Effects of Effluent Chemistry on Soil Properties

Robert A. Patterson

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Phone 61 2 6775 1157 Web site www.lanfaxlabs.com.au

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Director, Lanfax Laboratories, Armidale

1. INTRODUCTION:

Effluent is the resulting liquid flow from a wastewater treatment system, hence its quality depends on both the source of the wastewater and the level of treatment. The most simple form of treatment is the sedimentation process where solids are removed by gravity separation (settling and/or flotation). Higher treatment processes may remove solids by filtration, flocculation and sedimentation, or air flotation. Dissolved materials require altering the wastewater chemistry, enhancing biological degradation, precipitating dissolved solids by addition of chemicals or gas stripping. The combination of treatment processes is a specialised field and needs to be matched with the quality and quantity of the wastewater generated. The solids removed at various treatment processes are called “sludge”, “scum” or “biosolids”.

The effects of effluent quality upon the receiving soil may range from behaving as a clean water input to that causing serious sodicity/salinity levels in the receiving soil, or clogging the soil micropores with solids. It is important that decisions about monitoring are based upon a clear understanding of the interaction between the effluent and the soil.

This section provides a demonstration of soil-effluent interaction under controlled conditions and invites critical analysis of the observations; gives an opportunity for participants to undertake field texture analysis and dispersion test of a range of soils; and provides a practical exercise in measuring soil pH and electrical conductivity.

2. EFFLUENT QUALITY

The effluent available for disposal (irrigation) may be compared to rainwater which is characterised by:

- pH about 5.5 to 6.5
- EC usually less than 20 uS cm^{-1}
- salts of low concentration,
- nutrient content extremely low (NPK)

Rainwater, as a natural part of the hydrologic cycle (rainfall / evaporation sequence), provides water essential for biological processes - plant and animal survival, growth and reproduction as well as being a natural flushing and leaching agent.

Effluent quality must be accounted for in the management of disposal options and in the decisions for soil and water monitoring programs. In other words - what do you measure that will indicate likely positive or negative impacts upon living systems?

The quality of the effluent should be measured in terms of:

- pH (acidity or alkalinity), pH 7 is neutral;
- EC - used as a gauge of all the ions in the solution; levels > 1 dS m^{-1} (1000 uS cm^{-1}) should be investigated further, EC may be used to calculate Total Dissolved Solids (TDS)
- nutrient status
  - cations Na, K, Ca, Mg,
  - anions -nitrate, phosphate, sulphate, chloride
  - metal ions, Cu, Zn, Mn, Fe, Al
- Biochemical oxygen demand (BOD_5)
- Total Solids (TS), Total Suspended Solids (TSS)

3. SOIL PROPERTIES

Understanding some basic soil properties that may be influenced by the effluent quality will permit the operator to select appropriate disposal options. Some important properties include:

- soil depth and the various soil profile horizons
- soil drainage (internal and external)
- soil texture (proportions of sand, silt and clay)
- soil structure (aggregation of soil particles)
- soil chemical properties - current nutrient status
- cation exchange capacity - nutrient storage
- exchangeable sodium percentage (ESP)

4. EFFECTS OF EFFLUENT ON SOILS

Alteration of soil pH As many nutrients depend upon a particular range of pH over which they are available for plant uptake, a shift in pH outside that range renders the nutrients less available, even though they remain in the soil. For this reason, the application of lime (to elevate pH) or sulphur (to lower pH) may be necessary. Gypsum has no effect upon soil pH.

Change Chemical Balance. The balance of nutrients within the soil is important for microbial and plant growth. The balance of C-N-S-P (100:10:1:1), Ca / Mg ratios (>4), and the availability of potassium and micronutrients must be maintained. When applying effluent, it may be necessary to alter the nutrient balance by supplementary application of particular fertilisers.

Increase in Salinity As well as impinging upon the water table, effluent irrigation generally adds significant quantities of salts to the soil environment, such as sulphates, phosphates, bicarbonates, chlorides of the cations sodium, calcium , potassium and magnesium. The total impact of these salts may increase soil salinity to extreme levels unless leaching by rainfall, clean water or excess irrigation occurs.

Sodicity, the effects of sodium on plant and soil environments may also occur where total salinity levels are low. In water, the potential for sodicity problems is monitored as the Sodium Adsorption Ratio (SAR) and in soils as the Exchangeable Sodium Percentage (ESP).

Alter hydraulic conductivity. The effects of sodium and salinity (EC) interact to improve or reduce the movement of water through the soil, that is from the surface down through the soil pores in all directions.

Effluent with a high SAR and low EC may significantly reduce the hydraulic conductivity through effects of dispersion and destruction of structural aggregates.

