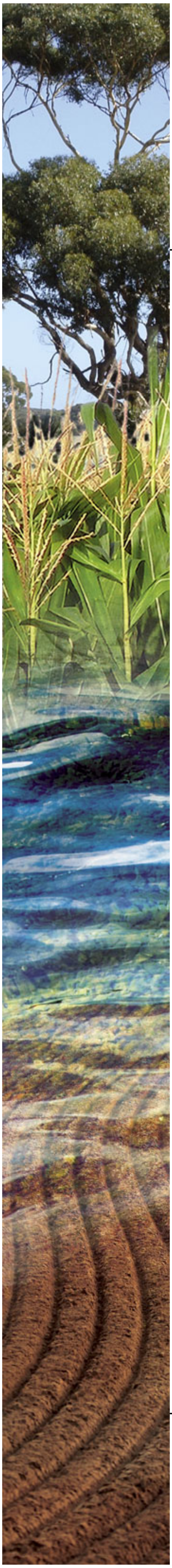

Sydney Environmental & Soil Laboratory

Specialists in Soil Chemistry, Agronomy and Contamination Assessments

Salinity and Structures: Measurement and Interpretation of Results

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Salinity and Structures: Measurement and Interpretation of Results

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Abstract

Conventional soil salinity maps are agriculturally based and do not provide a basis for interpreting possible risk to structures. An environment pronounced saline for agricultural purposes may pose no threat to built structures. These maps do provide warning that site investigation should occur.

There are accurate test methods available to provide qualitative assessment of corrosion and aggression risk. These include measurement or assessment of permeability, pH, total salinity, electrical resistivity of the soil mass, and measurement of the ions sulphate, chloride, ammonium, calcium and magnesium. A risk category can then be assigned.

The type of intervention required to protect structures in a saline environment increases in cost and complexity with increasing risk category. In most situations avoidance (burial of saline soil) and good building practices (vapour barriers, coverage of reinforcing) is quite adequate to protect the structure. Only in highly saline environments are specific measures such as stainless reinforcing, densified and water proof concrete justified.

Corrosion and Aggression

This discussion focuses on the effects of salts on metal and concrete. Other factors such as acidity and low calcium carbonate saturation can also cause corrosion and aggression.

Salts are responsible for hastening the corrosion of metals and disruption of the crystal lattices of concrete (aggressiveness). To cause the corrosion and aggression these substances must be dissolved in water, either as free water or as soil pore water.

Corrosion of metals is essentially an electrical conductance phenomenon either oxidative (rusting), where oxygen is the oxidant (rusting) or galvanic, where a dissimilar metal or other ion is the oxidant. Salts in water themselves have no direct role in corroding metal other than by promoting electrical conductance. Thus an aqueous environment high in oxygen (or a dissimilar metal) and high in ionic substances such as the intertidal splash zone is the most corrosive known. Combine an oxidant (oxygen) with a solution of high electrical conductance (seawater) and corrosion is acute and rapid.

Aggression toward concrete is not dependant on electrical conductance but depends on the types of ionic substances present. Different ions will cause either an expansive change, and/or a loss of cementitious properties thus affecting concrete strength. Permeability of the concrete itself to air and moisture is the overriding factor influencing concrete durability/resistance to chemical attack. Three types of degradation can occur-

- Spalling, due to mechanical stresses within the concrete resulting from the formation of expansive salts within the matrix itself. Disruption caused by any salt is more severe with wetting and drying cycles and no leaching. Any porous masonry is prone.
- Leaching: leaching of the Ca in the concrete, especially with soft water (low [Ca^{2+}]).
- Destabilization of the Ca silicate structure. Cation exchange of Mg^{2+}, NH_4^+ with the Ca in the concrete, anion replacement (SO_4) as well as acids dissolving CO_3 and Ca^{2+} result in the formation of voids within the concrete. Sulphide ions, are also highly aggressive.

In all discussions on salinity for built structures we should clearly differentiate between **acute** corrosion or aggression and insidious or **chronic** corrosion and aggression. The tables and criteria given in the various guidelines mentioned below relate to risk of acute aggression and corrosion. Steel for example will slowly oxidise even in the atmosphere but this is not acute or rapid corrosion. Concrete or masonary will slowly ablate (or spall) above a poor quality damp course due to salt rise and mechanical disruption of structure even at very low salt levels.

