From: Westernso2 [mailto:westernso2@aol.com]
Sent: Monday, January 10, 2011 9:58 AM
To: Macaulay, Terry@DeltaCouncil
Subject: Delta Stewardship Public Comment

Ms. Terry Macaulay:
Attached are pdf files of two papers I wrote and sent to the National Academies of Sciences to describe long term solutions to our nation's water related problems, including how to remove key stressors now impacting the Sacramento-San Joaquin Delta.

The Importance of Integrating Nature Into Our Artificial Systems describes why the element of *hydrogen* is the the common denominator that drives our planet, and why we must emulate the natural acidification process in order to resolve our water related challenges.

Processing Wastewater For Sustainability: A New Class of Recycled Water describes: the inability of conventional wastewater treatment systems to produce and condition recycled water specifically so that it can be sustainably applied to land; how increased land application removes it from our natural waterways and enables us to utilize the ammonia nitrogen it has to grow a variety of high value crops and bio-fuels; how to return a more natural and higher quality of water will resuscitate the Delta and mitigate damage to our state's vital agricultural economy.

I hope my input will be helpful. I will assist in any way I can just let me know. Thank you.

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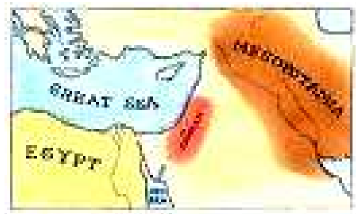
Processing Wastewater for Sustainability: A New Class of Recycled Water

Introduction

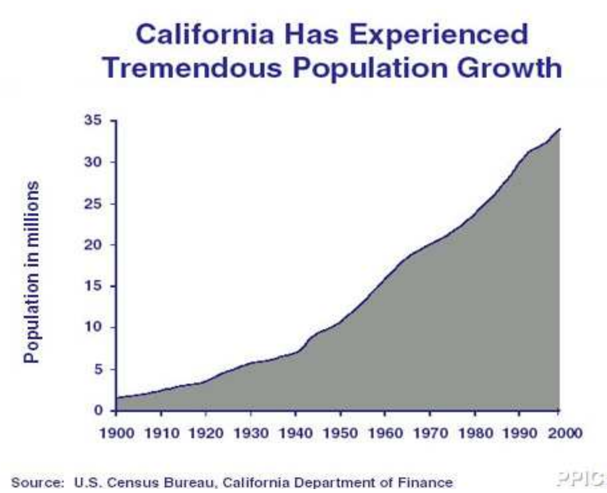
Current wastewater treatment methods are the result of an evolutionary process that has taken many years. While these methods have gotten us to where we are today, the near collapse of the San Francisco Bay Delta Estuary, and the premature retirement of precious farm ground, indicate that the direction we are on is no longer sustainable. Can we restore this ecosystem without inflicting economic hardship to this vital agricultural region? This paper will explain how both problems are interrelated and suggest that the solution to both will be to produce a new class of recycled water for irrigation.

Sustainability



When the word *sustainability* is applied to human civilization, in this context, it means to be compatible with nature as we simultaneously dispose of our waste materials while obtaining food to feed ourselves. So, if we consider the ancient civilization of Mesopotamia, which lasted roughly six thousand years before succumbing to salt accumulation as a result of irrigating their farmland, we must acknowledge that they did a lot better in comparison to what we have done, as we have already begun to retire farmland after less than sixty years of practiced irrigation. History reveals that the principal issue for every civilization located in a semi-arid or arid part of the earth has been to prevent and overcome the nagging problem of soil salinity. And yet, for the most part, we keep putting it off and have never given this issue the attention it deserves. This general lack of concern has even caused us to compound and accelerate this problem even more.

For example, in California, whenever our Sacramento and San Joaquin valley wastewater treatment facilities use sodium hypochlorite *(NaOCl)* to disinfect or sodium meta-bisulfite ($Na_2S_2O_5$) to de-chlorinate, we essentially add more sodium (Na^+), chlorides (*Cl*), Total Alkalinity (bicarbonates HCO_3^-/carbonates CO_3^{2-}), trihalomines (*THMs*), ammonia nitrogen (NH_3), etc., into our natural waterways. We started doing this when our population was small, and we thought that if we placed a Total Maximum Daily Limit on our treatment facilities and we abided by it, we could get rid of everything with dilution within our natural waterways and by letting it all flow through the Delta Estuary, San Francisco Bay, and on out to the ocean.



