TERRASYSTEM®

TERRA-3000

PHYSICAL AND CHEMICAL REACTIONS

Physical and Chemical Reactions During Ion Exchange with TERRA-3000

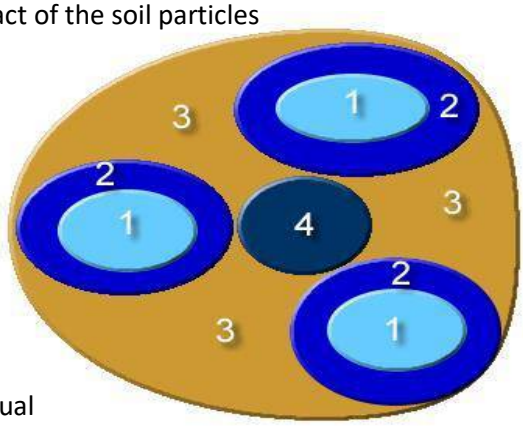
How does TERRA-3000 work as an ion exchanger and how does it work on silt and colloid particles during treatment?

This section looks at the specific reactions between water and soil particles. In soil mechanics, one usually draws a distinction between two water phenomena: static water and water in motion (such motion is caused by gravity). This greatly helps to accelerate many reactions which are triggered by TERRA-3000.

Static water, though not moving under the influence of gravity, cannot be regarded as fully motionless. However, the motion caused by osmotic forces or molecular movement is negligible. However, over a long period of time, considerable masses of water may be transported either in liquid or gaseous form (evaporation).

Static water contained in the soil can be classified into four categories. This classification is based on the order of magnitude of the force with which they can adhere to soil particles.

1. Chemical water bound within the crystalline structure of the soil
2. Absorbed water which is held on the surfaces of the soil particles
3. Water which is bound by surface tension to the points of contact of the soil particles
4. Capillary water in the pores between soil particles



Except for molecular water (point 1), which is chemically combined, all the above water categories are involved in the TERRA-3000 reaction process.
The main purpose of TERRA-3000 is to reduce the amount of water held in the soil, which forms voids in the soil. These voids can then be closed during compaction, therefore enabling optimum compaction.
The water reduction also decreases the swelling capacity of the individual soil particles.
We will now consider the functions of the different water categories in the soil.

Chemical Water

This water is incorporated in the crystal structure and makes up a very low percentage. It cannot be driven out by drying even at 110°.
This water is an integral constituent of the soil and so its influence can be disregarded here.

Absorbed Water

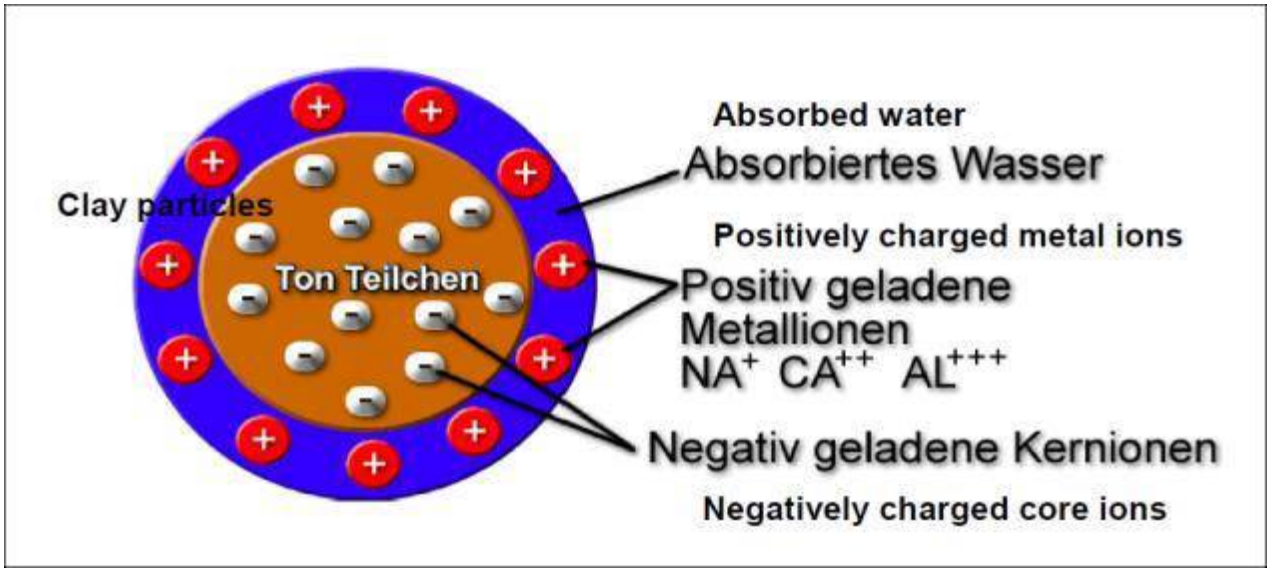
Water adhering to the surface of the soil particles can be partially, but not entirely, driven out by drying in an oven. During the cooling period, exposed, oven-dried soil will reabsorb water in an amount dependant on the humidity of the air around it.
Most of the water retained in soils is water held by surface tension. This either takes place at the points of contact between particles or otherwise moves as pore water or as free water in the capillaries, channels and passes.