The Scale of Salinity

All soil solutions contain some level of salts. The effect of these salts on plant growth is very well established through countless experiments. The soil maps available usually from public authorities (eg the Soil Conservation Service of NSW 1:100,000 series) have been produced by soil scientists, usually from an agricultural use background. It is important to remember that a soil pronounced as saline by an agronomist may not be any particular threat to built structures. Figure 1 schematically illustrates the range of salinities impacting on plants vs built structures in comparison with seawater as the datum.

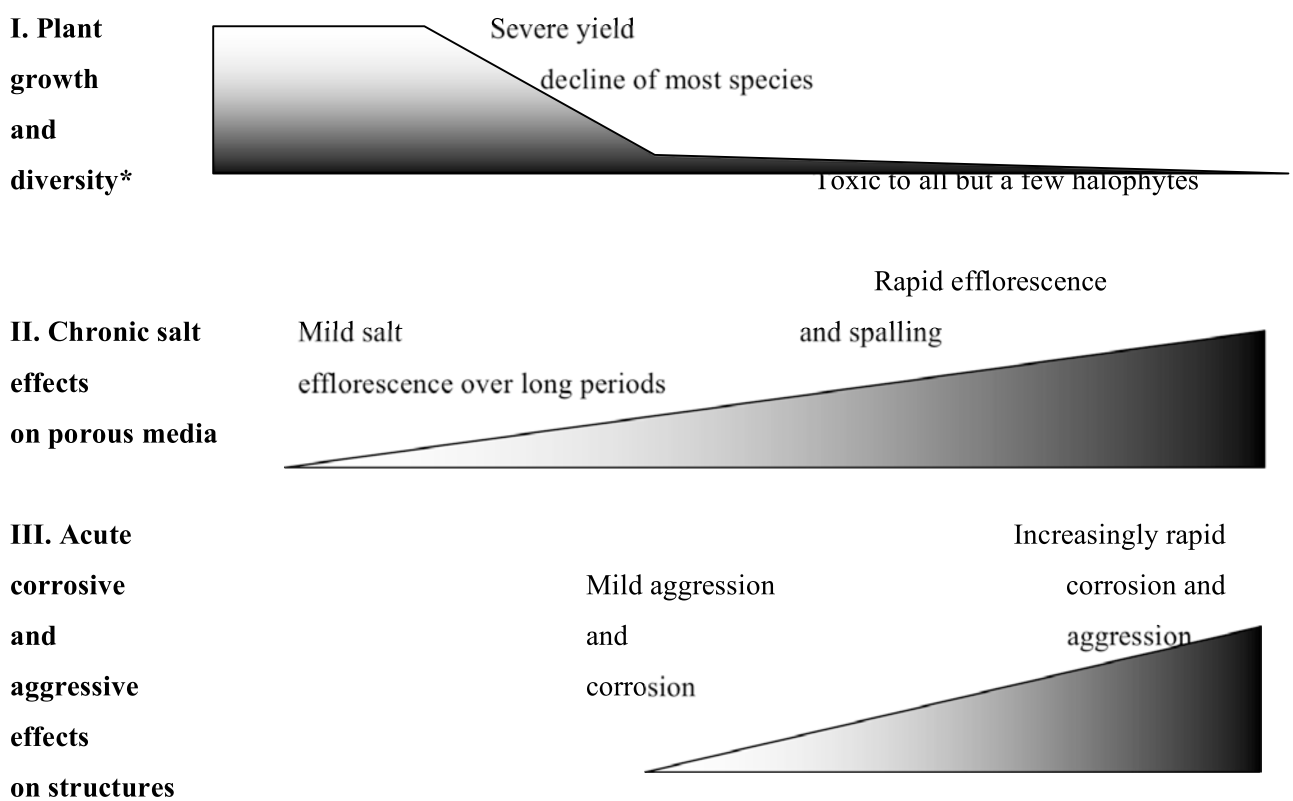
Analytical Note: EC or Electrical Conductance of a solution is the inverse of electrical resistance and is measured with a conductance meter. The units used to be in mhos (inverse of ohms for resistance) now they are in Seimans (S). The common unit is mS/cm or uS/cm but the true SI unit is dS/m, meter being the SI denominator.