While this plan may have worked initially, our population grew and we now divert more fresh water away from the Delta Estuary than ever to supply: our growing cities with additional drinking water; cooling water for power plants; food processing operations; farmers with irrigation water to grow food; etc. All of which created a return flow back into the estuary that is thermally warmer and with a lot more contaminants such as: agricultural drain water; industrial pollution; pharmaceuticals; and what we add during the wastewater treatment process.

These artificial contaminants, combined with: native constituents; lower flows; drought; foreign and invasive species; increased water diversions; etc., in their aggregate, have adversely impacted the entire ecosystem. They are also contributing to the acceleration of soil salinity to our valuable farmland when these materials are pumped and transferred via the California Aqueduct and Delta Mendota Canal, and applied to the soil each year during the irrigation of crops. Sadly, this same type of scenario is likely to be happening in other parts of our country as well.

Natural dissolved salts combined with salts/contaminants added by wastewater treatment facilities are pumped and re-conveyed via California Aqueduct & Delta Mendota Canal where it is then redistributed onto farmland during irrigation.

Developing a comprehensive solution by creating a new class of recycled water that can improve soil

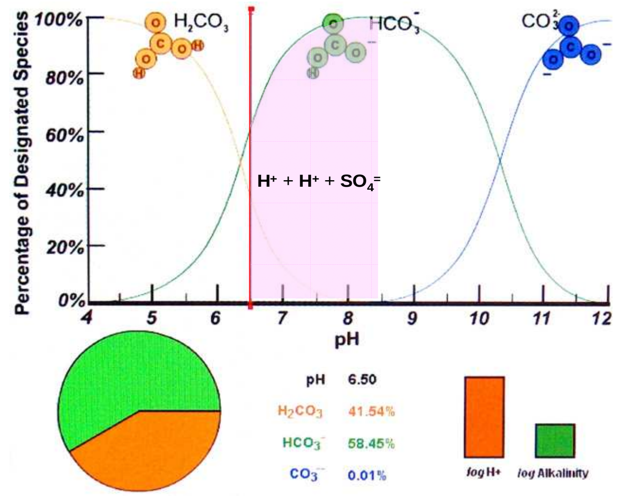
If the definition of insanity is doing the same thing over and over again and expecting a different result, let us remember our history and avoid repeating the same mistake. We must consider finding a way to shift away from the flawed infrastructure that we have been using, and to start applying our resources toward developing a better and more sustainable way to process and dispose of our wastewater, and to create an entirely new class of recycled water. A kind specifically processed to irrigate and grow a wide variety of crops including bio-fuels, and one that can progressively improve the agronomic conditions of our soils instead of making them worse. If we can do this, in a few short years, our growers will develop the confidence to switch from what they are currently using, over to this new type of recycled water. And, over time, we will be able to significantly reduce and/or eliminate virtually all treated wastewater from entering our natural waterways. This will allow a more natural and higher quality flow of water to return back to resuscitate this impaired ecosystem without causing economic harm to our nation's most important agricultural regions.

To prevent salts from accumulating in the soil and to improve it, recycled water must be transformed to carry acidity into the soil. This is because in order to leach salts and prevent their accumulation, additional pore space must be created deeper throughout the soil profile. To do that requires the neutralization of soil carbonates which needs *twice* as much acid as compared to bicarbonates. That reaction is:

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

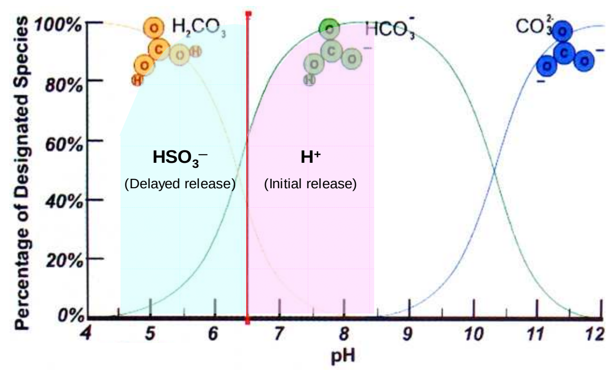
$2\,H^{+}$	+	$CaCO_3$	$\rightarrow$	Ca^{++}	+	H_2CO_3	$\rightarrow$	Ca^{++}	+	H_2O	+	$CO_2\uparrow$
Acid	+	Calcium Carbonate	yields	Calcium	+	Carbonic Acid	yields	Calcium	+	Water	+	Carbon Dioxide