Capillary Water

This water is held in the pores between the soil particles. It can be reduced through distillation, evaporation or extraction.
The biggest problem is in the form of absorbed water which is distributed across the whole surface of the soil particle and which is practically an integral constituent of the soil. This layer is mostly responsible for the swelling or shrinkage of soil particles.
The absorbed water cannot be driven out by purely mechanical means, although it can be increased or reduced through temperature changes, by adding or removing water, or via mechanical pressure.
This is the ideal point for TERRA-3000 to come in.

We will now look in more detail at the electro-static properties of soil particles.

By lowering the dipole moment of the water molecule, a dissociation takes place into a hydroxyl (+) and a hydrogen (-) ion. In turn, the hydroxyl ion transforms into an oxygen and hydrogen ion, and the hydrogen atom of the hydroxyl is transformed into a hydronium ion.
This hydronium ion, in the nascent state, can accept or reject positive or negative charges, according to need.
The finest grained soil particles normally have a negative charge. The outer layer of the absorbed water has enough positively charged metal ions such as sodium, calcium, aluminium or magnesium to balance out the negative soil ions.

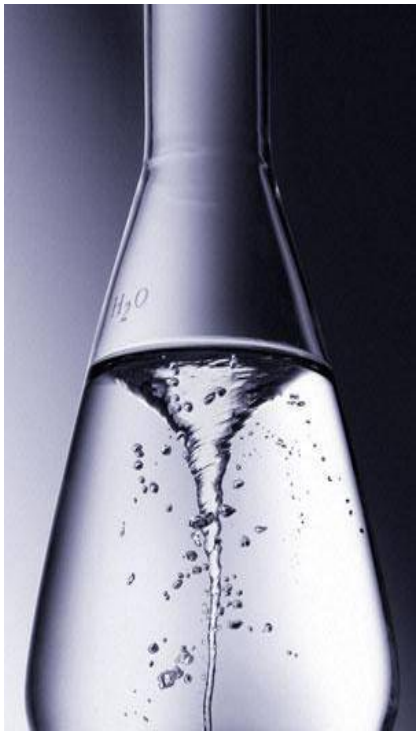


Absorbed, or hydroscopic, water is mainly responsible for the swelling or shrinkage properties of soils.
A soil particle which only has chemically combined water cannot swell, i.e. it cannot alter its structural density. Only the firm of absorbed water which is held to the particle surface with substantial force can expand in volume when water is added. Since this absorbed water is attached to the clay particles in a "stable" form, thickening of this film will cause the particle cores to move against one another.
The overall effect is an increase in the total volume. Therefore, to achieve the densest possible compaction of clay particles and to prevent such soil from swelling and shrinking, one must reduce the thickness of the water film (which, as explained earlier, is held to the particles with substantial force) or otherwise break the film.