The addition of ameliorants (such as gypsum) to either the effluent or the soil will work to increase the EC of the soil solution and assist in reducing the negative impact of sodiumon hydraulic conductivity. Organic matter (OM) has an ameliorating effect upon enhancing soil aggregate stability and increasing hydraulic conductivity.

Below and the following four pages are practical sheets

DEMONSTRATION OF EFFECTS OF SODICITY ON SOIL HYDRAULIC CONDUCTIVITY

Outline: The demonstration is designed to illustrate the comparative behaviour of poor effluent quality (with respect to sodium) to that of clean water upon a range of soil types from alluvial sands to highly sodic clays.

The following terms, each reported in millimetres per hour or millimetres per day, require clarification:

Infiltration is the movement of water from the surface of the soil into the soil mass below.

Percolation is the movement of water through the soil in a vertical downwards direction in response to gravity

Permeability is a measure of the speed (rate) at which water moves vertically downwards in the soil in response to gravity and capillary forces. Permeability is a measure of soil hydraulic conductivity.

Effluent quality

A synthesised effluent has been prepared for the purpose of the demonstration to show the effects of effluent upon a variety of soil types and the loss in hydraulic conductivity in response to high concentrations of sodium and low EC.

Typical effluent analysis is:

pH 10.3 EC 1.9 dS m^{-1} (1900 µS cm^{-1})
SAR 12
other salts sulphates, phosphates, chlorides, carbonates, bicarbonates, hydroxides.

The water has a high SAR and a low EC, thus a high risk of reducing soil hydraulic conductivity.

Soil Properties

Alluvial sand - surface soil from a coastal river flood plain, dominantly sand, with clay and OM.

Black Earth - medium clay, clay content 40-50%, high shrink swell capacity, high fertility, pH around 6.5

Red Brown Earth - clay loam, red colour due to iron oxides, poor OM content, sets very hard on drying.

Krasnozem - red loam, high in iron oxides, aggregates extremely water stable, pH 5.4

Yellow solodic - medium clay, high sodium content (ESP = 12%), extremely dispersible, erodible, poor wet strength

Exercise

1. Observe the arrangement of the soil tubes and the percolating liquids (clean water, effluent).

2. Record the time of the first observation and the volume (mL) of liquid under each respective soil column.

3. At a later time record the completion time and the new volume of liquid. Calculate the percolation rate in mL/min for comparison between samples and effluents. (Conversions to mm / hour would require measurements of the soil columns - beyond the scope of this demonstration.) Record percolation rate and comment on the variations.

Table 1. Results of soil percolation testing (disturbed cores)

Start time: .... End time: ....

Soil type	**Clean water leaching volume in mL**		**Effluent leaching volume in mL**		**Percolation mm/ min**	**Suitability for disposal**
Alluvial sand						
Black Earth						
Red Earth						
Krasnozem						
Yellow Solodic						

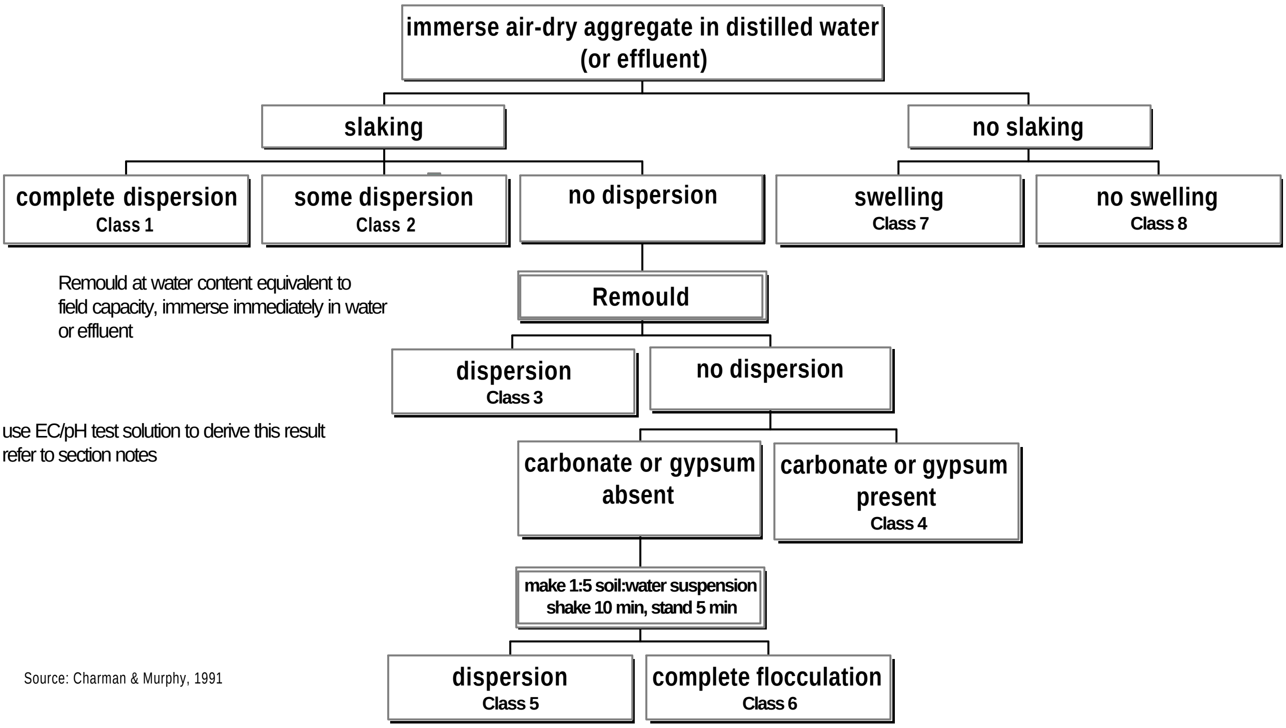
Comments: Make some general comments on the behaviour of the soil in response to the disposal of effluent to soils