To make recycled water carry and deliver acidity into the soil, we must understand what the basic differences are between a weak acid versus a strong acid. The Carbonate Curve will help to explain. For example, if a farmer receiving 8.5 pH recycled wastewater were to use a strong acid acidifier like sulfuric acid (H_2SO_4) to lower its pH, the disassociation of its two hydrogen ions ($2\ H^+$) would release at the same time to start the neutralization of the Total Alkalinity, bicarbonates (HCO_3^-) and carbonates (CO_3^{2-}). In order to protect irrigation system components from the corrosive effect of over acidifying, the farmer would strive to achieve a target pH of 6.5 (the pink shaded area on the top curve depicts the simultaneous release of the two hydrogen ions and the amount needed to achieve pH 6.5). It is important to note that, at this pH equilibrium, less than 42% of the bicarbonates/carbonates will be neutralized. This leaves more than 58% intact where they can later react with dissolved salts and precipitate out of solution. Consequently, because all of the hydrogen from sulfuric was used just to lower the pH to that level, no acidity will be left in solution to dissolve soil carbonates. In addition, since 1 meq./L of bicarbonates (61.02 ppm) per acre foot of water has the ability to precipitate out of solution about 200 lbs. of salt, and recycled water averages about 3.3 meq./L of bicarbonates (200 ppm) per acre foot, left untreated, it would form about 660 lbs. (3.3 x 200 lbs). If this water were to be treated with sulfuric acid to 6.5 pH equilibrium, even with the 42% reduction, it would still allow the formation of about 389 lbs. of salt [(3.3 x 200 lbs.).58] to precipitate and plug the soil.



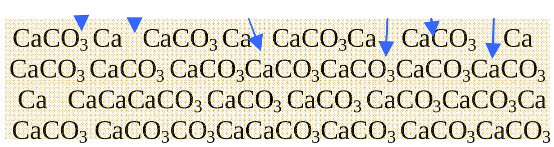
Carbonate Curve

www.marshall.edu/highlandpark/amd/carbonatecurve.shtml



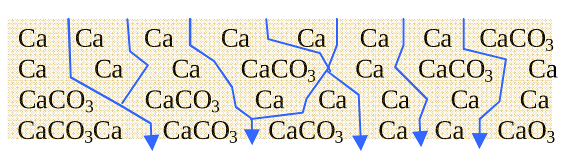
Conversely, sulfurous acid is different because as a weak acid, it releases its two hydrogen ions sequentially, which allows the first hydrogen ion *(H^+)* to release and the second hydrogen ion *(H^+)* to remain in solution as Bisulfite *(HSO_3^-)*. Thus, a recycled water solution at 6.5 pH equilibrium containing Bisulfite, in reality, has an overall acidity that is greater, and twice the amount of sulfuric. Because after it is applied to the soil, within minutes *Thiobacillus* and/or *Acidithiobacillus* bacteria complete the reaction by oxidizing the Bisulfite into sulfate *($SO_4^=$)*, and upon doing so, releases the remaining hydrogen ion *(H^+)* into the soil (the first release on the bottom curve is depicted in pink and the second is in blue). The major advantage of this delayed release of acid enables this new class of recycled water method to: be safe for irrigation conveyance systems; be capable of providing the necessary acidity to neutralize all of the bicarbonates within the water; and deliver the additional acidity to dissolve native soil lime formations, including those formed from using current forms of recycled water, and to prevent their reformation.

6.5 pH water treated with sulfuric acid ($H_2O + SO_4^=$)



Because all of the hydrogen ions have been used to adjust the irrigation water to 6.5 pH equilibrium, no free hydrogen is left in the irrigation water solution to contact and amend the soil.

6.5 pH water containing Bisulfite ($H_2O + HSO_3^-$)



The initial release of the first hydrogen ion from sulfurous acid adjusts the irrigation water to 6.5 pH equilibrium, which permits the second hydrogen ion to remain as Bisulfite in the irrigation water solution. Upon contact with the soil, this acidity penetrates and dissolves soil carbonates to facilitate the leaching of salts away from the root zone.

