



REMEDICATION AND REINSTATEMENT OF SOILS DAMAGED BY BICARBONATES AND SODIUM



The most comprehensive combination of sustainable turfgrass management amendment solutions to address salt and bicarbonate-related problems in turf

Salt accumulation in soils is estimated to affect nearly 25% of agriculture and turf acreage maintained via irrigation in the U.S. Most agronomists and scientists will point to irrigation water drawn from underground aquifers containing high levels of soluble salts as the primary cause.

The escalation of salt affected soils on golf courses in recent years indicates that a number of other factors also come into play as well.

Social and Regulatory Pressure

Increasing urban water demands in arid regions often makes high quality water less available for irrigation on golf courses. Many golf courses have been forced to use poor quality, recycled water that often contain high levels of sodium and bicarbonates in order to meet demand for potable water, demonstrate environmental responsibility, and in many cases comply with mandated use of these poor water quality water sources.

Golf Course Site Location

The vast majority of new golf course properties have been developed in coastal or wetland areas of the southern half of the U.S. These areas are prone to salt water intrusion in aquifers used for irrigation. These sites are also subject to tidal influences that carry salt water onto turfgrass sites.

Use of Salt-Tolerant Varieties

As the introduction of salt-tolerant turfgrass varieties found welcome audiences in many coastal and wetland areas, use of irrigation

water containing high levels of bicarbonates and sodium were allowed. Over time, soils with high salt content resulted, leaving many golf course superintendents suffering with heavily damaged soils and weakened turfgrass stands.

Irrigation Water Problems

Sodium. Sodium exists in nearly all irrigation water. At elevated levels (where Na ions are more than 15% of the exchangeable sodium percentage), Na ions replace Ca ions. Because the Na ions have smaller electric charges than Ca ions, they are adsorbed less coherently to the surface of the clay particle. When the soil particle are wetted, the hydrated radius of the Na ions force the clay platelets apart (swelling) and weaken the attractive forces. This process essentially destroys the structural units resulting in deflocculation and particle dispersion.

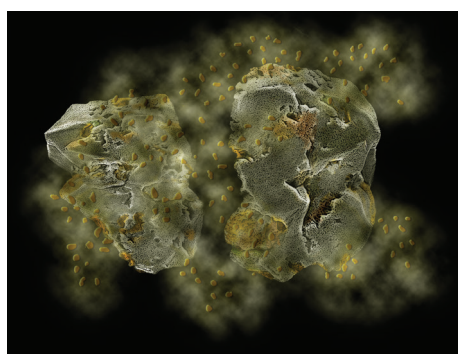
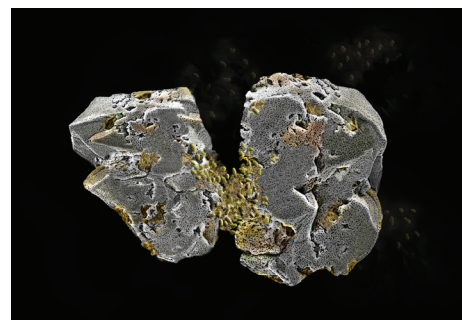


Illustration showing disassociation of clay aggregates and platelets.

In sandy soils, clay colloids can move in the soil solution and plug pore channels at pore interfaces.



Graphic depiction of plugged pore channel by colloidal clay particles and organic matter.

Carbonates. Carbonates greatly complicate the management of excessive Na. If bicarbonate ion levels exceed 150 ppm (> 150 mg/L, respectively), they will react with calcium and magnesium in the soil to form insoluble calcium carbonate and magnesium carbonate that precipitate from the soil solution. This leaves excess soluble Na to replace Ca or Mg on CEC sites – creating conditions for sodic soil development.

When water containing carbonates collect and dry at the soil surface, Ca and Mg carbonate deposits are formed (crusts) that inhibit infiltration of water into the soil profile. Furthermore, the deposits fill up the pore space between particles and greatly reduce the saturated hydraulic conductivity and air-filled porosity of the soil profile.

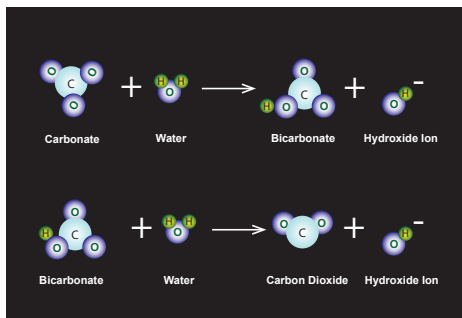


Illustration showing bicarbonate formation and increase in pH through OH⁻ production

Traditional Management Strategies

The traditional remediation treatment for saline soils was through application of massive amounts of water to leach the salt below the root zone. Multiple applications can leach most of the salt from a nominally salt-impacted (but not sodium salt-impacted) soil. Sodic soils require that the sodium first be displaced with calcium and then leached out of the root zone.