The most important conclusion from this comparison is that salt levels that will affect plants are much lower than those that will acutely affect built structures. From this conclusion arises the statement that agricultural based predictions of salinity are of little use in interpreting possibly acute affects on structures. For example, at about ¼ the salinity of seawater most plants are dead but acute corrosion and aggression toward structures would not be predicted.

Other factors that influence the propensity of a soil to cause corrosion are its pH (acid soil and water will literally dissolve the carbonate matrix of cement) and its permeability. A highly porous and permeable soil will allow a more rapid flow of ions and corrosive agents. Poorly permeable soils tend to insulate the structure from rapid flow of salts and electricity. Thus for the same pore water salinity a sandy soil may prove more rapidly corrosive or aggressive than a heavy clay. The texture of soil is sufficient knowledge to assign a “Permeability Class” as an aid to diagnosis.

Figure 1. Indicative Salinity Risk to Plants and Structures

Determinant	1/10 seawater	1/4 seawater	1/2 seawater	1 x seawater	2 x seawater
EC dS/m	5.5	13.8	27.5	55.0	110.0
Cl mg/l	1990	2488	9950	19900	39800
SO_4	280	350	1400	2800	5600



qualitatively estimated from Umali (1993).

Agricultural soil salinity maps are useful only to alert us to the need for **specific corrosion and aggression measurement** techniques.

Measurement of Corrosion and Aggression

The assessment of the potential impact of salinity on built structures is not a precise science. Corrosion does not simply start at some minimum level of salinity, a sliding scale of increased risk occurs with a complex interaction of exacerbating factors.

Salinity measurement itself, having been based in agricultural science, is done by simple EC measurement in a water or by making a dilute extract of a soil, usually a 1:5 extract ratio. This dilute extract can then be converted back to an estimate of what the actual soil pore water would be (ECe) by multiplying by a texture factor. An EC can further be converted to mg of salt per litre of solution (TDS) by multiplying by 640 (ie an EC of 1dS/m = 640 mg salt/l). The ECe or TDS is regularly interpreted for its impact on plant growth (See DLWC 2002 Table 6.1 page 21 for example). It is of limited use for interpretation of impact on structures other than perhaps as a cheaper initial screening test.

Analytical Note: Electrical Resistivity of Soils in the context of corrosion and aggression assessment is not the same as the reciprocal of the conductivity measurement on a water extract as described above. Rather it is the electrical **resistance of the total soil mass as saturation moisture content**. The method requires a paste to be made of the soil and the measurement of resistivity of the entire paste using the AS1289.4.4.1(1997) method. While we perform the measurement in the laboratory the same hand held equipment can be used in the field by inserting probes into the soil. Resistivity of the total soil mass is the ultimate test of its propensity to promote the flow of electrical current and hence corrosion. It takes into account the salinity of the soil solution as well as the permeability of the soil and the inherent electrical conductivity of the soil minerals (clays vs sands).

Sydney Environmental and Soil Laboratory has developed a “Corrosion and Scaling Assessment (CSA) pro-forma for both soils (CSA-s) and waters (CSA-w) attached as Appendix I and II. This result form was developed using the various Australian and International Standards as given in the reference list. Basson (1989) is also a particularly useful reference for an understanding of the causes of concrete aggression.

Currently the interpretation of these results is judgemental and qualitative. Not only do we consider the worst aspect of the soil or water (for example it may be very acidic but not particularly saline) but how the factors may interact. For example a given salinity level may be less alarming in an impermeable soil than a permeable soil. Even these standards are naïve. For example they rely on pH, an intensity measure and ignore buffer capacity, a quantity measure more likely to cause long term effects. Again the sort of criteria given in Table 6.1 page 22 of DLWC 2002 are a guide only to the sort of precautions that may be applicable. No one can precisely determine corrosion rates from these measurements.

Comparing Risks, Agriculture and Structures

As stated above it is highly likely, as a result of the agricultural based history of salinity assessment that builders could be falsely alarmed at indications of salinity from published literature. Taking the ionic concentrations in seawater this discrepancy between salt levels that cause risk to plants and to structures can be illustrated in Figure 2.

Figure 2. Dilutions of Seawater and their risk rating to plants and structures.

