
40%
20%
0%
H_2CO_3
HCO_3^-
CO_3^{2-}
$H^+ + H^+ + SO_4^=$
Sulfuric
4
5
6
7
8
9
10
11
12
pH
pH 6.50
H_2CO_3 41.54%
HCO_3^- 58.45%
CO_3^{--} 0.01%
log H+
log Alkalinity


Percentage of Designated Species
100%
80%
60%
40%
20%
0%
H2CO3
HCO3-
CO3 2-
HSO3–
(Delayed release)
H+
(Initial release)
Sulfurous
4
5
6
7
8
9
10
11
12
pH
pH 6.50
H2CO3 41.54%
HCO3- 58.45%
CO3-- 0.01%
log H+
log Alkalinity

If a situation required feed rate of 300 moles of hydrogen (H^+) to neutralize bicarbonates (HCO_3^-) to attain a pH equilibrium of 6.5, here are the reactions:

Sulfuric

Sulfuric Acid	+ Bicarbonate	yields	Carbonic Acid	+ Sulfate	yields	Water	+ Carbon Dioxide	+	Sulfate	
H_2SO_4	+ $2\ HCO_3^-$	→	$2H_2CO_3$	+ $SO_4^=$	→	$2H_2O$	+ $2CO_2\uparrow$	+	$SO_4^=$	
			Requires 150 moles of sulfuric acid to achieve this						equilibrium	with no residual H^+ left in solution.

→ **Directional flow within the conveyance system** **6.5 pH** **amended irrigation water** →

SO$_2$/Sulfurous

Sulfurous Acid	+ Bicarbonate	yields	Carbonic Acid	+ Bisulfite	yields	Water	+ Carbon Dioxide	+	Bisulfite	+ Oxygen &	yields	Acid	+ Sulfate
H_2SO_3	+ HCO_3^-	→	H_2CO_3	+ HSO_3^-	→	H_2O	+ $CO_2\uparrow$	+	HSO_3^-	+ $.5O_2$	→	H^+	+ $SO_4^=$
			Requires the oxidation/dosing of 300 moles of *S* into SO_2 to achieve this						equilibrium	with 300 moles of residual H^+ in solution			

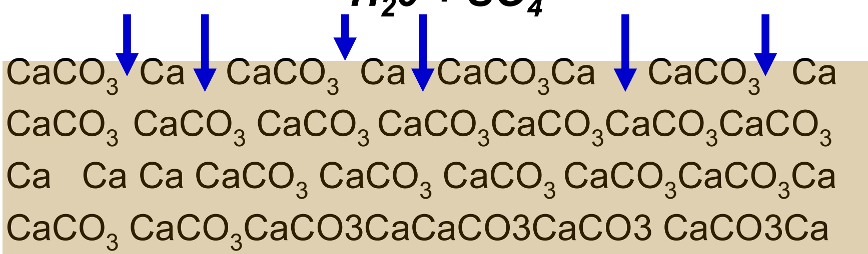
Neutralization of Calcium Carbonate

Acid + Calcium Carbonate yields Calcium + Carbonic Acid yields Calcium + Water + Carbon Dioxide

$$2\,H^+ + CaCO_3 \longrightarrow Ca^{++} + H_2CO_3 \longrightarrow Ca^{++} + H_2O + CO_2$$

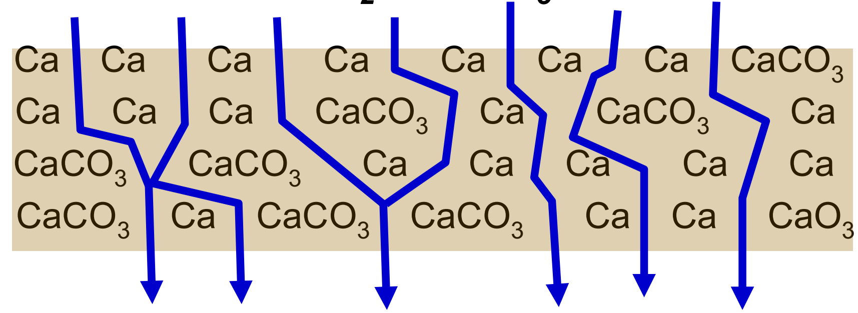
Irrigation water treated with sulfuric acid to 6.5 pH has no residual acidity; leaves 58% of Total Alkalinity Intact.

$H_20 + SO_4^=$



Irrigation water dosed with SO_2 to 6.5 pH still contains residual acidity; sequentially eliminates remaining Alkalinity

$H_20 + HSO_3^-$

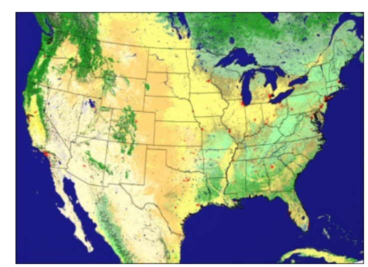


Soil always takes on the characteristics of the materials applied upon it

Amending with SO_2 liberates acidifying H^+ protons and bisulfite HSO_3^- from irrigation water and delivers it into the soil

Rainwater

Accelerates the overall amount of *H^+ protons* and *HSO_3^-* bisulfite a geographic area would receive under normal conditions.



