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EMERSON AGGREGATE STABILITY TEST FOR WASTEWATER: An interpretation for consultants and regulators

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1. Introduction

The Emerson aggregate test (Emerson, 1967) was designed to help farmers classify the structural stability of a soil aggregate (ped) under rainfall, and indicate the effects of physical manipulation (cultivation) on soil at an elevated moisture level. Structural stability is essential for macroporosity, the pathway of water movement through soil (drainage), while microporosity functions by capillary action, holding plant available water. Both these processes are important for effluent disposal into the soil profile. Dispersed soil colloids that move with drainage water have the potential to block these pores and reduce hydraulic conductivity. Slaking of a soil ped is mostly due to low organic matter and is not a detriment to effective effluent dispersal, although it may lead to some temporary hard setting on a bare surface.

2. Dispersibility Testing

AS/NZS 1547:2012 *On-site Domestic Wastewater Management* refers to the Emerson Aggregate Test (page 109). Firstly, the test method requires the ‘three undisturbed aggregates …. are carefully immersed in a beaker of distilled water’. The method fails to indicate that the aggregates (peds) have to be air-dry. Secondly, distilled water is not indicative of the actual chemistry of effluent. Those instructions are wrong with respect to the impact of effluent on the soil, or soil in effluent, and provide no evidence of performance under actual in-field conditions. Emerson (1967) indicated a test period of two hours, not 24 hours as stated in AS/NZS1457:2012.

Thirdly, because the soil in the land application area is not manipulated (cultivated) when wet, the ‘remould’ and subsequent parts of the Emerson test (Classes 3-6) are irrelevant for effluent assessment. Irrespective, a remoulded bolus (ball) should not be taken from the bolus used to determine field texture because excess manipulation plus salt from the operator’s hand unduly influence the performance of the remoulded sample. Such actions, as suggested in AS/NZS 1547, are contrary to AS1289.3.8.1-1997 where the remoulded ped is manipulated with a plastic spatula at a moisture content consistent with that required for determining plasticity (plastic limit test), as required by Emerson. The two standards are contradictory – which one correctly follows Emerson’s publication?

The *NSW Environment and Health Protection Guidelines (1998)* (page 73) refer to ‘the Modified Emerson Aggregate Test’ but fail to indicate the need for air-dry peds. The method does require the use of a solution with a sodium adsorption ratio (SAR) of 5 but does not indicate the salinity level (as electrical conductivity (EC) of this trial solution. One could mix an SAR 5 solution using sea water, but that would not mimic domestic effluent.

The VicEPA *Code of Practice Onsite Wastewater Management* (891.3) defers testing for dispersion without qualification, presumably to AS/NZS 1547:2012. The VicEPA *Land Capability Assessment for Onsite Domestic Wastewater Management* (746.1) does not indicate any requirements for the Emerson Test and seems confused between dispersion and slaking (page 8); the former a property of the colloids and the latter related to organic glues.

To accurately gauge the effect of effluent on soil structural stability, the test liquid requires similar EC and SAR as the effluent discharged from a septic tank, aerated wastewater treatment system, wetland or other process.

3. Modified Aggregate Test for Wastewater Assessment

The only results of interest in wastewater management are those shown in Figure 2. The method requires 3-5 air-dry soil peds of about 5 mm be immersed in a solution having SAR 5 and EC about 1 dS/m to mimic domestic effluent (Patterson, 1994). The peds are examined after two hours and the appearance of the peds is compared with Figure 1. Sample dishes should be covered to avoid disturbance by air currents. Note that, as discussed previously, there is no requirement for remoulding because the land application area for effluent dispersal is not physically altered when wet.

Figure 1. Assessment of appearance of air-dry peds in artificial effluent (SAR 5; EC 1 dS/m).

Note: The layout of Figure 1 matches the set out in Figure 2.

A typical quality domestic effluent has an EC of about 1 dS/m and an SAR of about 5. Both these properties are critical to soil structural stability as shown by Figure 3, where high SAR requires a high EC (high salinity) to maintain soil structural stability, that is, the high salinity (as EC) overcomes the effects of high sodicity (as SAR).

The most severe influence to a soil ped is where the liquid has a very low EC, such as distilled water or rain.

SAR is measured on the effluent and is a ratio of the concentration of sodium ions to the combined concentration of the calcium and magnesium ions. The formula is a little more complicated than a straight ratio but sufficient for understanding at this stage. The higher the sodium relative to calcium plus magnesium, the greater the potential for a decrease in structural stability of the peds in water, as shown in Figure 3.

