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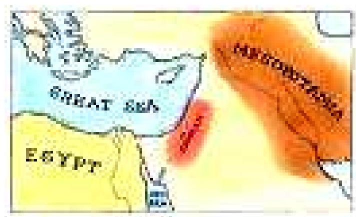
The Future of Wastewater Treatment: Organic Processing For Sustainability

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, numerous signs also indicate that we cannot improve upon them any further because they may be inherently flawed and incapable of meeting requirements for sustainability. Nature always has the final word and we have already been given enough warning to know that we are heading in the wrong direction. Why do we keep misinterpreting all of the facts? Perhaps we should consider that *when we can't find what we are looking for, instead of digging and simply making our hole bigger, sometimes we may be better off digging a new hole somewhere else*. This paper will identify what that fundamental flaw is, and explain why the future of wastewater treatment must adopt "an organic processing method."

Sustainability



The word "sustain," is defined as: *to hold, maintain; keep in existence; and implies long-term support or permanence*. When this term is applied to human civilization, sustainability means to have full compatibility with nature as we simultaneously process and dispose of our waste materials and obtain our food to feed ourselves. So, if we consider the ancient civilization of Mesopotamia, which lasted roughly six thousand years before collapsing from the accumulation of naturally dissolved salts on their farmland from irrigation water, we need to admit that they were "magnificent" in comparison to what we have done, because we are already retiring farmland after less than sixty years of practiced irrigation and our ecosystems are on the verge of collapse. What are we doing wrong and why are we on such a fast track?

Understanding what is going on and seeing the big picture

The principle 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 salt accumulation on farmland. History reveals this to be true, and yet, for the most part, we keep putting it off and have never given this issue the attention it deserves. Our general lack of concern has even caused us to compound it by building an infrastructure that contributes more alkalinity, salts, and other contaminants into natural waterways – the source for most of our irrigation water – than what they originally had.

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 add more sodium *(Na^+)*, chlorides (*Cl*), Total Alkalinity (bicarbonates HCO_3^-/carbonates CO_3^{2-}), trihalomines (*THMs*), ammonia nitrogen (NH_3), and pharmaceuticals, etc., into our natural waterways. We are doing this because when our population was smaller, 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 them by diluting them in our natural waterways and letting them flow through the Delta Estuary, San Francisco Bay, and on out to the ocean.

While this plan may have worked initially, things change, and we're now realizing that the systems that we are currently using and are so dependent upon are obsolete, and fundamentally incapable of doing what we need them to do.

Our population has increased dramatically and this has caused us to divert more fresh water from flowing into the Delta Estuary to supply: cities with drinking water; cooling water for power plants; farmers with water to grow food; industrial uses; etc. And, in return, we have replaced it with water that has a much higher level of wastewater treatment contaminants, is thermally warmer, with increased agricultural drainage, industrial pollution, and non-point source pollution, etc.

The aggregate of these artificial contaminants combined with natural constituents, lower flows, drought, foreign and invasive species, etc., has not only adversely impacted the entire Delta Estuary ecosystem, it is causing a massive degradation to our precious farmland when these materials are transferred via the California Aqueduct and Delta Mendota Canal and applied during the irrigation of crops.

Sadly, this same scenario is also happening in other parts of our country as well. Insanity is doing the same thing over and over again and expecting a different result. So, instead of building upon a system that we already know is flawed or trying to make our existing wastewater treatment systems become something that they can never be, let's process and dispose of our wastewater specifically so that it can be land applied to grow crops, and make our soils *better* not worse.

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.

Teamwork and working together

While government mandates have given the wastewater treatment industry a way out and the means to get around the regulatory limits concerning Total Maximum Daily Load limits, we must all recognize that the underlying problem has not been solved. It has only been shifted over to the end users and the property owners where that recycled wastewater will be applied. The problem is, if they can't solve it, and/or make a decent enough of a profit using it, they will try to get out of their original contract, use their property for something else, sell out their property, litigate, or give up and go broke.

On the other side, if end users and landowners see their crop yields and quality go up, and see a measurable improvement to the fertility of their soil, not only will they be eager for more, they will want a much longer term too. And the word will get around that using recycled water isn't such a bad thing after all. As it becomes more acceptable, it will make others eager to use it too. After all, nothing gets others to join in than a good old fashion success story. So how can we get there and where do we begin?

The first thing we need to do is to realize that the recycled water must be able to improve soil, not degrade it. At this time, none of our current wastewater treatment methods are able to do this, because they cannot transform or impart into recycled water what it needs. To understand why requires us to look to nature.