SO_2/Sulfurous Acid Generator/Sulfur Burners have been used for nearly sixty years to acidify agricultural irrigation water and can be easily adapted to transform recycled wastewater to have the qualities described. The following points explain the many other benefits of this new processing method:

1. SO_2/Sulfurous Acid Generator/Sulfur Burner can be used to disinfect wastewater exactly the same way wine makers inject SO_2 to stop fermentation and preserve the wine. By lowering the pH of the wastewater (to around 3.5); bisulfite (HSO_3^-) and free sulfur dioxide (SO_2), which is known also as *molecular* SO_2, can exist in solution. Of these two chemical species, only molecular SO_2 can kill bacteria. Disinfection correlates to the pH of the solution – the lower the pH, the higher percentage of molecular SO_2.
2. Sulfurous acid as a weak acid releases its first hydrogen ion (H^+), and the remaining portion converts into bisulfite (HSO_3^-), a compound that, depending on how it is being used, functions as a reducing agent to de-chlorinate water; and/or as an aid to deconstruct pharmaceuticals and perchlorate.
3. After disinfection, calcium carbonate ($CaCO_3$) is then added to increase the pH of the wastewater to 6.5 and to condition and offset the high levels of sodium that is often found in wastewater. This transforms the treated wastewater to contain more dissolved calcium than sodium, which lowers the Sodium Adsorption Ratio (SAR). And, because this water still contains some bisulfite, it will continue to release free and active hydrogen after it is applied into the soil. This can be done either at the wastewater treatment facility and/or while it is being applied on the land.

4. Removing ammonia nitrogen from recycled wastewater is too costly for conventional wastewater plant operations to perform; land applying it and letting crops such as cotton, alfalfa, bio-fuels, etc., utilize it would be a more cost effective way to remove it.
5. When wastewater becomes highly buffered with Total Alkalinity (bicarbonates/carbonates), it impedes the separation of sludge from the wastewater, which then: requires more materials to be used such as polymers; creates additional steps to dry it; increases handling and transportation costs to haul it away; and adds greater volume to landfills; etc. The SO_2/Sulfurous Acid Generator/Sulfur Burner processing method can separate and de-water sludge without the use or cost of polymers, and will dry solids enough where they can then be used and disposed of as co-generation fuel.
6. Unlike other methods that acidify by “importing” hydrogen from outside of the system, this technique uses a side stream of the raw wastewater to wet scrub the SO_2 gas into solution to break apart free and active hydrogen within itself.
7. This method can also be used to: improve the percolation of wastewater treatment ponds; increase the infiltration rate and field capacity of soils; reduce tail-water runoff and non-point source pollution; enhance ground water recharge; reduce State and Federal pumping costs; achieve what will be the biggest breakthrough in water conservation; etc.

Summary

Current wastewater treatment methods, because they add more contaminates into our natural waterways, are contributing to the impairment of the San Francisco Bay Delta Estuary and our precious farmland. To reverse this trend, we must consider changing the way we process our wastewater and land apply as much of it as possible. This will require us to process an entirely new class of recycled wastewater so that it can improve the soil it is applied to. Conventional wastewater treatment methods are incapable of doing this and the SO_2/Sulfurous Acid Generator/Sulfur Burner wastewater treatment process has been recently developed to meet this purpose. This method can either amend the recycled water now emanating from conventional wastewater treatment facilities, or be used as a complete and separate wastewater processing system. Implementation of this method will enable us to: resuscitate this impaired ecosystem; protect the soil and economic productivity of our nation’s most important farming regions; and solve a multitude of problems.

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The Importance of Integrating Nature into Our Artificial Systems

Introduction

"The mere formulation of a problem is far more essential than its solution, which may be merely a matter of mathematical or experimental skills. To raise new questions, new possibilities, to regard old problems from a new angle require creative imagination and marks real advances in science."

Albert Einstein

Given the fact that we are constantly struggling to overcome the many problems associated with our artificial water based systems, it is important for us all to remember the above statement as it summarizes our current situation rather perfectly – after all these years, could it be that they persist because we have never understood and are still confused as to what the *actual* problem is? To provide input and advance toward a solution, this paper approaches the problem using a different point of view by: emphasizing free hydrogen (H^+) as the primary driver behind earth's natural process; correlating it to the degradation and breakdown of these systems; and submitting the hypothesis that if we mimic and integrate the same natural acidification process used by nature into our artificial systems, we can optimize and make them perform considerably better than before.

Paradigm Shifts

When we consider that problems can only be solved when their *root causes* become known, our ongoing difficulties with so many of our artificial systems should not be viewed as a mere coincidence; we must realize the possibility that we could also have misinterpreted the entire problem all along. As human beings, our personal biases will often prejudice our ability to think clearly with an open mind, and it causes us to pre-conceive the form and manner in which we think what the solution should be like.