The only way to do this on a permanent and cost-effective basis is through ion exchange.
The electro-kinetic properties of the TERRA-3000 solution mean that it influences both the positive and negative charges of the soil particles.

This has three consequences:

1. The absorbed water layer is strongly reduced or even completely broken.
2. The soil particles tend to agglomerate.
3. Through the movement of particles towards one another, the surface becomes smaller and can take in less absorbed water, in turn, this means that the swell capacity is reduced. Moreover, these three factors make it easier to compact the soil (or make it all possible).



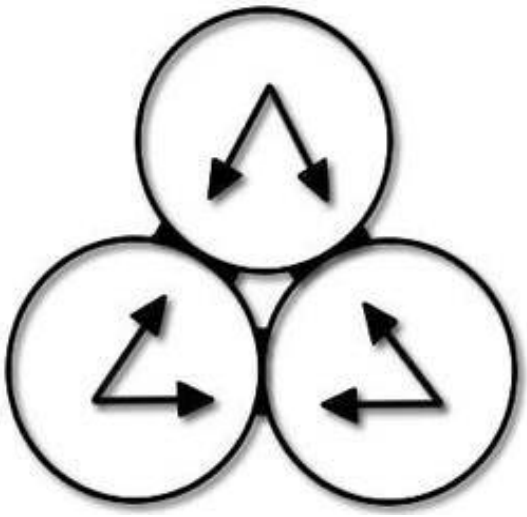
In this context, negatively charged Hydronium ions or the negatively charged Hydroxyl ions normally combine with the positive metals of the ionised water at the surface of the particle. Due to charge reduction triggered by TERRA-3000 in the water molecule, there are now sufficient quantities of negative charge to exert the requisite pressure on the positive metal ions of the absorbed water layer. As a result, the electro-static potential barrier is broken.

After this reaction takes place, metal ions can move across to the free water, which can then be separated from the soil or evaporated.

There follows a reduction in the layer of absorbed water, and soil particles lose their swelling ability, and develop a crumbly structure in the whole layer. This process is non-reversible.

The hydrogen ions which are liberated during dissociation of the water molecules can once again react with free hydroxyl ions to form water and gaseous H2. It is important to note that the moisture content of the soil affects the surface tension and is thus a factor affecting compaction.

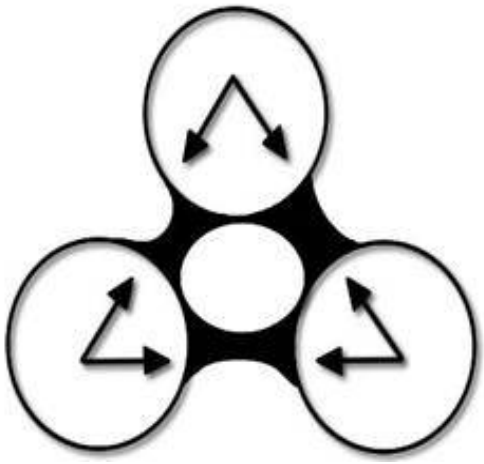
It should also be noted that dry soil is poorly suited for compaction only because of the surface tension of the water contained within it. Therefore, a certain quantity of TERRA-3000 solution is necessary for treating the ground in question. This is important, since if less than the total required quantity of solution was applied, this would adversely affect its penetration in the ground. The two phenomena (gas and water formation and surface tension) can be reduced by increasing the moisture content.



Large Surface Tension

Increasing the moisture content (less moisture content and reduction in the formation of gas and free water), the TERRA-3000 solution can penetrate more easily into the capillary structure of the soil and the ion exchange process can take place more rapidly. The water thus released can therefore either seep away or be driven out by the kneading action of say a sheep foot roller (and subsequently evaporate).