Therefore, testing air-dry soil peds with an artificial effluent provides a better understanding of the influence of the effluent upon the soil than testing with distilled water. The same can be said for testing the soil in any irrigation area with a water of similar quality to that being irrigated, not with distilled/deionised water.

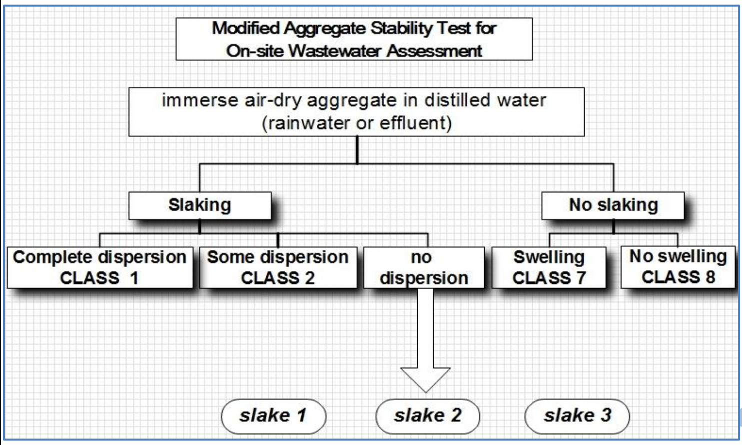

Figure 2 First part of Emerson test without remoulding

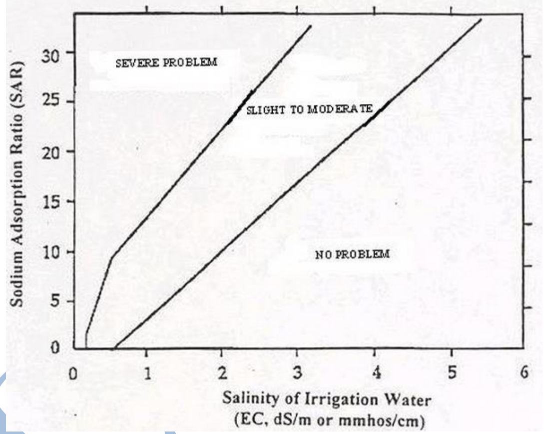

Figure 3 Correlation of SAR with EC for soil structural stability (after Hanson et al., 1999)

The proportion of sodium ions, in the soil, to the sum of all the exchangeable cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, H^{+} and Al^{3+}) is called the exchangeable sodium percentage (ESP). Again, the higher the sodium relative to all the exchangeable cations gives a greater propensity for the soil to disperse, particularly in distilled water (rainwater). Sodicity can be assessed from soil chemical analysis – reported as ESP. Values greater than ESP 6% may need amelioration.

The behaviour of the peds in clean water is important where an understanding of the effects of rain on surface soil structural stability is required, such as rain on soil irrigated with greywater, septic tank effluent or coal seam gas water. Such testing would require alternate treatment with effluent and distilled water under controlled conditions.

The modified Emerson test results include Classes 1, 2, 7 and 8 and the degree of slaking for others, as shown in Figure 2. Peds that only slake may be classed as *3/6, slake 1, 2 or 3. The determination of classes 3 to 6 is irrelevant.

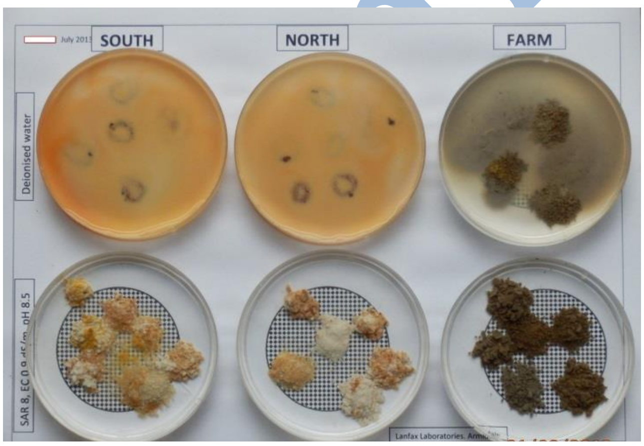

Figure 4 Comparison of water chemistry with dispersion

A comparison of peds of three soils in deionised water and irrigation water (SAR 8, EC 0.9 dS/m) is shown in Figure 4. Note that in deionised water all three soils disperse, South and North as Class 1 and Farm as Class 2.

In irrigation water, the soils only slake, showing that the problem of dispersibility is removed because of the chemistry of the irrigation water.