SURABIAN AG LABORATORY
105 Tesori Drive
Palm Desert, CA 92211
(760)200-4498

REPORT OF ANALYSIS

for: Desert Valley Date

report date: listed below

Description	depth (feet)	1/4/11 pH	1/4/11 EC (mmhos/cm dS/m)	1/4/11 Na (mg/Kg)	1/4/11 Na (meq/L)	4/9/11 EC	5/13/11 EC	11/8/11 pH (after sulfur burner brough on line end of May 2011)	11/8/11 EC	1/24/13 pH	1/24/13 EC
	site 1										
All 3 feet is Gillman	0-1	9.60	61	>10000	>435	74	33	8.40	2.40	8.35	1.40
v.f. sandy loam with	1-2	9.40	15.0	3500	152	49	52	8.05	1.60	8.75	1.39
silty clay loam layers	2-3	9.65	12.2	2900	126						
	site 2										
v.f. s.l. w/s.c.l. layers	0-1	9.85	97	>10000	>435	50	5.2	7.95	1.46	8.10	1.50
v.f sandy clay loam	1-2	10.00	29	6600	287	38	45	8.25	1.60	8.05	1.43
v.f. sandy loam	2-3	8.40	3.6	660	28.7						
	site 3										
v.f.s.l. w/s.c.l. layers	0-1	10.10	33	8200	357	55	18	8.15	2.20	7.95	2.80
v.f. sandy loam	1-2	10.05	9.0	1700	74	25	41	8.70	1.24	8.45	7.40
fine sand	2-3	9.85	5.8	1100	47.8						
	site 4										
v.f.s.l. w/s.c.l. layers	0-1	8.85	72	>10000	>435	92	2.9	8.40	6.60	8.25	3.90
v.f.s.l. w/s.c.l. layers	1-2	9.20	52	>10000	>435	20	1.4	9.05	15.05	8.25	1.90
very fine sand	2-3	9.70	20	4300	187						

Sites and depth of analysis per client instructions.

Field Stages:
1/4/11 = raw land, never farmed
4/9/11 = after ripping, raw sulfur, compost, first flooding
5/13/11 = after additional flooding
Drip system installed and used for further leaching
End 5/11 = sulfur burner brought on line
11/8/11 = date palms planted

Comparing the last samples tested on 11/11/11 to these new samples taken on 1/24/13, we can see that pH and EC continues to lower overall. This indicates that the sulfur burner continues to aid in reducing alkalinity and salinity in these soils to these safe levels.

SO2/Sulfurous Acid vs. Sulfuric Acid

Pricing for Central Valley as of May 5, 2018

What is the cost difference of SO2/Sulfurous Acid compared to Sulfuric Acid?

The cost of 99.9% elemental sulfur and 93% sulfuric acid for this example adjusted for material purity is computed as follows:

454 grams in one pound
32 atomic weight of sulfur

14.2 moles of sulfur per lb.
x 2 hydrogen ions derived per mole of sulfur
28.4 moles of hydrogen derived from lb. of sulfur

Cost of sulfur: ($365.00 ton + .1%) ÷ 2,000 lbs. = .1827 per lb.

Cost per mole: .0064 (.1827 ÷ 28.4)

600 moles of *hydrogen* (*H+*) from sulfurous acid would have a material cost of **$3.84** (600 x .0064)

454 grams in one pound
98 atomic weight of sulfuric acid

4.6 moles of sulfuric acid per lb.
x 2 hydrogen ions derived per mole of sulfuric
9.2 moles of hydrogen derived from lb. of sulfuric

Cost of sulfuric: ($175.00 + 7%) ÷ 2,000 lbs. = .0936 per lb.

Cost per mole: .0102 (.0936 ÷ 9.2)

600 moles of *hydrogen* (*H+*) from sulfuric acid would have a material cost of **$6.12** (600 x .0102)

Conclusion: Amending water to pH 6.5 with sulfuric will still leave 58% of the Total Alkalinity intact and no residual acidity. Oxidizing sulfur and dosing it as sulfur dioxide (SO_2) in water enables you to manufacture sulfurous acid on-site, **double** the amount of acidity at **63%** of the material cost of sulfuric ($3.84 ÷ $6.12), and deliver acidity directly into the soil to dissolve soil carbonates, leach salts and prevent their accumulation, enhance fertility, and optimize the use and efficiency of water.

Integrating the Harmon Sulfurous Acid Generator into your Farming Operation

1. **Irrigation Suitability Analysis of the water source that will be amended (particularly, what is the *bicarbonate* (*HCO_3^-*) and *carbonate* (*CO_3^-*) level?)**

2. **What is the minimum and maximum irrigation flow rate (GPM) at this location? In the future, will this amount increase or decrease?**

3. **Does your irrigation system draw water from a holding reservoir or canal?**

4. **If it is directly from a deep well, what is the maximum water pressure (PSI) of the irrigation line downstream of the pump/filter station?**

5. **What type of power do you have available at this location?**

   Do you have single or three phase electrical power (240v or 480v)?

   Does it use a gas/diesel booster pump?

   Have you ever considered using a diesel powered electrical generator (gen-set)?

- Obtain twice the acidity of sulfuric at less than half the cost
- Safe to handle and touch
- Clean drip lines & emitters
- Amend water and soil pH
- Prevent salt accumulation while using marginal & impaired waters
- Improve water penetration and eliminate run-off
- Increase crop quality and yields

For information contact:

Terry R. Gong

(925) 250-4559

westernso2@aol.com

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