HOW TO INTERPRET IF YOUR SOIL IS SODIC, USING SOIL PHYSICAL & CHEMICAL TEST RESULTS

Can do Sheet No. 11

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Sodicity in Practice

Sodic soils limit plant growth via poor **water infiltration**, increased **mechanical resistance** to root growth, and poor **water availability** in the soil profile. **Sodic soils** are also more prone to **erosion**, increasing the risk of topsoil loss and therefore the inevitable decline in **soil fertility**. The property of **sodicity** can be demonstrated by observing the reaction of an air-dry aggregate (3-5 mm in diameter) of soil placed in half a glass of rainwater. If the soil is **sodic**, within about 2 hours of being placed in the water a **milky halo** will appear. This is evidence that the clay particles have lost their 'grip' (**ionic bonds**), separating into individual particles (**dispersion:** refer to **Figure 1**).

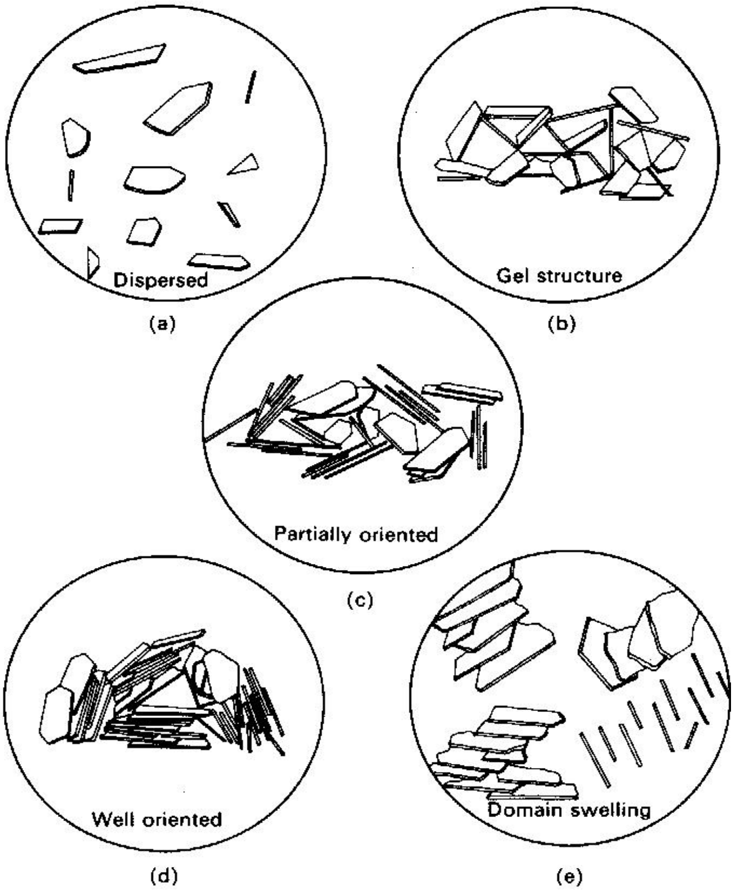


Figure 1:

The orientation of clay particles in water:-

- **a) dispersed clay particles, typical of sodic soils**
- **b) aggregated clay particles, retaining their structure due to the presence of stronger ionic bonds**
- **c) and**
- **d) partial collapse of clay particles, still with sufficient bonding not to disperse totally**
- **e) swelling of clay layers characteristic of some grey and black cracking clays**
  Source: figure 8.4 E W Russell (1973) Soil Conditions and Plant Growth 10th Edition

Why Clay Soils Disperse

Only soils with a **clay** content greater than about 20% have the potential to **disperse**. As indicated in **Figure 1**, clay types differ in the degree to which individual particles can bind together. Changing the **mineral** composition of the clay changes the strength of the bonds, and their ability to maintain their grip when placed in water. **Minerals** are solids, constructed of atoms that bind together in a systematic arrangement, which is repeated in three dimensions. All substances with a regular, ordered **mineral** structure are termed **crystals**. A common **crystal** encountered on a daily basis is halite, also known as **rock salt.**

In **rock salt**, each chloride molecule has a **negative** charge, which binds to a **positively** charged sodium ion. The packing arrangement of each of the molecules produces a characteristic cube (see Figure 2). The large size of sodium relative to its small charge, makes rock salt very **soluble** in water. Water is the product of the bonding of two hydrogen atoms with one oxygen atom. In water the atoms can repel each other, allowing for interactions with atoms held in weakly bound solids such as rock salt -**dissolving** it.

