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Soil Hydraulic Conductivity and Domestic Wastewater

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Introduction

The disposal of effluent from conventional septic tanks, aerated wastewater treatment systems (AWTS) and sewage treatment works (STW) has the potential to cause serious problems in our environment and more particularly to the soils to which ultimate disposal occurs. The concentration and composition of household chemicals in domestic wastewater are poorly controlled and the usage, by type and quantity is decided upon through arbitrary non-scientific decisions. This heterogeneous matrix of chemicals in domestic effluent mostly passes through the treatment system with only minor fluctuations and with few alterations. Sodium, a common constituent in domestic wastewater, remains in ionic form and is not removed by precipitation and filtration processes available in on-site or STW treatment. The effect of sodium on the dispersive properties of soil is well documented.

This project examined the concentration of sodium and its likely sources in wastewater produced by the domestic consumption of water. A component of the wastewater stream is also the clean water inputs which vary markedly in their input chemistry because of geological effects and conventional water treatment processes.

Methods

The sources of sodium from clean water inputs were compared with those of STW outflows and with effluent from on-site systems such as septic tanks. The impact of typical sewage effluent was examined in relation to changes in saturated hydraulic conductivity (Ksat) for A and B horizons of a range of six soil types from Northern New South Wales. From the measured reduction in Ksat, suggestions are made with regards to controlling chemical use within the household.

To examine the impact of domestic effluent on soil Ksat, water of varying SAR (0, 3, 8 and 15) and EC values equivalent to septic tank effluent of a similar SAR was infiltrated through undisturbed samples of the soils in replicated trials. *In situ* tests were conducted using the CSIRO type disc permeameter while laboratory tests were performed on 50 mm diameter undisturbed soil cores wrapped in heat shrink plastic and treated as defined by Darcy's equation.

Standard percolation tests and double ring infiltrometers were also evaluated with varying SAR solutions. The percolation test suggested by Australian Standard AS 1547-1994 is performed using clean water inputs, however, the quality of the clean water is not defined by either SAR or EC. *In-situ* measurements made with the disc permeameter were restricted to 2.5 h duration because of poor control over the vertical movement of the water and the influence of subsurface discontinuities. Undisturbed cores were selected to better represent a typical vertical section of the soil horizon to which effluent was to be disposed and were treated for 82 h to determine the impact of increased pore volumes of effluent on Ksat measurements.

Results

It was found that for a household consuming rainwater the average SAR of septic tank effluent (STE) was 3.9 ± 0.3, while effluent from reticulated urban systems had an average SAR of 3.9 (range 2.5 to 4.1) for 14 STWs examined. Sodium salts are added and remain in solution while many calcium and magnesium salts precipitate out during the treatment processes, increasing the SAR above that of the wastewater. Laundry detergents, soaps and the waste products of the human diet add sodium salts to the wastewater stream at concentrations around 63 mg $Na^+ L^{-1}$ (range 26-318 mg L^{-1}). It was found that an average household used a top loading automatic washing machine 7.3 times per week.

There was a significant interaction between soils and treatments, statistically significant ($P<1\%$) with some soils while others showed a trend between treatments. The differences varied according to the method used to percolate water through the soil sample.

A typical reduction in Ksat for a red-brown earth A horizon is illustrated in Fig.1. The values have been ranked within each treatment to allow better visual evaluation of the range of values for each SAR. The reduction in Ksat was highly significant as SAR 0 >SAR 3 > SAR 8, SAR 15. Ksat decreased by 50% from SAR 0 to SAR 3 and by 79% from SAR 0 to SAR 15. For the sub-surface soil Ksat varied according to SAR 0, SAR 3 > SAR 8, SAR 15. The overall loss in Ksat was of the order of 30% from SAR 0 to SAR 3 but 60% from SAR 0 to SAR 15.

Discussion

A large proportion of the sodium in laundry salts is used to deceive the consumer and as a "filler" takes no constructive part in the washing action. That laundry products are chosen by householders because of product image and price and not because of environmental consequences of the component chemicals is a result of strategic marketing by the product manufacturers. Few laundry products manufacturers alert the consumer to the matrix of chemicals in their brands, while sodium is not generally seen as an environmentally hazardous element.

When the cumulative effects of sodium from the domestic use of the water and the sodium concentration of the clean input water are considered, domestic effluent has the potential to introduce water of high sodium adsorption ratios (SAR) and low electrical conductivity (EC) to the soil environment.