Instead of relying on the same old conventional wisdom and paradigm – which is, as it pertains to this subject, the most popular and prevailing way world academia *thinks, interprets, and perceive*s earth and how its natural processes function – we need to question its validity by becoming more acquainted with specific aspects about the earth that we know very little about.

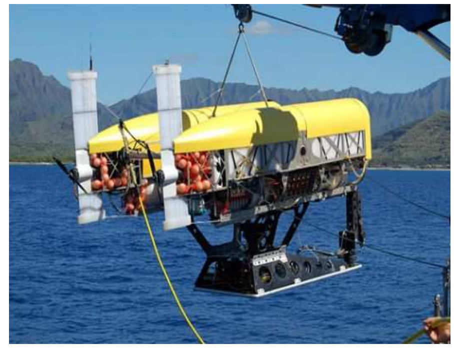
The old paradigm

Most of the informational data we have amassed and learned so far about the earth has been derived from accessible areas only, which pertains to things gathered at or slightly below the surface, or above our planet. Given that: nearly 71% of our planet is covered and underneath the ocean and we have charted and mapped less than 5% of the ocean floor (NOAA); we have never gained access into earth's inner core and the 12,262 meter bole hole on the Kola peninsula is the deepest penetration we have ever made and represents a fraction of the earth's outer crust (ICDP); etc., we must humbly acknowledge that our entire base of knowledge and everything that we perceive to know about this planet remains rather limited and skewed.

Planet Earth
NASA Goddard Space Flight Center Image

Because our knowledge of the earth is so unbalanced, there is a high probability that many of the solutions we have already adopted or are about to implement may be – because they were based using our old paradigm – flawed as well. We just haven't realized it yet. Does this mean we should abandon everything that we have learned so far? No. It just means that we need more information from specific areas to provide the balance we need to properly discern what is true from the things that are not.

The new paradigm



Nereus Hybrid Remote Operated Vehicle
Woods Hole Oceanographic Institution

For centuries, our inability to overcome the extreme depth and pressure at the bottom of the oceans has kept this vast region and the major portion of the earth virtually hidden from us. However, with the recent advent of unmanned submersible hybrid remote operated vehicles (HROV), digitized video images can now be transmitted in real time to scientists all over the world, and physical samples can be gathered for analysis. Some of this new information has already revealed things about the earth that we never knew before – because they were out of sight and out of mind.

More importantly, it is reminding us about the *common denominator* behind earth's natural process, how it functions, and why our planet is the way it is. As we continue throughout this new age of oceanic exploration, the information we obtain will help to dispel the myths within our old paradigm, and shift us towards the adoption of a newer and more accurate one.