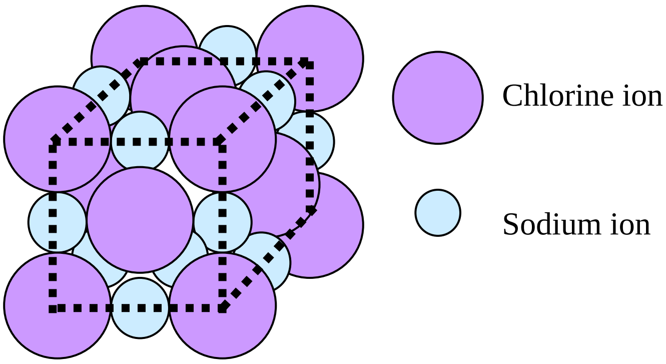


Figure 2:

The packing of ions of sodium and chlorine into the three-dimensional (dotted line), crystalline structure known as rock salt. Each single positively charged sodium ion is surrounded by six single negatively charged chlorine ions, and each single chlorine ion is surrounded by six sodium ions. Modified from Ernst 1969

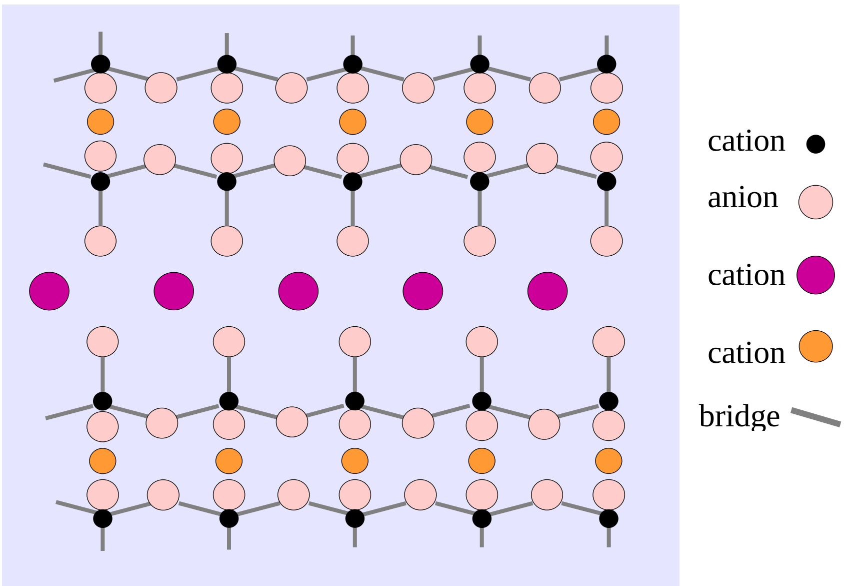
Sand grains or **quartz** are another common form of **crystal**, consisting of atoms of silica and oxygen. Every two silica (**cations** or positively charged) atoms bind with four oxygen atoms (**anions** or negatively charged). The balanced charge shared between the silica and oxygen atoms is very tight, prohibiting interactions with water molecules in soil water or with other cations. In contrast to clay particles, pre-existing grains of **quartz** break down only slightly under physical weathering.

In **clay** particles, the **minerals** are less regularly packed. The most common **minerals** forming clays are silica (**positive** charge or **cation**) and oxygen (negative charge or **anion**). In clays, the oxygen **anions** are shared with two silica atoms and other **cations** (including sodium, magnesium, calcium, iron, manganese and aluminium). The oxygen **anion** directly links two silicates (a bridge), with sufficient charge left to bind to the other **cations** that may be present in soil water. This bridging results in the formation of sheets of atoms, bound in layers or sandwiches linked by other cations (refer to **Figure 3**). If the **cations** in the sandwich are predominantly **sodium** ions, the layers lose their grip when water is added, allowing the broken layers to separate (**dispersion**).