Determinant	1/10 seawater	1/4 seawater	1/2 seawater	seawater	2 x seawater
EC dS/m	5.5	13.8	27.5	55.0	110.0
Cl	1990	2488	9950	19900	39800
SO_4	280	350	1400	2800	5600
Risk Category for the use and the ion causing the risk					
Concrete	non aggresive	mild – Cl	moderate SO_4	Severe- SO_4	V. severe SO_4
Steel	mild – Cl	mild – Cl	mild – Cl	moderate – Cl	Severe – Cl
Plants	most plants showing yield decline	very severe yield decline all plants	Acute toxicity to all crop plants	Specialist halophytes still alive	Few specialist halophytes still alive

This simple analogy then illustrates that a soil considered too salty for agriculture could have virtually no or a very mild effect on concrete structures and only a mildly corrosive effect on steel.

Comment on Sampling

DLWC 2002 provide some quite thorough advice on the frequency and methods of soil sampling. As experienced field consultants SESL would emphasise the catenary relationships (topographic position) and the profile relationships (order of soil horizons). This arises because the location of salts in the environment is predictable since water flows downhill and carries the salt with it. Thus salts are more likely to collect at the bottom of the hill or the bottom of the soil profile. In humid environments saline topsoils are very unusual even if subsoil is highly saline.

Our general advice would be to spend most of the clients money on the lower slope positions and on the lower parts of the profile. Any soil survey should end up with more subsoil samples than topsoil and more lower slope soils than upper slope soils. A very useful exercise is to conduct some soil profiling (take a salinity measurement every say 200mm down the profile) to inform the detailed site survey. This can save much useless analysis of the salt free upper horizons.

Aside: Salinity in Western Sydney. In natural soils of this area formed on saline shale the topsoil is usually perfectly free of salts as is the B horizon. Only into the C horizon is the salinity present. This is not the case in degraded soils for example those seriously eroded or scalded by alteration of the hydrology.

Degree of Risk and Intervention

There is some degree of hysteria in regard to the intervention required to reduce the risk of acute corrosion and aggressiveness toward built structures. There is also a design life consideration. We have had rumours of councils requiring stainless steel reinforcing and all sorts of measures which increase costs for home owners, consume resources and may be totally unnecessary.

The first and most necessary step in protecting structures is not to bring saline material and the structure into contact. Soil stripping and correct reinstatement is paramount. SESL has emphasised the importance of recovering non saline B horizon to cap cut and fills on saline C horizon. This is also important for landscaping purposes, 100mm of topsoil on top of saline cut C horizon is not satisfactory, 200mm of non saline B and then 100mm of topsoil would be far preferable. We call this Avoidance. Table 1. Provides a Qualitative guide to the kinds of intervention that may be appropriate.

Table 1. Indicative Interventions at the Risk Levels

Classification	Risk Types	Intervention
Non Aggressive or Corrosive	Slow spalling and slow corrosion	Appropriate metal finishes, integral damp courses.
Mildly Aggressive or Corrosive	Spalling, moderate corrosion	Avoidance, appropriate metal finishes, integral damp courses, adequate coverage of reinforcement steel, attention to site drainage.
Moderately aggressive or corrosive	Rapid spalling, moderate corrosion and galvanic effects.	Avoidance, Appropriate metal finishes, integral damp courses, increased coverage of reinforcement steel, attention to site drainage.
Severely Aggressive or Corrosive	Rapid spalling and corrosion, severe galvanic risks	Avoidance, Non corrosive metals in exposed situations, integral damp courses, increased coverage of reinforcement steel, increased concrete density, water resistant bricks. Attention to site drainage. Galvanic precautions.
Very Severe Aggression and Corrosion	Rapid spalling and corrosion, severe galvanic risks	Avoidance, Non corrosive metals throughout, integral damp courses, increased coverage of reinforcement steel, attention to site drainage, increased concrete density, water resistant bricks, water proof concrete. Full galvanic protection.

Disclaimer: This information is not comprehensive and not issued by a qualified engineer. It is given for illustrative purposes. Qualified advice should be sought with regard to specific protective measures.

The single most important protective devices in a saline environment are avoidance and good damp course integrity. Salt damage from wick effects (chronic) is usually confined to older buildings where footings were porous brick and damp courses either non existent or inadequate in comparison with modern materials. Where more modern structures suffer damage this is most often the result of poor building practices (connection of soils above the vapour barrier). It is probably exacerbated by carelessness or ignorance of avoidance techniques when cutting and filling sites, allowing deep saline material to the surface. Good site assessment is essential to managing avoidance techniques and rigorous building inspection and public education is required to ensure the integrity of vapour barriers.

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