Achieving sustainability requires us to understand how nature works

Just as a problem cannot be solved until we know what the actual problem *is*, we cannot be compatible with nature if we don't understand how earth's natural process functions. Fortunately, nature has always provided us with an abundance of phenomena to observe. When we reexamine nature closely, we quickly learn that the element of hydrogen (H^+), also known as *acidity* in a free and active state, is the *common denominator* to earth's natural process, and estimated to be nearly 75% of all matter. Because hydrogen is so vast and constant throughout nature, it's easy to overlook and not include it when we approach problems and formulate solutions. Nature liberates it when it oxidizes elemental sulfur (S) into sulfur dioxide gas (SO_2), and bonds it with water (H_2O) to create the unstable compound known as sulfurous acid (H_2SO_3), a weak acid that sequentially releases its hydrogen ions ($2\ H^+$). That reaction is:

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

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

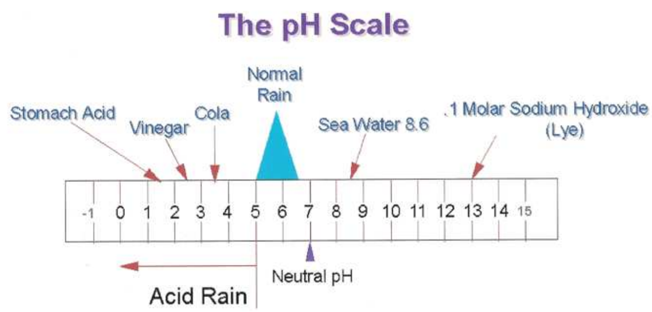
This same acidifying process takes place when sulfur dioxide (SO_2) emanating from undersea volcanoes causes seawater to break apart and release free and active hydrogen (H^+). The significance of this phenomenon cannot be overstated because by neutralizing the Total Alkalinity, bicarbonates (HCO_3^-) and carbonates (CO_3^{2-}), it appears that this is how nature has kept the oceans of earth from reaching super-saturation and precipitating out of solution. That reaction is as follows:

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

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

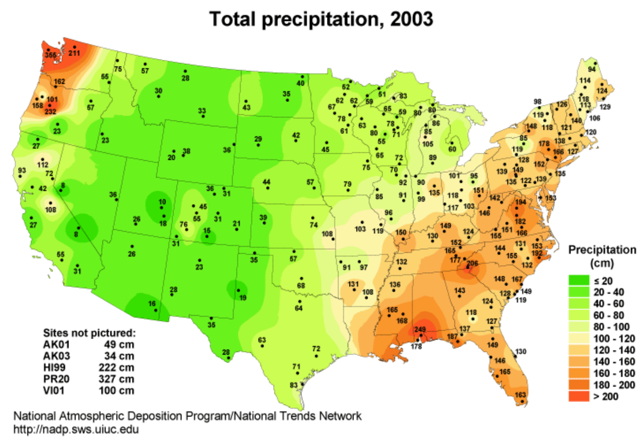
Hydrothermal vent Nikko caldera, Mariana Arc, South Pacific Submarine Ring of Fire; Black Smoker Vent, Juan de Fuca Ridge, North American Plate, located off CA OR WA coast NOAA; Mt. Pinatubo, Philippines; Mt. Etna, Italy

Nature also uses sulfur dioxide (SO_2) emissions from surface volcanoes to coalesce atmospheric water vapor to form into raindrops and causes rainwater to have a normal pH of 5.6 as it free falls from the sky. The acid component in natural rainwater is equally as important because upon contact with the earth, the natural acidity is neutralized as it dissolves rocks and minerals. And, it is through this process that earth's surface ecosystems are largely determined and is how they came to be.



http://www.ems.psu/info/explore/acidr/phscale.gif

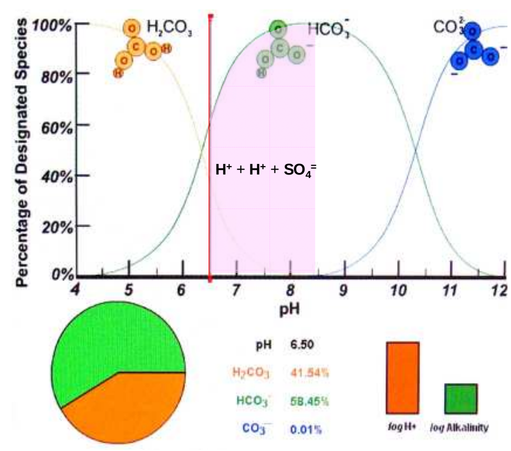
It also explains why high rainfall areas generally have acidic soils, and low rainfall areas, such as the southwestern part of the United States, tend to remain alkaline, and why soil salinity problems in high rainfall areas are rare. Thus, the correlation is obvious. If we want to prevent the problem of salt accumulation on soil, instead of approaching the overall problem from the perspective that there is an *abundance* of salt and we need to remove it from the water source, we need to reconsider the problem from the point of view that it is actually a *deficiency* of hydrogen (H^+) or acidity within that system instead. Please note that the neutralization of soil carbonates requires *twice* as much acid as compared to bicarbonates. That reaction is:



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

While we may have known of the need to add acidity into our artificial systems for quite sometime, the part that remains ambiguous to us is being able to determine the best and most efficient way to introduce it. This requires a more thorough understanding as to what the basic differences are between a weak acid versus a strong acid. The Carbonate Curve will help to explain.