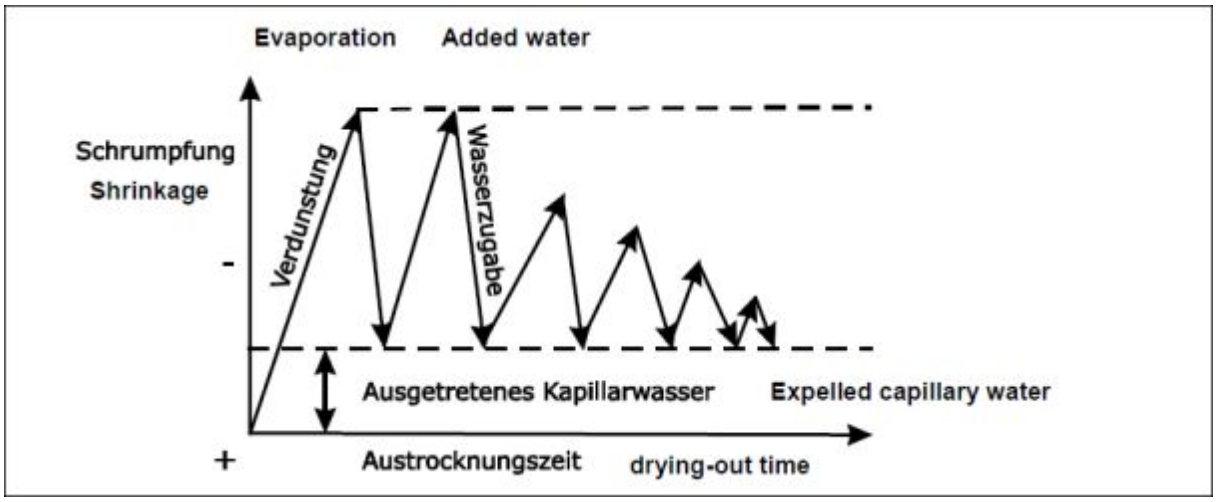
TERRA-3000 therefore creates favourable conditions for compaction by changing the zeta potential of the clay and silt particles. The zeta potential (electro-kinetic potential) decreases with an increase in concentration of ions of opposing charges from the TERRA-3000 solution. The cations and anions are liberated from the diffuse double layer, which reduces the swelling properties of the soil.



Reduced Surface Tension

The shrinkage versus time graph below clearly shows a saw-tooth pattern above the expelled capillary water, with shrinkage gradually diminishing towards zero. In other words: when water is added after shrinkage has occurred, the shrinkage decreases to amount matching the amount of capillary water that was expelled.

If the soil shrinks further through evaporation, the shrinkage that will then occur will never be of the same magnitude as before. This underlines the fact that those surfaces treated with TERRA-3000® solution and left uncovered will always increase in stability over a longer period.



The Properties of TERRA-3000® and their effects:

1. Reduction of the dipole moment which has a water repelling effect on the individual soil particles while at the same time reducing their swelling capacity.
2. The electro-kinetic phenomenon causes stabilisation of the soil particles. As a result, the soil acquires a higher shearing strength and its compatibility is significantly improved (thickness is a function of expended energy). Its penetration capacity is also strongly increased compared with untreated materials. Cylinder pressure tests and CBR tests can be used to demonstrate these effects.

In general, the soil particles align themselves parallel to one another due to the formation of an electrical "cushioning", which causes a sliding effect in the horizontal molecular structure (a good comparison here is the molecular structure of graphite).

Broadly speaking, a soil of colloidal character has the characteristics of a house of cards. This allows it to contain a reasonably large number of voids which are filled with either air or water. During treatment with TERRA-3000®, these voids must in any case be filled with pore water derived from the static water, or saturation of the soil triggers the previous flow effect. Only in this way can ion exchange through higher valency actions take place and the dipole moment of the soil particles be reduced. After the reaction has occurred, less water can accumulate in the soil than was possible before. This reduces the swelling capacity and the internal moisture of the soil. Maximum possible compaction then becomes possible because of the space made available through precipitation of the pore water.