For soils that aren't calcareous and have a limited ability to supply their own soluble calcium, the initial use of calcium amendments is a common recommendation for soils with depleted calcium (Ca²⁺) and magnesium (Mg²⁺) levels and high sodium (Na⁺) levels.

However, in many sodic soils, poor water penetration and blocked pores due to build-ups of calcium carbonate and magnesium carbonate are insufficient to leach Na (usually in the form of NaSO₄).

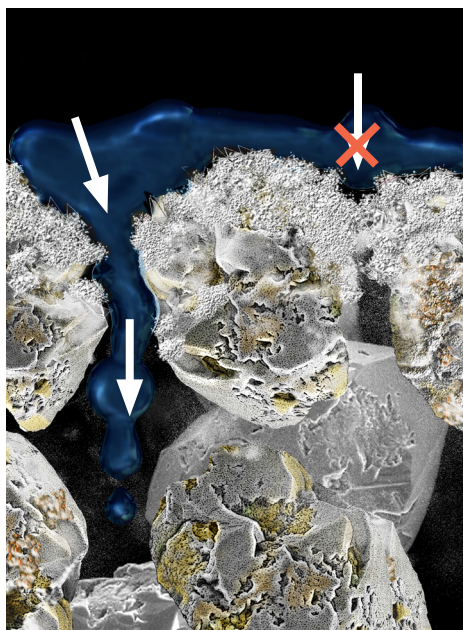


Illustration of sandy soil profile with calcareous deposits. Note unobstructed flow of water through pores on the left versus the blockage of applied water through pores on the right side of the soil profile.

Under these conditions, it is recommended that an amendment initially be applied to the soil as a surface spray first to dissolve and break up the surface obstructions.

Initial application of a surface applied amendment should be followed by routine surface sprays or injection of similar amendments through the injection system to maintain open pore spaces for penetration and infiltration of water to flush salts and sodium from the soil profile.

Not Just Clay Soils Are Affected by Bicarbonate and Sodic Conditions

Sodic conditions are normally attributed to just clay profiles. However, as sand-based root zones such as found on greens and tees mature, changes in the physical and chemical characteristics of the soil profile occur that also make them susceptible to problems associated with sodic conditions.

Soil Physical Characteristics. Following an 8-year USGA funded field study at the University of Nebraska's John Seaton Anderson Turfgrass Research Facility, researchers reported that infiltration decreased by 70% for a 80 : 20 (80% sand : 20% sphagnum peat) profile and 74% for a 85 : 15 : 5 (85% sand : 15% sphagnum peat : 5% soil) profile as sand-based root zones matured. They attributed reductions in root zone infiltration to build-up of fine particles, fine particle migration and organic matter layering.

Organic Coatings. Throughout the aging process, highly managed turfgrass produce large quantities of soil organic matter (plant materials, humic substances, root exudates, thatch, and roots). Once subjected to microbial action, soil organic matter (SOM) becomes the primary source of problematic organic compounds that coat the surface of soil particles – a major cause of water repellency and non-uniform movement of water through the soil profile.

Why Most "Traditional" Remediation Programs Fail

Successfully dealing with bicarbonate and sodic conditions cannot be accomplished without an approach that can deal with the broad range of problems associated with bicarbonates and sodic conditions on golf courses.

Yes, they can provide a short term remedy by promoting flocculation of dispersed clay particles as calcium displaces sodium ions on soil particles via the exchange processes. However, additional inputs of water containing sodium can rapidly reverse this mediation strategy in short order.

Other conditions such as hydrophobicity that can interrupt or prevent adequate pathways for sodium "flushing" and potential sodium toxicity in turfgrass also require solutions other than calcium-based initiatives as well.

Must Go Beyond Mediation of Bicarbonate and Sodic Conditions

Today, many soil scientists recognize that effective sustainable management of alkaline and sodic conditions call for going beyond just mediation of pH, bicarbonate complexes and hydrophobicity.

Poor soil structure and soil stability are the legacy of mediation efforts that target only symptoms and products that don't address longer term, soil quality issues. This requires that mediation efforts be supplemented with products and actions that lead specifically to the reinstatement of soil quality to the functional capacity that existed prior to their exposure to bicarbonates and sodic conditions.