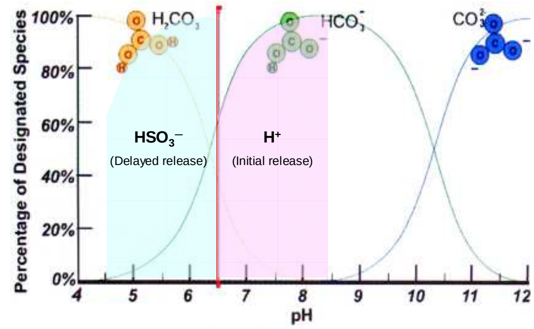
For example, if a farmer receiving 8.5 pH recycled wastewater were to use a strong acid acidifier like sulfuric acid (H_2SO_4) to lower its pH, the disassociation of its two hydrogen ions ($2\,H^+$) would release at the same time to start the neutralization of the Total Alkalinity, bicarbonates (HCO_3^-) 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 to a target pH of 6.5 (the pink shaded area on the curve depicts simultaneous release of the two hydrogen and the amount of needed to achieve pH 6.5). The reality is, 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

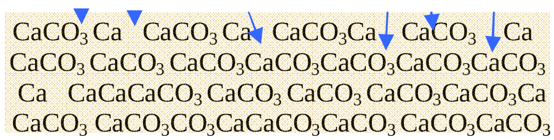
Conversely, sulfurous acid is different because as a weak acid, it releases its two hydrogen ions sequentially, which allows the first hydrogen ion *(H^+)* to release and the second hydrogen ion *(H^+)* to remain in solution as Bisulfite *(HSO_3^-)*. Thus, a water solution at 6.5 pH equilibrium containing 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 hydrogen release is depicted in pink and the second is in blue).



Carbonate Curve

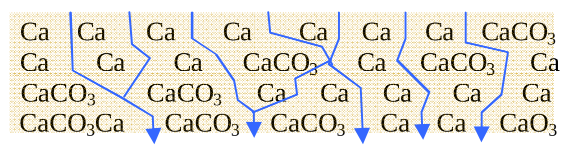
The major advantage of this delayed release of acid enables this method to: be safer for irrigation systems; be capable of providing the necessary acidity to neutralize all of the bicarbonates within the water; and deliver additional acidity into the soil in order to dissolve lime formations, both native and those created by using un-amended irrigation water.

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.

Thus, in order to become fully compatible and sustainable with nature, we must reintroduce a sufficient amount of free and active hydrogen (H^+) back into our artificial systems (irrigated farming) whenever possible. By transforming recycled irrigation water in these areas to carry and deliver the same level of acidity that normal rain provides, it may be possible to still improve the soil in semi-arid and arid areas despite the high salt content within recycled wastewater and absence of rain.




SO_2/Sulfurous Acid Generator/Sulfur Burners have been used for nearly sixty years to synthetically imitate the same acidification process nature uses for that same purpose, and was recently approved by the United States Department of Agriculture's National Organic Standards Program (NOSP) for the on-site manufacture of sulfurous acid for organic crop production.

The future of wastewater treatment

The following points explain how this technique can be used to improve farmland, benefit wastewater treatment operations, and protect the environment.

1. SO_2/Sulfurous Acid Generator/Sulfur Burner can also 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 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. This process improves the infiltration and percolation of wastewater treatment ponds and can also be used as a method to improve ground water recharging.
7. Unlike other methods that can only acidify by "importing" hydrogen from outside of the system, the way strong acids like sulfuric acid (H_2SO_4) do, 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.
8. This method will: increase field capacity and improve infiltration rates; reduce tail-water runoff and non-point source pollution; enhance ground water recharge; lessen the contamination of our natural waterways; leave more natural water to preserve the Delta ecosystem; reduce State and Federal pumping costs; and achieve what will be the biggest breakthrough in water conservation.
9. This method is viable because it is a cost effective solution to the overall problem, and may be the only way we can achieve consensus among the wastewater treatment industry, the agricultural community, environmental groups, governmental agencies and compliance regulators, and the public.

Conclusion

Our current wastewater treatment methods are fundamentally flawed, because they add additional contaminates into our natural waterways, degrade the environment, and increase the amount of contaminants being applied to our precious farmland. To reverse this trend, we must convert our treatment facilities so that we can land apply as much of our recycled wastewater as possible. For this to happen, recycled wastewater must be processed in such a way that will improve the land we apply it to. Present wastewater treatment systems cannot do this because they are physically incapable by design, and it appears that the SO_2/Sulfurous Acid Generator/Sulfur Burner water treatment process may be ideally suited for this purpose. This method has been amending water for conventional agricultural crop production and was recently approved by the USDA for organic crop production. The golf and turf industry has also adapted this technique to counteract the negative affects of recycled wastewater. There are plans to develop and integrate this technique as a post treatment process, and to operate it as a complete and separate wastewater treatment system. As this method continues to gain acceptance, it will give us a better sense as to the direction we must go to achieve sustainability and endure as a civilization.