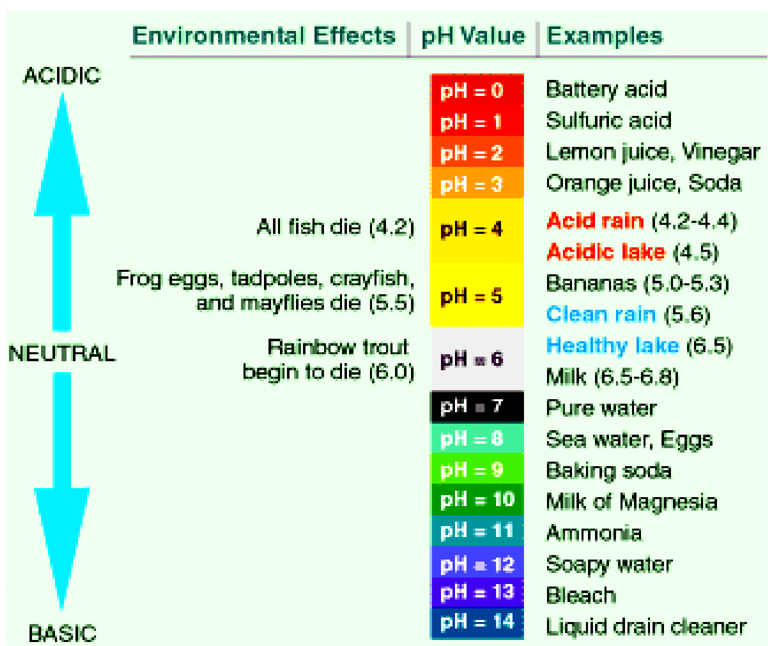
Rediscovering the common denominator

Chilean Chaiten Volcano Jan. 2009

Kilauea, HI Volcanic Fumarole

Alaska Mt. Redoubt Mar. 2009

There are about five hundred and fifty known volcanoes on the surface of the earth. Over the past four decades, an average of fifty to seventy volcanoes has been confirmed to be simultaneously active each year (USGS). As these volcanoes erupt, they spew and emit into the atmosphere large amounts of sulfur dioxide (SO_2). This gas, because it absorbs easily into water, helps to coalesce water vapor into raindrops containing sulfurous acid ($S + O_2 \rightarrow SO_2 + H_2O \rightarrow H_2SO_3$), and causes rain to have a normal pH average of 5.6 throughout the world. Note that "acid rain" occurs at pH 4.2-4.4 (U.S. EPA). The manner in which nature naturally acidifies rainwater to this very day still remains largely overlooked. The pH level of rain as it free falls from the sky is often misperceived and considered by many to be abnormal and thought to be caused mainly by human activities such as burning coal and fossil fuels, instead of recognizing that, in reality, it is a common function and part of the earth's natural process.



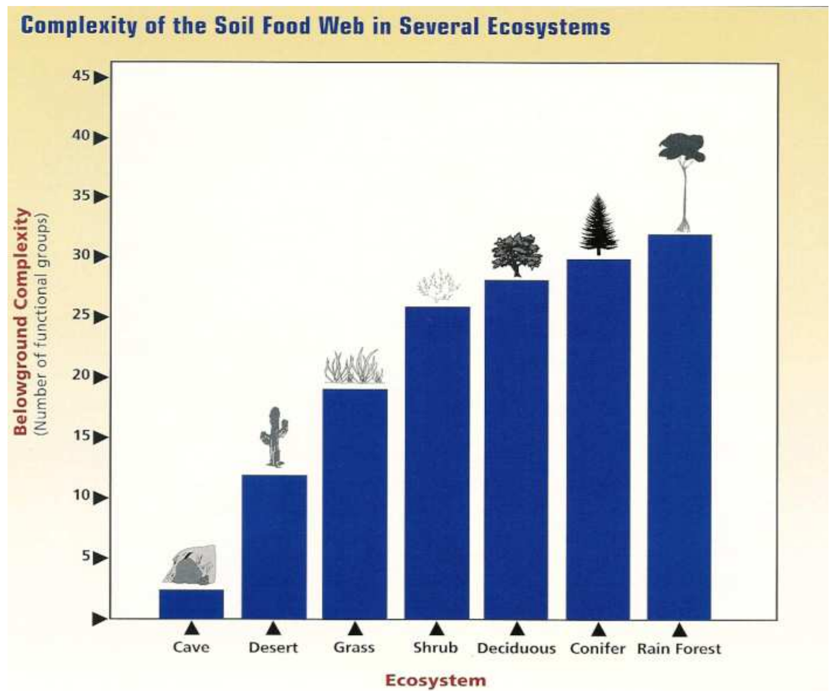
U.S Environmental Protection Agency

So, while it is important for us to look for ways to minimize pollution and protect the environment, it is equally important for us to avoid becoming confused as to how earth's natural process actually works. This is because when we formulate and choose our solutions, in order to become fully compatible and sustainable with nature, we must also be able to mimic and integrate the exact same process used by nature into our artificial systems (the ones that are failing) as well. And, we certainly can't do that if we continue to misinterpret it and believe in myths.


Coal Burning Power plant

The phenomenon of numerous volcanoes emitting sulfur dioxide (SO_2), and the ensuing reaction with atmospheric water vapor and seawater to liberate and create acidity, offers perhaps the most persuasive explanation as to why the element of hydrogen (H^+), is, and always has been, the real *common denominator* that sustains earth's ecosystems and how they became the way they are.

