

SUMMARY QUESTIONS CONCERNING SSAA TECHNOLOGY

1- What are sodic soils?

Sodic soils have a high level of sodium in them. Under the influence of the sodium, the clays contained in these soils can react with moisture and swell and clump. Once clays are swollen they do not allow any further water to permeate the surface. Clays that swell are often sought out for use as liners in dams. Evaporation is the only means by which these clays release the water.

2- Why are sodic soils bad?

Sodic soils are undesirable because when the reactive clays are wetted and clump, they form a surface crust or a hardpan and prevent the moisture from soaking into the soil. This crust formation makes the soil hard and retards nutrient availability and plant growth. With very low soil moisture potential, the growth of anything but shallow rooted salt resistant species is not likely. Typically, areas of severely sodic soils will have little if any vegetation.

3- What is the origin of the sodium?

Geologically, the sodium in soils originates from either the decomposition of alkaline rocks, or from leaching of ancient marine sediments. Groundwater dissolves the sodium from either of these sources and carries it into the soils according to its normal flow.

4- Why does the sodium accumulate in certain soils?

The level of sodium accumulation in soils varies with the geology, geography, and environment of the land. Two of the primary reasons for sodium accumulation are:

1) The flow of either surface or subterranean groundwater containing sodium is restricted by landforms, causing the saline water to pool in an area. The restrictions may be natural, e.g. an impermeable rock formation, or the result of human activity, e.g. soil compaction under a road construction. Evaporation of the water at this point concentrates the sodium.

2) Subterranean sodic groundwater rises to the surface because tree clearing has removed the deep-drawing root system which maintained the depth of the water table. Once sodic water affects soil clays at the surface of such a system, flushing is severely limited, and water is lost through evaporation. The clays then continually “wick” sodic water to the surface in a cycle which eventually leads to soil degradation. This mechanism is responsible for significant productivity losses in farmland throughout Australia.

5- What is the underlying cause of farmland degradation through sodicity?

As intimated above, human activity is a significant cause of soil degradation. The application of inappropriate, unsustainable, and environmentally damaging farming practices such as extensive tree clearing over subterranean sodium reservoirs has allowed these stores to come to the surface. In doing so, the soil structure is altered by the cycle of clay swelling and wicking, which eventually results in soil unfit to support agriculture.

6- Can sodic soils be remediated?

With reference to the Queensland Department of Natural Resources (QDNR) studies, sodic soils can be treated by a number of methods:

- 1) Pumping the sodium-containing groundwaters to a disposal area,
- 2) Implementing surface or subsurface drainage to remove incoming sodium-containing groundwaters from affected sites,
- 3) Mechanically opening up the soil to improve surface drainage, by ploughing or ripping to break up the clay crusts and open pathways for moisture penetration deeper into the soil,
- 4) Structurally improving soil permeability, by incorporating materials such as sand or compost which interfere with the clays clumping,
- 5) Chemically improving soil permeability, by reacting the clays with cements or other chemicals to reduce their tendency to swell, and
- 6) A combination of the above.

In considering these treatment options, it must be borne in mind that mechanical treatments such as ripping or ploughing must be periodically repeated in order to maintain the benefit, and this necessity rules out no-till farming methods. Likewise, structural modifications of the soil through incorporation of organics such as composts or mulches require high rates of addition.

7- How do sodic soil treatments work?

Quoting from the QDNR study regarding the treatment of surface soils: “This option refers to treating the surface soil with ameliorants, mulch or via mechanical means, aiming to improve soil conditions sufficiently so that water infiltration is improved, and vegetation can establish and grow. It may be considered on sodic, saline, hardsetting, or surface crusted soils.” Therefore these soil treatments work by increasing infiltration to flush salts from the soil surface, decrease evaporation and thus decrease the concentration of salt at the soil surface, and decrease the need for irrigation while plants are establishing.

8- What makes an ideal candidate soil for sodic soil treatment?

Four principal risk factors have been identified for determining the threat of sodification:

- 1) The presence of subterranean reservoirs of sodium within the rocks or groundwater.
- 2) Extensive tree clearing which gives scope for potentially saline water tables to come to the surface.
- 3) Nearby groundwater flow systems which go through sodic rock systems. Rainfall feeding these groundwater flow systems would give mobilise any latent salt stores.
- 4) It is generally accepted that soils in which sodium constitutes more than 6% of the mobile metals will be adversely affected by sodicity.

Therefore, a candidate for sodic soil treatment will be a soil overlying a subterranean sodium-rich reservoir, which was cleared of trees, and already contains a high level of sodium.

9- What agronomic benefits are derived from sodic soil treatment?

Besides retarding plant growth as discussed above, sodic soils have surface crusts which seal when wet and prevent rainfall infiltration. Therefore, they do not retain rainwater effectively. Formerly degraded soils which have been treated to reverse the effects of sodicity make more suitable matrices for plants to spread roots into and retrieve nutrients from, and are better able to absorb and retain rainwater. These

benefits result in higher sustainability and productivity from the soil, which in turn reduces the production pressure on other viable farmland.