No single product today can fulfill the requirements of both mitigation and reinstatement of soils damaged by bicarbonates and sodic conditions.

However **RIGHT WAY** represents a suite of products, methods and techniques that repair the damage caused by bicarbonates and sodic conditions and promote long term reinstatement of soil stability and biogeochemical function.



The combination of amendments that comprise the **RIGHT WAY** program for remediation and long term soil quality reinstatement is highly effective when dealing with salinity and bicarbonates on sand-based constructed soils such as found on greens, tees and surrounds. They also add additional value on older sand-based sites and clay-based soil profiles that may be subject to additional soil structural problems due to sodic conditions.

Treating Salt Affected Soils With pHAcid

Today, many soil scientists recognize that effective management of alkaline and sodic conditions in coarse textured soils found in greens, tees and surrounds centers on tactics that 1) reduce the pH of the soil, 2) remove calcareous build-up that inhibits effective leaching strategies to be initiated and 3) solubilize Ca and Mg carbonate – allowing these cations to displace Na from the soil CEC.



pHAcid is a unique combination of a blend of acidifying agents combined with a multi-purpose, high molecular weight surfactant.

This combination of complementary technologies is designed to be applied in a tank spray to provide the superintendent with a proactive approach to:

- Neutralize the negative effects of high bicarbonate and carbonate levels in irrigation water and the soil solution
- Lower pH of irrigation water and soil water

- Maintain the solubility of Ca and Mg in irrigation and soil water
- Dissolve calcium carbonate and magnesium carbonate salts on the surface (crusts) and in the soil profile
- Improve the ability of soil-applied Ca-based amendments to produce soluble Ca
- Flocculate dispersed colloidal-sized clay particles

pHAcid acidifying agents. pHAcid is an innocuous, non-fuming and non-corrosive acidifier that is very easy to use and environmentally safe. The pHAcid formulation is ideally suited as a replacement for strong acids used to treat carbonate-affected soils.

The pHAcid acidifying agents help eliminate the threat by carbonates (CO_3^{2-}) and bicarbonates (HCO_3^-) that tie up calcium and magnesium, allowing: (a) Ca and Mg in irrigation water to remain soluble so it can displace Na from soil sites, and (b) allowing soil applied amendments to be more efficient and effective in producing soluble calcium (versus being precipitated as lime or dolomite).

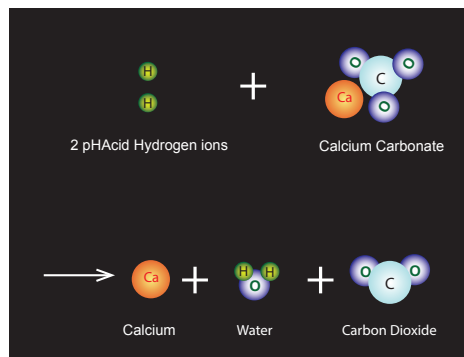


Illustration of acidification of calcium carbonate forming “free” calcium (exchangeable), water and carbon dioxide.

High Ca/Mg, High $\text{HCO}_3^-/\text{CO}_3^{2-}$. When high levels of calcium, magnesium, carbonates and bicarbonates are present in irrigation water and problems with high pH and/or infiltration rates are noted, acidification of the problem area with pHAcid Sprayable is recommended to neutralize the pH condition as well as to improve infiltration of applied or rain event water by solubilizing calcite deposits.

High to moderate Na, High $\text{HCO}_3^-/\text{CO}_3^{2-}$. If high levels of sodium (Na^+) are present in conjunction with high levels of carbonates and bicarbonates, acidification with pHAcid Sprayable is recommended to 1) release calcium from calcium silicate deposits so “freed” sources of Ca can be used to displace Na from the soil C.E.C. and 2) remove excess CO_3^{2-} and HCO_3^- so that Ca^{2+} and Mg^{2+} in the irrigation water and calcium applied amendments are allowed to remain soluble (rather than precipitated as lime) to displace Na from the soil C.E.C.

USE DIRECTIONS

We strongly recommend that water and soil samples be taken and analyzed on a routine basis in order to develop and maintain a comprehensive management plan to correct soils affected by bicarbonates and sodic conditions.