Figure 3:

The sandwich structure of silicate clays.

Layers of silica ions (●) bridged with two oxygen ions ( ), form bonds with other cations (and). The strength of the bond differs with the cation. Weak bonds such as those formed with sodium ions cause clay particles to break up in water, clogging soil pores and increasing the mechanical resistance to root growth.
(Modified from Ernst 1969)



Physical Evidence of Sodicity: The Dispersion Test

Check how prone your soil is to **dispersing** by collecting a crumb (3 to 5 mm diameter in the air-dry state) of the suspect soil and placing it in a wide-mouthed glass jar. The wider the mouth of the jar, the less likely you will be to physically disturb the crumb when you add water to the jar. Place the jar on a dark surface, to allow for easier observation of the fate of the finer particles. Carefully add water to a depth of 1 cm or so, and leave the jar undisturbed for 2 hours. Examine at 2 hours, and then again if necessary at 20 hours.

If the bonds between the clay layers are very weak (sodium ions), then you will see a **halo** of very fine milky particles forming in a concentric ring around the crumb, even within 5 to 10 minutes. After 2 hours, considerable milkiness will be evident and much of the original crumb will have disintegrated, as indicated in **figure 1a**. If the bonds remain very strong, then even after 20 hours very little milkiness will be evident and the soil crumb will retain its original shape. If your soil is marginally **sodic** and you are irrigating with **saline** water, you may wish to repeat the test using irrigation water. Any additional **sodium** ions in the system will increase the potential of the clay particles to react with the water molecules, increasing the tendency of the fine particles to **disperse**.

Chemical Evidence of Sodicity: Interpreting the Results of Soil Chemical Analyses

The broken edges of **clay particles** have the potential to reversibly bind with **ions** in soil water (refer to **figure 3**), a property responsible for the high **cation exchange capacity** of clays. In some soils the bonding between clay and other ions may be so strong that despite being present in large amounts, the ions will not dissolve in soil water, and are therefore **not available** for plant uptake. Soil chemists differentiate between the **total** (including the tightly bound portion), and the **available** (less tightly bound or **exchangeable**) concentration of a cation. The chemical procedures used to extract the **available** or **exchangeable cations** are designed to reproduce the chemical conditions that occur in soil water.

Check your soil test analysis and add your results to **Table 1** beside the examples provided. Calculate the **sum of the base exchangeable cations** by adding up the exchangeable cation values in the column labelled **meq per 100g.** Add this value below the example of 29.01 meq/100g listed in the table. Now divide your **exchangeable sodium** value (bottom value that you wrote into the meq per 100g sample column) with the value just calculated for the **base cation exchange capacity.** Multiply this value by 100 to express it as a percentage, and add this value next to the example of 31% given in **Table 1**.

Base exchangeable cations	meq per 100g sample	Cation as percentage of total
Potassium (K)	0.71	2.4%
Calcium (Ca)	4.6	15.9%
Magnesium (Mg)	14.7	50.7%
Sodium (Na)	9.0	31.0%
Calculations derived from the data:		
Base cation exchange capacity (sum exchangeable cations in meq per 100g)		29.01 meq/100g
exchangeable sodium percentage (exchangeable sodium divided by sum base exchangeable cations in meq per 100g: x 100)		31%

Table 1:

Base exchangeable cations results for a hard-setting redbrown earth sampled at a depth of 30 cm. The base cation exchange capacity and exchangeable sodium percentage were calculated from the base exchangeable cations (K, Ca, Mg, Na) data

Under Australian conditions, a soil is classified as **sodic** when the adsorption of sodium on the surface of clays exceeds **6%** of the **base cation exchange capacity** (referred to as the **exchangeable sodium percentage** ESP=6). In contrast under American conditions, an ESP of above **15%** is used as the threshold value. The difference is related to the greater degree of weathering of Australian soils, resulting in a lower soluble mineral concentration in the soil water. Sodium leaches readily in soil water, concentrating at depth. High levels of exchangeable magnesium can also increase the risk of dispersion.