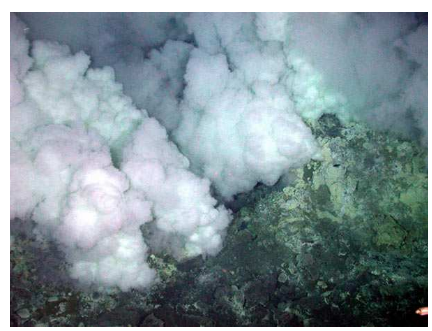
When we analyze the complexity of various ecosystems that exist on the surface of the earth, more often than not, we almost always assume that the most distinguishing feature and what sets them apart is the aggregate amount of water they receive. After all, it does seem to correlate and make sense. However, when we examine further, in the end, we could also find ourselves concluding that this may not be so true after all. Because while the role of water is indeed important, it may not be the volume or amount of water that really creates and sustains these ecosystems, it's the total aggregate amount of free hydrogen (H^+) that an ecosystem receives that makes them different. Rainwater is just the medium that carries and delivers it. Logic dictates that this must be so because, if normal rainwater had no acidity within it, it wouldn't be able to dissolve or breakdown rocks and minerals into soil. Without acidity in rainwater, none of these surface ecosystems would exist and everything on earth would be different.



Ingham, Elaine, Soil Biology Primer 2000

Recent discoveries of undersea volcanoes and hydrothermal vents reveal that this same acidifying process is also taking place on the ocean floor, as the pH range near them have been found to be 1.0 to 1.5, resembling battery acid and stomach acid (NOAA). Although the actual total has yet to be determined, current observations appear to indicate that they may number one million, and the overall volume of emissions from these underwater sources occur with much greater intensity and duration than we have ever thought or imagined, in comparison with those active and now happening on the surface (SIGVP).

Black Smoker Vent, Juan de Fuca Ridge, North American Plate, off CA OR WA coast NOAA


Hydrothermal vent Nikko caldera, Mariana Arc, South Pacific Submarine Ring of Fire NOAA

The chemical reaction below explains how nature converts elemental sulfur into sulfur dioxide (SO_2) to break apart molecular bonds of water to release two free and active hydrogen ions ($2\ H^+$) to create acidity.

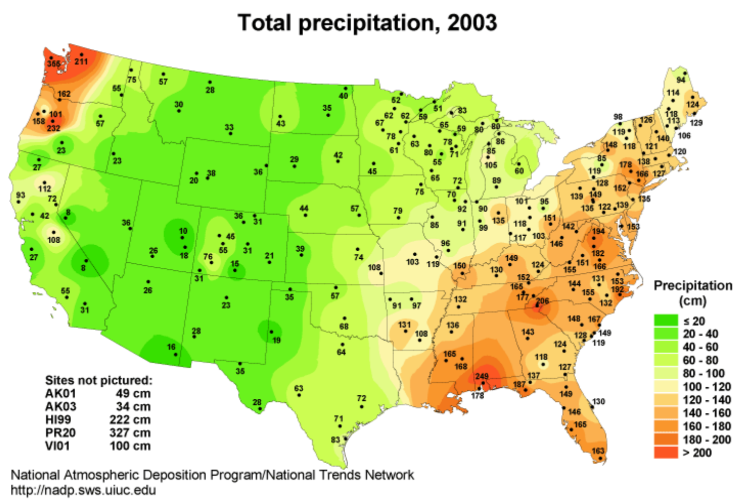
$$S + O_2 \rightarrow SO_2 + H_2O \rightarrow H_2SO_3 \rightarrow H^+ + HSO_3^- + .5O_2 \rightarrow H^+ + SO_4^=$$

Sulfur + Oxygen yields Sulfur Dioxide + Water yields Sulfurous Acid yields Hydrogen + Bisulfite + Oxygen yields Hydrogen + Sulfate

As this acidity becomes available, nature then utilizes these two hydrogen ions ($2\ H^+$) to neutralize and transform the Total Alkalinity, which is measured as bicarbonates (HCO_3^-) and carbonates (CO_3), within seawater and recycles it into pure water (H_2O), carbon dioxide (CO_2), and sulfate ($SO_4^=$).

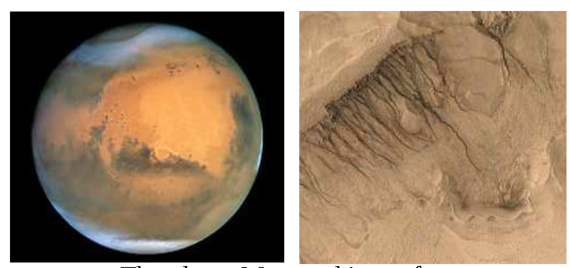
$$H_2SO_3 + HCO_3^- \rightarrow H_2CO_3 + HSO_3^- \rightarrow H_2O + CO_2\uparrow + HSO_3^- + .5O_2 \rightarrow H^+ + SO_4^=$$