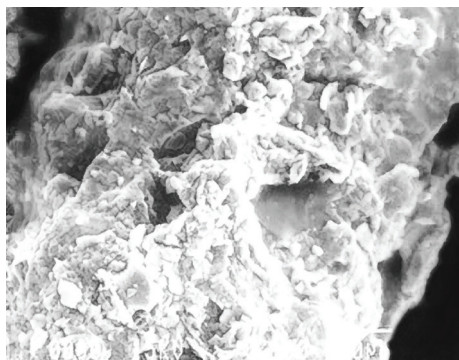
pHAcid Sprayable application program: 1 to 1.5 oz /1000 sq. ft. every two weeks Apply sufficient water to move product into the soil profile.

pHAcid treatments (in combination with soluble sources of calcium if needed) should be continued until calcareous deposits and water movement problems have been addressed and sodium-affected soil levels are below hazardous levels (base saturation <5.0).

Improving Water Movement (“Flushing”) with REVERT Surfactant

From a sustainable salt and bicarbonate management strategy perspective, areas of soil profile that are hydrophobic and exhibit non-uniform water movement patterns are highly problematic inasmuch as they prevent both water and selected amendments from doing their job – removing salts from the rootzone and reclaiming soils damaged by sodic conditions.

Development of these water repellent organic coatings on soil particles is progressive in nature. As a result, these coatings exist as thin films on the particle surface (early stages of development) that progress to a layer-on-layer build up (“caking”) of water repellent organic substances during later stages of development.



Electron micrograph of non-wettable (hydrophobic) soil particle. Layer-on-layer deposition of humic substances is very visible.

When water molecules encounter hydrophobic areas as they move through the soil profile, they cannot adhere to the surfaces of the soil particles, resulting in the disruption their uniform movement through the rootzone.

This disruption interferes with the ability of water to “flush” harmful precipitates such as water from the root zone.



REVERT is a unique formulation of DEPRO¹²⁹⁹, a blend of unique organic coating removal agents, combined with a best-in-class surfactant complex designed to provide the golf course superintendent with a broad, proactive approach to amelioration of localized dry spots, poor penetration and infiltration of applied water and non-uniform water movement into the root zone (the symptoms of water repellency).

Mode of Action

In REVERT’s Soil Water Repellency Management System, both its surfactant complex and the organic coating removal agents found in DEPRO¹²⁹⁹ participate in the dissolution of hydrophobic organic coatings on particle surfaces – both early stage films and later stage polymer build-up (“caking”).

DEPRO¹²⁹⁹ Organic coating removal agents. The DEPRO¹²⁹⁹ organic coating removal agents in REVERT deprotonate (remove) critical hydrogen atoms from areas on humic substances. Removal of the hydrogen atoms promotes conformational decay that leads to *separation and dissolution of organic layers due to repulsive forces*.

Removal of the organic coatings from soil surfaces contributes to sustainable reinstatement of the soil profile inasmuch as it returns the soil surface to a functional condition similar to what was present prior to its hydrophobic state.

Surfactant Complex. The surfactant complex used in the REVERT formulation are included to enhance the removal process by loosening and solubilizing the humic substances into the bulk solution as well as to facilitate the movement the coating removal agents in a uniform manner throughout the rootzone.

When used on a monthly basis, it’s best-in-class non-ionic surfactants will overcome hydrophobic conditions and promote a consistent and effective pattern of hydration and re-hydration of the soil profile.

USE DIRECTIONS

Apply REVERT at 6 oz. per 1000 sq. ft. in 2 gallons of water (180 ml. per 100 sq. meters in 8 liters of water). For best results, apply monthly throughout the growing season. No watering is required when used at recommended rates.



Converge Turf is a calcium silicate - based soil amendment and soil conditioner specifically designed to integrate within sustainable turfgrass management practices with emphasis on improving unfavorable characteristics in soils as well as increasing the physiological adaptive capacity of turf plants to tolerate abiotic stresses.

Reinstating Soil Structure and Stability

Sand, silt and clay particles are the primary mineral building blocks of soil. Soil structure is the combination or arrangement of primary soil particles into aggregates.

Flocculation and dispersion are important characteristics of clay soils. Flocculation is the process where the individual particles of clay are combined to form aggregates.

The degree and permanence of flocculation depend on the nature of ions present. For example, calcium cations tend to increase flocculation and sodium ions tend to decrease flocculation.

The process of cations swapping from solution to become bound to clay surfaces and vice versa is called cation exchange. It is this "exchangeability" characteristic of calcium with ions such as sodium that also reduces its ability to establish long-term stability (permanence) of aggregated soil particles.

Silicon's activity in the soil and plant result in the formation of "Collective Impact" solutions. Multiple effect solutions to problems in the soil such as improved soil structure and stability (improved air water ratios, drainage, salinity), mediation of metal toxicity and improved nutrient availability prevent exposure of these potential abiotic stress factors to the plant. This decreases the vulnerability index of the plant.