10- Which chemical treatments are available for sodic soil remediation?

Sodic soil remediation can be performed using the usual “clay breaker” products, including lime, cement, or gypsum (which must be periodically reapplied to maintain the benefit). These treatments provide calcium to the soil, temporarily cements the clays. Alternative technologies also exist such as ferrihydrite treatment, which also cements the clays through permanent reactions of the clays with insoluble iron and aluminium compounds. However, any iron salt can be used to produce ferrihydrites to achieve the same reactions described above. The SSAA technology developed and patented by AGR is one such ferrihydrite treatment process.

11- What is SSAA?

SSAA is the acronym for a technology developed by AGR for the remediation of soils which contain sodicity-affected clays. The initials stand for “Sodic Soil Amendment Agent”. It is a patented chemical treatment which cements the clay particles to prevent their swelling reactivity to water, hence surface water is free to pass through the crust to be absorbed into the subsoil.

12- What is the chemistry of SSAA?

SSAA contains iron and aluminium salts. The iron and aluminium are in fact the principal active components which form a type of cement material known as ferrihydrite. Ferrihydrite is synthesised by reacting soluble iron and aluminium salts with alkalis to produce a colloidal hydroxide compound. This colloidal ferrihydrite is able to react with clays and prevent their swelling and clumping.

13- What is the ideal composition of SSAA?

Ideally, SSAA consists of a suspension or slurry of colloidal iron hydroxide which contains a significant percentage of aluminium hydroxide within its structure. The aluminium intermediate composition produces a cement material with superior strength to either the pure iron or aluminium products. Furthermore, when the material is delivered and homogenised into the soil in slurry form, rather than in powder or cake form, it is better dispersed into the target clay minerals for their more effective treatment.

14- Are there any naturally occurring examples of these ferrihydrite cements?

Yes, many natural tropical soils with high clay and iron contents (e.g. laterites, and specifically ferrosols) do not suffer from the same swelling problems of other clay soils. Their low reactivity is because of the iron having formed a natural cement known as a ferricrete.

15- Does the level of SSAA treatment depend on the soil?

Yes, since soils differ in their chemical characteristics and clay contents, the level of SSAA ideally required to treat them must be specifically calculated.

16- How is the SSAA application rate calculated for a soil?

Since the concentration of ferrihydrite required to treat a given clay can be established, the required SSAA dosage can be calculated from the quantity and nature

of the clays present. This result is further modified by other practical concerns such as application methodology and contaminant loadings.

17- How is SSAA made?

SSAA is made by blending an appropriate selection of iron-rich waste streams such as spent pickling acid from galvanisers and waste alkalis from aluminium extrusion plants. The iron in the acid reacts with the aluminium and hydroxide in the alkali to form the iron hydroxide compound known as ferrihydrite.

18- Why choose these waste streams in particular?

Galvanisers' spent pickling acids are rich in iron, while caustic soda from aluminium extrusion processes contains aluminium and hydroxide. Each of these waste streams therefore contains an essential component for ferrihydrite synthesis.

19- Can SSAA be made from commercially available products?

SSAA can in fact be made from purchased raw materials such as ferric chloride and alkalis, however, the cost of such chemicals is prohibitive. The additional benefit of deriving a reuse for these otherwise recalcitrant waste streams would also not be realised. Furthermore, the heavy metals contaminant issue would still exist to some degree, since in reality these so-called "tech grade" chemicals will not be pure.

20- How is SSAA applied?

SSAA is applied to a candidate soil by:

- 1) Identifying the soil type and performing a chemical and mineralogical analysis to establish the required SSAA dose rate.
- 2) Ripping the affected clay soil to the required depth, while injecting the SSAA at the required volume per treated area.
- 3) Ploughing the injected soil to homogenise it, using a range of square and disk ploughs.
- 4) Retesting the treated soil to determine whether the desired level of SSAA has been incorporated.
- 5) Making additional adjustments to the SSAA dose, or final adjustments to the soil pH with lime additions, then re-ploughing.
- 6) Further amending the soil with other organics, (e.g. biosolids), followed by additional incorporation.

21- What are the issues with using waste streams?

Since ferrihydrite is manufactured from waste streams, there are issues of product compositional variability and contaminants. Product compositional variations are dealt with in a number of stages: firstly by distributing sources of known high compositions across several production batches, secondly by bulk averaging of all other received volumes of materials, and thirdly in homogenising the SSAA product through the soil at the application stage by multiple pass ploughing. The foreign components of the SSAA blends include zinc, heavy metals (e.g. lead and cadmium), sodium and aluminium. Of these, zinc has an agronomic value, and aluminium is of chemical benefit to the ferrihydrite production, while the heavy metals and sodium are the contaminants which require management.