Therefore **sodic soils** are characterised by a **dense**, highly dispersed clay subsoil. The example referred to in Table 1 is a **hard setting** red brown earth, with a **medium to heavy clay subsoil** occurring at a depth of 30 cm. Root penetration is difficult due to the massive structure of the subsoil, and its proneness to becoming waterlogged (poor drainage). How well does you soil score? Do you have **physical**, **chemical** and **anecdotal** evidence (your experience) to suggest that your soil is **sodic**?

Making the Most of Sodic Soils

Sodicity and **salinity** are **not** the same thing! Soils may be **sodic** or **saline, or both. Saline soils** have a sufficiently high concentration of salts (commonly sodium chloride) in the soil to inhibit the growth of sensitive plant species. Moreover, **saline soils** generally do **not** change their structure at depth, and occur across sandy **and** clay soil types. **Sodic soils** limit plant growth via poor **water infiltration**, increased **mechanical resistance** to root growth, **waterlogging**, and poor **water availability** in the soil profile.

Sodic soils are also more prone to **erosion**, increasing the risk of topsoil loss and therefore the inevitable decline in **soil fertility**. Adding gypsum, lime or dolomite may reduce the dominance of sodium in the exchangeable cations. However it will not feed the soil animals that produce the micropores (better water infiltration), nor the soil microbes that bind soil particles together (better soil aggregation). The best management strategy is to improve the **litter layer** and the **organic carbon** content, **as well as** replacing the sodium ions by applying inorganic products (**Figure 4:** refer also to Can Do sheet 4: What is a Healthy Soil).

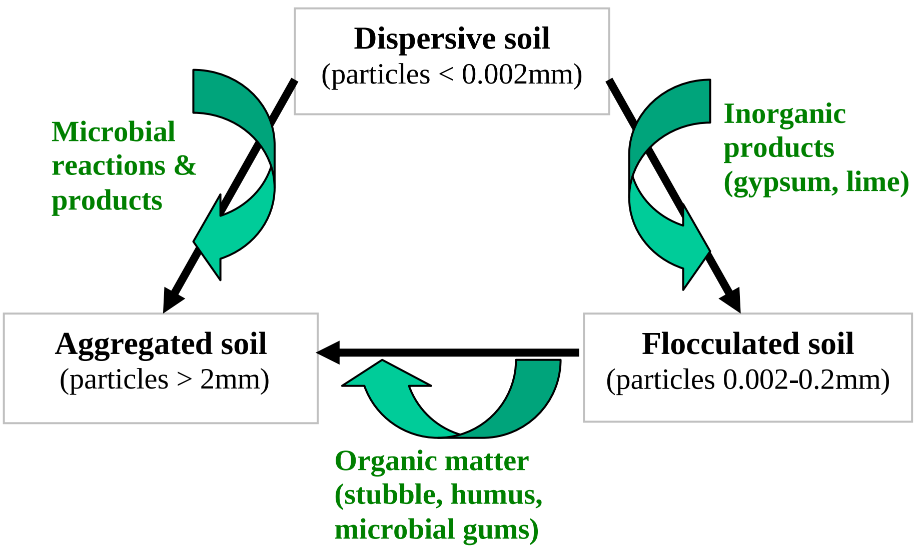


Figure 4:

The role of organic and inorganic amendments and microbial activity on the development and maintenance of structure in a sodic soil. In the absence of organic matter both the microbial processes and aggregation will be reduced. Modified from Rengasamy and Olsson (1991) Aust. J. Soil Res/ 29: 935-52

In summary **controlled traffic** and **conservation tillage** will assist in protecting the surface of the soil and will maximise the activity of soil animals, increasing the **infiltration** and the **water holding capacity** of the soil. The addition of **organic amendments** (retained stubble, green manures, composts) in combination with **inorganic products** such as gypsum, lime or dolomite will overcome the dominance of sodium in the clay particles, and will improve the **aggregation** of the soil.

Sheet last updated 03/2002