Initially, soluble silicates react with calcium or aluminum to form film or gel-like "binders" in the soil. These reactions are called "pozzolanic reactions." In high pH soils the reaction forms with calcium and/or aluminum to form calcium-silicate-hydrates (CSH) and with calcium and aluminum to form calcium-alumina-hydrate (CAH).

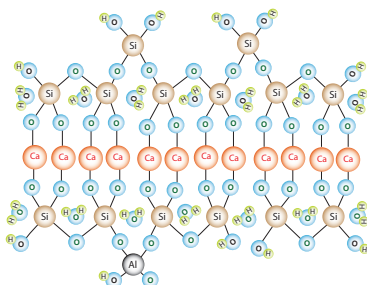
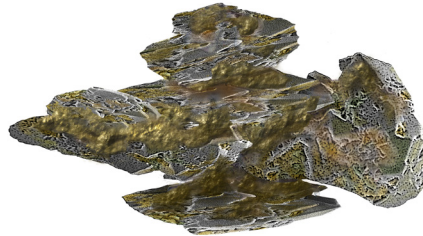


Illustration of calcium silicate hydrate (CSH) gel binder structure.

The binders formed following Converge application(s) have considerable advantages over calcium alone. They demonstrate more robust flocculation and aggregation characteristics than calcium alone and form significantly stronger bonds with the clay platelet matrix.

As the silicon matrix adhesive dries, its film and gel properties harden forming a more permanent cementitious chemical structure. When compared to calcium alone, CSH or HAS is far less susceptible to reversal should sodic or acidic conditions return. Both CSH and HAS are extremely insoluble.



Dehydration of CSH or HAS hardens gels and forms more structurally stable agglomerate.

Treatment of sodic or acid soils with Converge promotes a more consistent stabilization of such soils, demonstrating longer term improvement in shear strength, swell behavior, aggregate formation, porosity and cation exchange.

Metal Toxicity in Soils

Soluble silicates released from Converge applications act to ameliorate or reduce the threat of metal toxicity in a number of ways:

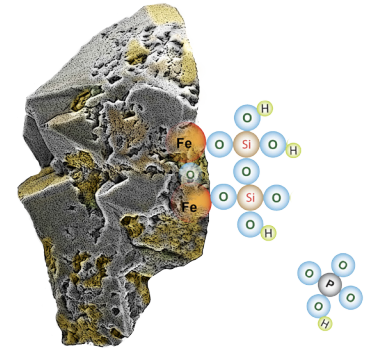
- Reaction of silicate anions with metals which then precipitate as metal silicates (co-precipitation)
- Adsorption of polymerized silicates onto metals on exchange sites
- Sequestration of metals and other contaminants with a silicate matrix

Phosphorus Fixation

The increased levels of silicates in the soil solution created by Converge applications provide the basis for key desorption process and adsorption processes that improve phosphorus availability in soils.

Desorption Processes of Silicates

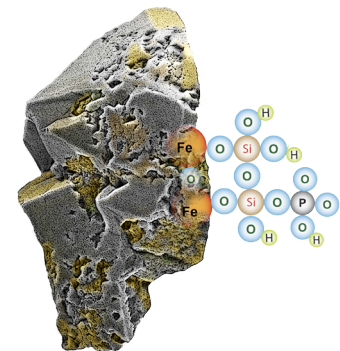
Increased concentrations of silicates allow them to free phosphate ions (desorb) from their attachment to metal oxides on particles surfaces. These previously "fixed" orthophosphates are now available for movement in the soil solution and absorption by the turfgrass roots.



Silicates "free" Phosphorus from metal oxides on soil particle surface

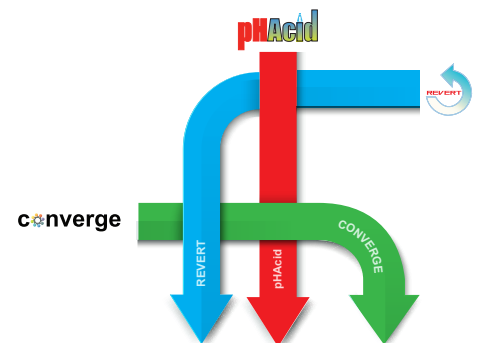
Adsorption Processes of Silicates

Once silicates have adsorbed onto metal oxides on the surface of soil particles, they establish sites new sites where phosphates can be adsorbed and later released for absorption by turfgrass plants.



Phosphate adsorbed to silicate complex attached to soil particle surface

In effect, the adsorption process of silicates reduces the phosphate fixation capacity of soils and also increases the phosphate "mining" potential of the soil.



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