Figure 4 shows that the difference between testing with deionised (distilled) water and effluent can be quite pronounced. Using deionised (distilled) water may give a false performance rating, raising issues that will not exist under field conditions.

4. Assessment of Performance using Modified Test

Classes 1 and 2 indicate that the soil colloids are easily disrupted (disperse) with a complete loss of stability, as reflected by the cloud of colloids (individual charged clay particles). The cause may be related to sodic properties (high ESP), or to water with very low EC. These soils may be remediated using lime or gypsum that increases the EC of the effluent, as indicated in Figure 3. Dispersion at the soil interface in a trench, as shown in Figure 5, presents practical difficulties.

When dispersed particles (clay colloids) move through the soil profile with drainage water, the colloids block the small capillary passages with a resulting loss of permeability, as in any filter system. As the soil dries, the more dense soil sets as a crust, further limiting the infiltration of water at the surface or the permeability through the soil at depth.

Dispersion at the interface of a soil trench only needs to be a few millimetres thick to block soil pores with the resulting loss of permeability. Such blockage is difficult to reverse with chemicals and a new trench may be required.

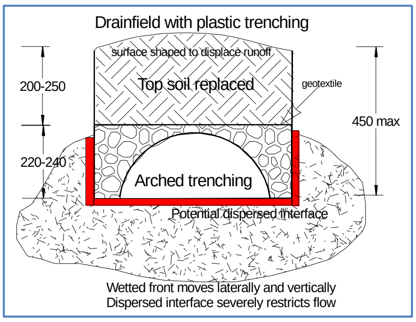

Figure 5 Dispersed interface in trench

Slaking soils result from low organic content, insufficient organic glues to hold individual soil particles together, hence when placed in water the escaping air easily disrupts the mineral particles and the ped falls apart, but does not separate into individual colloids. Most Australian sub-soils slake to some extent. The addition of organic matter may resolve the slaking issues. Slaking soils pose very minor stability limitations for effluent disposal.

Soils that do not disperse or slake are usually well endowed with organics and are able to maintain their original shape when placed in effluent, they are water stable. Many surface soils are water stable. Class 7 soils usually swell because of their mineralogy. Classes 7 & 8 have no stability limitations for effluent dispersal.

Sandy soils, such as sands, loamy sands and clayey sands mostly have insufficient clay to form peds, hence unlikely to disperse in water or effluent. Any peds that are available will usually slake because of insufficient organic glues holding the soil minerals as a ped.

All soils, over time, may be influenced by effluent chemistry and their susceptibility to disperse in effluent slowly increases. This effect is not only a function of the effluent, particularly SAR and EC effects, but also the soil ESP.

5. Reporting Modified Emerson Test Results

The modified Emerson test can be reported and interpreted, with respect to domestic wastewater application as:

Class 1 - severe dispersion, maybe related to high sodicity which forces the clay particles apart in water. Amelioration with lime or gypsum may improve structural stability by increasing EC. Class 1 soils have a major limitation to wastewater application because of reduced permeability and potential to compact as the pores block.

Class 2 – moderate dispersion, maybe related to high sodicity. Amelioration may be effective by increasing EC. Without amelioration, this class has a major limitation to wastewater application as for Class 1.

Classes 3-6 –remoulding, and 1:5 soil:water suspension tests are irrelevant to wastewater assessment, but one can report the test results with degree of slaking as:

Slake 1 (slight), slake 2 (moderate) or slake 3 (completely slumped) (as shown in Figure 1). Slake 1, 2 or 3 – no limitation to wastewater application, but may benefit from additional organic matter for surface irrigated soils.

As a shorthand, this category of slaking soils may be reported as ***3/6, slake 1** indicating that the class may be within the group of classes 3 to 6, but the general behaviour of the ped in the synthetic effluent (SAR 5, EC 1 dS/m) is that that the ped slakes slightly. Replace slaking with grade as 2 or 3 as appropriate.

Classes 7 and 8 – these soils are water stable, but may swell (Class 7) or retain original size and shape (Class 8). Neither of these classes is a limitation to wastewater application.

6. Interpretation by Consultants and Regulators

Assessment of the Emerson test results is reasonably clear. Sandy soils have insufficient clay to strongly bind soil mineral particles into peds. It would be inaccurate for a sand to be rated on the Emerson scale.

Dispersible soils have major limitations and the consultant/regulator should note the need for amelioration or special treatment of the soil to overcome the potential for reduced permeability and compaction of Class 1 and Class 2 soils.

Soils that slake but do not disperse (Classes 3-6) and soils that neither slake nor disperse (Classes 7 & 8) have no limitation based on modified Emerson's test.

7. References

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