Subsequent additions of water cannot reverse this process (the swelling capacity is destroyed and the shearing strength is increased). According to the laws of physics, the above reaction must also be able to take place in soil layers, in which water is not directly "moved" through penetration of the pores. The reason being that static water can also serve as a means of conveying ions. It is very difficult to establish the speed with which the reaction takes place in static water, since other electro-kinetic variables also play a part.

Many factors are involved: the resistance or potential barrier (which varies according to the type of soil), the specific pore water requirement of individual soil particles, which of course strive for saturation, the size of particles, the size of the area involved and the pH value of the soil. To ensure the working solution works perfectly, determine the minimum requirement according to the optimum water content of the soil, while a slight increase will result in a more intense reaction.

Under no circumstances, bring the water content to the saturation limit as this will lead to a loss of penetration and effectiveness.

Similarly, were the saturation point to be reached, the surface would then be sealed, because the original swelling effect.

General methods of treatment for clay and silt surfaces with TERRA-3000® as a chemical physical agent

The main property of TERRA-3000® is ion exchange. Since this cannot take place without water, it is of absolute necessity that the treated soil has a moisture content which ideally is a little higher than the optimum moisture content.
Subsequent addition of water weakens the forces between particles and almost breaks down surface tension completely, i.e. TERRA-3000® can penetrate more easily or reduce the layer of absorbed water by encircling the soil particles, and therefore penetrate the capillary structure completely.

It is not possible to reach all soil particles immediately through seepage of the solution. For this reason, we advise that you wait for the ion exchange through the movement of water by osmosis, considering the three-dimensional rod structure. At the same time, the gases resulting from the chemical reactions involved should be given sufficient change to escape into the atmosphere unhindered.

These processes, should run almost in parallel with one another. In climatic conditions with extremely high levels of evaporation, treatment should be postponed where possible until late afternoon or following morning during strong sunlight (drying out period). This is to prevent water losses.

The surface may need to be watered daily in the period between the last treatment with TERRA-3000® and compaction.

Re: Considerations for the examination of capilliarity
According to previous geological studies, it has been shown that the rise in capillary water remains within specific limits for various soils/soil types. As an example, the capillary rise for different soil types is given below.

Sand	2.0 – 0.6mm = 3 - 10cm 0.6 – 0.2mm = 10 - 30cm 0.2 – 0.1mm = 30 - 100cm 0.1 – 0.06mm = 30 - 100cm
Silt	0.06 – 00.2 mm = 1 - 3m 0.02 – 0.006 mm = 3 - 10m 0.006 – 0.002 mm = 10 - 30m
Clay	0.002 mm = 30 – (300)m

Labortest: After **2 weeks** in the water

Nr.: 1 without **TERRA-3000®**

Nr.: 2 + 3 other soil stabilisators

Nr.: 4 with **TERRA-3000®**

The assumption made here is that the capillary rise can be measured to this height. This would mean that all previous capillarity surveys relating to TERRA-3000® are not correct, since all such investigations, only soil cubes were used which were produced with a height of approx. 10cm. As a result, one had no way of measuring the capillary rise, since it went beyond the 10cm height of the cube. According to the expert opinion of a certified engineer, in this case, TERRA-3000® changes the properties of binding soils so drastically that the individual soil particles are no longer able to take in water in the form of pellicular water.

The main effect lies in binding soils treated with TERRA-3000® being able to be treated and compacted in the same way as loose soils can. As a result, it follows that the capillary rise must adjust itself to the changed soil material.

This would mean for example that a silt soil which, untreated, has a capillary rise of 1-3m, would only be allowed to have a capillary rise of approx. 10-30 cm after treatment with TERRA-3000®. This would mean that all previous surveys carried out with TERRA-3000®, in which soil cubes having a height of 10cm were used, cannot provide any meaningful data on the capillary rise. In turn, this would mean that for a soil treated by TERRA-3000® having a depth of approx. 2m plus, a capillary rise of up to 50cm could be possible. Nevertheless, the soil remains completely frost proof up to a depth of 150cm.

Given that the capillary rise is always the same for the same soil material, it logically follows that the deeper penetration of TERRA-3000® also means that the frost resistant foundation layer becomes more and more stronger.

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