6. Measurement of Soil Dispersion in Relation to Effluent Disposal

Outline: Soil dispersion is the response of soil colloids (particles generally less than 2 micron) to water (or effluent) and the behaviour of those colloids relative to others soil particles. Dispersion occurs when the forces of disruption are greater than the forces for cohesion, soil colloids display structural instability and move out into the soil solution. Dispersed particles are free to move with water as it drains through the soil, leading in extreme cases to tunnel erosion. Under non-erosive conditions, dispersion leads to physical clogging of soil pores, decreased percolation and increased bulk density.

Loss of soil structural stability and movement of clay colloids are two important considerations for avoiding conditions favouring the increase in dispersibility. Emerson's dispersion test is a measure of soil structural stability in water.

Table 2. Emerson Aggregate Test



Dispersion Exercise

As a group, take six plastic containers, place on work sheet and half fill each container with deionised water.
Take three soil peds (about 5 mm cross section) from each of the set of 6 soil peds.
Drop the peds gently into the water and place the container to one side. DO NOT disturb the container until the final measurement is made. You will need to examine the changes at the end of the period (after one hour).

This is only the first part of the Emerson's dispersion test, the second part will be explained and demonstrated. The test should be conducted with the effluent or a simulated effluent - pH, EC and SAR equivalent.

Table 3 Record of Aggregate Stability for Six Test Soils
(T tick relevant box) (Source: Patterson, 1998)

Aggregate stability (Class)	**A**	**B**	**C**	**D**	**E**	**F**
no slaking, no swelling (8)						
no slaking, swelling (7)						
slaked, no dispersion (need to remould)						
slaked, some dispersion (2)						
slaked, complete dispersion (3)						
other procedures - write class						

7. DETERMINATION OF FIELD TEXTURE

Aim: To determine field texture of a range of soil materials.
Equipment: Each group will have four different soils (A-D) and a squeeze bottle filled with water.

Procedure: Individually take a small quantity of soil in the palm of your hand (approximately a tablespoon full), spray with water and kneed until the ball of soil just fails to stick to your fingers (similar to your days with plasticine). Continue kneading and moistening until there is no apparent change in the feel of the soil. Should too much water be added, add some more soil. Appreciate the feel of the soil (plastic, silty, smooth, sandy) while you are doing this - for a number of reasons.

When the bolus is well formed, squeeze the soil between your thumb and forefinger in an attempt to form a ribbon of soil over your forefinger. Continue until the soil breaks away.

Compare the length of the broken ribbon with the table below.

Describe also the stickiness and the plasticity of the soil bolus as it feels during kneading, record in Table 5.

Table 4. Field Texture Grade

Field Texture Grade		**Behaviour of moist bolus**	**Ribbon length (mm)**	**Approx clay content %**
S	Sand	coherence nil to very slight, cannot be moulded; sand grains of medium size; single sand grains stick to fingers	nil	< 5%
LS	Loamy sand	slight coherence; sand grains of medium size; can be sheared between thumb and forefinger to give minimal ribbon.	about 5	about 5%
CS	Clayey sand	slight coherence; sand grains of medium size; sticky when wet; many sand grains stick to fingers; discolours fingers with clay stain	5 - 15	5% to 10%
SL	Sandy loam	bolus coherent but very sandy to touch; will form ribbon; dominant sand grains of medium size and are readily visible	15 - 25	10% to 20%
L	Loam	bolus coherent and rather spongy; smooth feel when manipulated but with no obvious sandiness or “silkiness”; may be somewhat greasy to touch if much organic matter present;	25	about 25%
SCL	Sandy clay loam	strongly coherent bolus, sandy to touch; medium size sand grains visible in finer matrix;	25 - 40	20% to 30%
CL	Clay loam	coherent plastic bolus, smooth to manipulate;	40-50	30% to 35%
LC	Light clay	plastic bolus; smooth to touch; slight resistance to shearing between thumb and forefinger	50-75	35% to 40%
LMC	Light medium clay	plastic bolus; smooth to touch; slight to moderate resistance to ribboning shear	75	40% to 45%
MC	medium clay	smooth plastic bolus; handles like plasticine and can be moulded into rods without fracture; has moderate resistance to ribboning shear	> 75	45% to 55%
HC	heavy clay	smooth plastic bolus; handles like stiff plasticine; can be moulded into rods without fracture; has firm resistance to ribboning shear	> 75	50% +