Sulfurous Acid + Bicarbonate yields Carbonic Acid + Bisulfite yields Water + Carbon Dioxide + Bisulfite + Oxygen & Thiobacillus yields Acid + Sulfate



The acidity within rainwater also illustrates why land mass areas that receive high amounts of rainfall generally develop into acidic soils and why semi-arid and arid areas continue to remain alkaline (NADP). In addition, because the acidity within rainwater progressively dissolves salt carbonates within soil, additional soil pore space is created and more of the soil/air interface remains open, enabling salts to leach away from the root zone. This allows both oxygen and carbon dioxide to penetrate and exchange deeper throughout the soil profile. The ability to receive a steady amount of acidity from rain over time provides the most plausible reason why in high rainfall regions: soil salinity issues are rare; soils have higher microbial population densities and are able to sequester more organic carbon compared to those receiving less precipitation.

Precipitated salt carbonates near Bonneville, Utah



The planet Mars and its surface

The chemical process of sulfur dioxide emanating from volcanoes to break the molecular bonds of water into free hydrogen, and to reuse it over and over to transform and recycle the alkalinity within seawater back into pure water and carbon dioxide, may also be the most compelling reason why: the oceans of the earth remain diluted and have not precipitated out of solution; this planet has and continues to have an atmosphere and is able to support life; etc. When we consider what has already happened to inland seas that have no volcanic activity and/or receive very little acidity from rainfall, the importance of acidity may not be so far fetched, because as we examine Mars, it appears that it no longer has any active volcanoes (NASA). Could this be why that planet: appears to have surface areas with hydrological influence; no longer has an ocean or atmosphere; has been discovered to have salt carbonates on the surface, etc.? And, if volcanic activity on Earth lessened or ceased, could the same thing happen here on this planet as well?

The following illustrates how salt precipitation occurs when a system lacks the free hydrogen needed to keep them in solution. Other possible combinations include: sodium; potassium; magnesium; chloride; etc.

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

Calcium + Bicarbonate yields Calcium Carbonate + Water + Carbon Dioxide

The relationship between sulfur, water, and alkalinity is consistently evident, which is why we must factor in how these components interact, and the role they have whenever we interpret earth's natural process, manage our artificial systems, and approach issues such as global warming and ocean acidification.

The importance of integrating nature into our artificial systems

Creating and integrating enough free hydrogen to control the level of bicarbonates/carbonates is the key to improving the performance of our artificial systems. Because whether the problem is: soil salinity on farmland; mineral scaling on reverse osmosis filtration membranes, cooling towers and boilers; or finding a better and more sustainable way to process and utilize waste water; etc., the operational success or failure of these systems will be determined primarily by our ability to efficiently supply and regulate the proper amount of free hydrogen and pH within them.


Soil Salinity


Reverse Osmosis Filtration


Cooling Towers


Wastewater Treatment

One such way is to use a special type of equipment known generically as a SO_2/Sulfurous Acid Generator/Sulfur Burner. Unlike the methods that basically acidify by "importing and bringing in" free hydrogen derived and made from outside of the system (the way strong acids like sulfuric acid do), this technique acts like a "miniature volcano" to artificially condition the water to break apart and release free hydrogen within itself. This allows all of the acidity needed for pH control to be made within the system and entirely on-site, the exact same way nature does.

Harmon SO_2/Sulfurous Acid Generator/Sulfur Burner

Since sulfurous acid is a weak acid, as it releases its first hydrogen ion (H^+), the remaining portion converts into bisulfite (HSO_3^-), a compound that can be used to: prevent bio-film from plugging reverse osmosis filtration membranes; as a reducing agent to de-chlorinate water; as an aid to help deconstruct wastewater pharmaceuticals and perchlorate. Using this process to lower the pH even further will also result in causing suspended solids to settle and molecular sulfur dioxide (SO_2) to form in solution, which enables this process to separate and disinfect both sludge and water simultaneously. The combination of these features makes this method of processing promising and worth looking into for a variety of applications.

Conclusion

The most important part of problem solving is determining what the actual problem *is*. This requires objectivity and the ability to realize the existence of a different and more accurate paradigm. By reexamining volcanic emissions of sulfur dioxide and the chemical reaction it has with water, both in the atmosphere and within seawater, we can learn to utilize the common denominator behind earth's natural process. We will also understand the root cause as to why our artificial systems deteriorate and why it is so important to integrate nature back into our artificial systems to make them more viable and sustainable.

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