It should also be borne in mind that few other beneficial reuses are available as alternative processing for these waste streams, and disposal is often limited to Regulated Waste landfills.

22- What is the fate of the metals in SSAA treated soil?

1) Iron: Iron is the principal active constituent of the ferrihydrite cement which is responsible for remediating the adverse effects of sodicity on the clays. The nett concentration of additional iron in the treated soil is negligible when compared to the level normally present in a native soil. Typically SSAA contributes an additional 250 to 250 mg/kg of iron to a soil which may contain levels of the order of 50 g/kg.

2) Aluminium: Aluminium is a minor constituent of the waste alkali stream present at about 2 to 4 %, and is a major soil structural component, typically constituting levels of the order of 100 g/kg. However, ferrihydrite formulations including this element make stronger cements, which are better able to treat reactive clays. Therefore, it is a desirable component of the ferrihydrite treatment process. Nett soil addition rates of this element are of the order of 50 to 150 mg/kg to soils, and are therefore minor.

3) Zinc: Zinc is a micronutrient element which may present as an environmental contaminant under the wrong conditions. Through the range of available soil reactions, the zinc is divided between the available and mobile fractions, the ferrihydrite-bound fractions, and the carbonate-bound fractions of the soil. Each of these fractions may be leached and become available for uptake by the plants over a broad span of time. When the zinc is taken up by the pasture crops, it is consumed and gradually removed from the property by the herbivores as a vital nutrient. With regard to the soil microbial ecosystems, their functionality has been shown to develop a tolerance for the element despite significant alterations to their biodiversity. However, while the diversity of the microbial ecosystems may be affected, higher orders of flora and fauna within the pasture system show a distinct requirement for the element. According to literature reviews, the native flora are also tolerant of the metal. Soils with less than approximately 10 mg/kg of zinc are considered deficient, while background levels are of the order of 100 to 200 mg/kg. SSAA treatment typically delivers soils with similar zinc concentrations.

It is noted here that while pasture crops take up this metal, it is still at a level insufficient to meet the nutritional needs of the grazing livestock.

4) Sodium: Sodium is added during the SSAA manufacture as an unavoidable constituent of the preferred alkali. The sodium added with SSAA is labile (i.e. mobile) and ephemeral. Since the clays are reacted and the soil is made permeable by the SSAA treatment, the native and added labile sodium may both be easily flushed downwards or outwards from the surface during rainfall events. This flushing takes approximately 3 seasons, and the resultant surface soil is immune to the detrimental effects of dispersible heavy clays. Sodium addition levels delivered during the initial stages of SSAA treatment are below levels known to cause declines in soil productivity.

5) Other metals: The additions of heavy metal contaminants such as lead, copper, cadmium and mercury are limited to trace levels. Lead, copper and cadmium have nominated Trigger Limits of the order of tens of mg/kg, while mercury is an order of magnitude lower. The SSAA treatment regime will contribute sub-mg/kg levels of these heavy metals, and therefore fall far below Trigger limits. Furthermore, elements such as lead and cadmium are largely locked up by the ferrihydrite, and the uptake of their available fractions into the food chain is antagonised by the zinc.

23- Isn't adding extra sodium to a sodic soil harmful?

The sodium in sodic soils arises from massive ground stores, and sodification is a process of the upward mobility and accumulation of the element through the wicking action of the dispersible clays. The sodium added during SSAA treatment is of the order of 100 to 200 mg/kg, and therefore represents a small fraction of the natural subterranean stores. Since the nature of the clays is altered by SSAA treatment to be more permeable, the net mobility of the sodium is reversed, i.e. downward and away from surface accumulations. Therefore, as the ferrihydrite treatment takes effect, the soil structure experiences no ill effects from the added sodium.

25- Could the current process be improved?

AGR is currently exploring a number of processing options for the ingredient waste streams, in addition to implementing soil monitoring programs.

26- What guarantees are in place that there is no risk of environmental harm due to heavy metals?

As discussed previously, soil additions of heavy metal contaminants such as lead, copper, cadmium and mercury are limited to trace levels of the order of sub-mg/kg levels of these heavy metals, which are well below Trigger limits. The co-application of zinc further antagonises the entry of these heavy metals into the food chain and minimises their potential uptake by pasture crops. Furthermore, elements such as lead and cadmium are largely locked up by the ferrihydrite.

27- Why should SSAA be used in preference to the other technologies?

- 1) The ferrihydrite cementation chemistry which underpins the SSAA technology is superior in its clay reaction to alternative chemical and mechanical processes.
- 2) A QDNR study has previously suggested that the cost of chemically remediating sodic degraded land is very often prohibitive. However, the cost effectiveness of beneficially reusing the iron and aluminium present in the metal surface finishing waste streams makes the remediation of large areas of land economically viable.
- 3) Finally, an environmental benefit is achieved in that sodic, degraded land may be remediated, while diverting otherwise recalcitrant wastes from landfill towards reuse and alleviating the pressure on ever-diminishing landfill capacity.