Source: McDonald et al.,. 1990

Table 5. Record of Field Texture Determination.

Soil	Grittiness	Stickiness	Plasticity	Stain	Ribbon (mm)	Grade (Table 4)
1						
2						
3						
4						
5						
6						

Record each of the first four qualities as:

NONE SLIGHT MODERATE VERY EXTREMELY

Grit - sand grains impart a gritty feeling to the soil, sand grains may be visible.

Stickiness - the adhesive forces between different materials, i.e. soil and hand. Press the soil between your thumb and your forefinger, observe adherence to your fingers.

Plasticity - property which allows soil to be deformed rapidly, without rupture, without elastic rebound and without volume change - can be moulded into any form by pressure. Try to roll the wet soil into a thin ribbon about 2-4 mm diameter. Plastic soils roll to 2 mm ribbons about 40 mm long.

Stain - some soils leave an obvious stain on the hand from organic materials (black) or minerals such as iron (red).

8. SOIL PH AND SALINITY MEASUREMENT

Soil reaction (pH) is a relative measure of the acidity of the soil; that is, the amount of hydrogen ions (H^+) present. When hydrogen ions dominate (pH <7), the soil is classified as acid. When hydroxide ions (OH^-) dominate (pH >7), the soil is classified as alkaline. pH 7 is termed neutral, that is H^+ and OH^- ions in equal proportion.

Under acid conditions, elements such as iron, aluminium, manganese and the heavy metals (zinc, copper, chromium) become highly soluble and may create problems for vegetation. Aluminium at pH 4 is readily available and highly toxic to plants.

Under alkaline conditions, nitrogen becomes less available and calcium and magnesium precipitate out of the soil solution. High concentrations of sodium will produce an alkaline soil reaction (pH> 8.5)

When soluble salts dissociate in water to form ions, there is a decrease in the electrical resistance in the water; that is, the water carries an electrical current more easily. Common salt (NaCl) will dissociate in water into sodium ions (Na^+) and chloride ions (Cl^-). We can measure how easily electricity travels through water with simple electronic instruments.

In this exercise you will dissolve the soluble salts from a soil sample into deionised water (1:5 soil:water ratio) and measure the electrical conductivity (EC) of the solution. As the salt content increases so does the EC in a simple linear relationship; twice the EC means twice the soluble salt content. The soluble salts Na^{+}, Ca^{2+}, Mg^{2+}, K^{+}, Al^{3+}, H^{+}, Cl^{-}, SO_4^{2-}, CO_3^{2-}, HCO_3^{-}, and others all increase EC. It is not possible to determine which ion has the greater concentration by this method.

Exercise

As a group

take four 50-mL centrifuge tubes labelled 1, 2, 3, 4
into each tube place soil up to the 7.5 mL mark
fill the tube to the 45 mL mark with deionised water, replace cap
(this represents about a 1:5 soil:water mix)
shake each tube for about 10 seconds, once every 10 min over 30 min
remove cap, dip a single Merck pH test strip into the liquid to wet the bars
hold strip in liquid for about 20 seconds, remove strip, shake off excess water
match the colour of the bars with the coded bars on the side of the pack

RECORD YOUR pH RESULTS IN TABLE 6 BELOW

pour liquid into 60 mL plastic container, dip conductivity probe into the solution, ensure that the liquid covers the probe up to the mark

multiply meter reading by 10, record value, including the units uS/cm

(if over-scale - 1 shows on LHS - record as >2000 uS/cm

rinse probe with deionised water before making next reading

RECORD YOUR EC RESULTS IN TABLE 6 BELOW

convert all results to deciSiemens per metre (dS m^{-1})
(1 dS m^{-1} = 1000 µS cm^{-1})

Table 6 Record of EC Testing

Sample	**EC reading** **µS cm^{-1} from meter**	**EC as dS m^{-1}**	**Salinity hazard** Low, medium, high	pH
1. EC- No. 1				
2. EC - No. 2				
3. EC - No. 3				
4. EC - No. 4				

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