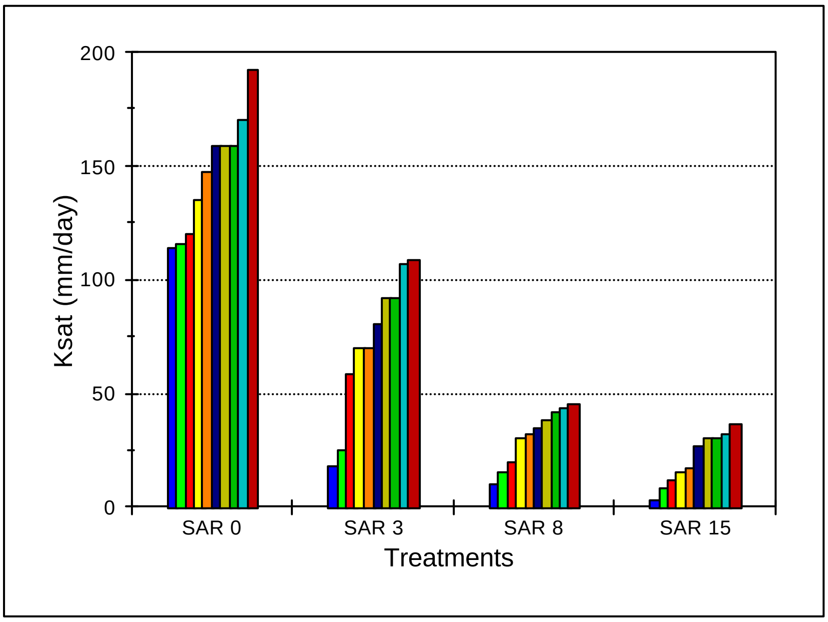

Fig.1. Ranked Ksat measurements for 10 replicates by four treatments for the red brown earth A1 horizon

Where a brand of laundry powder high in sodium (55 g Na per wash) was chosen and the effluent disposed of by surface irrigation over 500 m^2 of lawn, in one year the household's laundry water will add the equivalent of 1.1 tonnes of sodium chloride per hectare to the soil. However, by choosing a low sodium detergent, the sodium addition can be decreased to 193 kg ha^{-1}, a reduction of 84%, with possibly no loss of washing efficiency. By choosing one of the liquid detergents the sodium load from this source can be largely eliminated. Thus the impact of effluent on the loss of Ksat can be minimised because of the decreased SAR of the effluent.

It is generally accepted that once the ESP of Australian soils reaches 5 soil structural stability decreases and consequently Ksat decreases. The average release of sodium in STE was calculated at 83 mg L^{-1}. To increase the ESP from 0 to 5 of the soil contained within a 100 mm zone adjacent to a drainfield of dimensions 20 x 0.6 x 0.6 m requires 17.5 kg NaCl (for example, a CEC value of 100 meq/100g and bulk density of 1400 kg m^{-3} have been assumed). This amount of NaCl would be supplied by the household in 80 days. In practice, the period to increase the ESP of the soil will be longer as only a proportion of the added sodium will be adsorbed by the soil colloids, while CEC will generally be a significantly lower value. Nevertheless, the inevitable consequence of continual addition of sodium in STE is a decrease in the soil's Ksat leading, in many cases, to drainfield failure.

Up to 700 pore volumes of effluent may pass through the interface of soil adjacent to the drainfield each year. In field and laboratory trials it was time consuming to measure the impact from 10 pore volume replacements. The effect of the reduced through flow of effluent is that less salt accumulates in the soil profile and the influence of sodium is not well pronounced.

A number of shortcomings of current methods of measuring Ksat of soils and inferring a long term effluent disposal rate arise from the spatial variability of the soil, inadequate time for equilibrium between the percolate and the soil to be attained, and no account being taken of effluent chemistry. This project has shown a high correlation between loss of Ksat for increasing SAR at low EC values. Since there is no universal correction factor that can be applied to all soils for converting Ksat values measured with clean water (SAR 0) to those for a solution of SAR 3. and that where effluent disposal is to be employed, *in situ* measurements must be made using an effluent of similar quality to that intended for long term disposal. Fig. 1 can be used to estimate the likely decreases in Ksat by varying SAR for the surface soil of a red-brown earth, however, only six soil types were examined in this project.

Conclusion

It was demonstrated in this study that increasing SAR, as occurs in domestic consumption of water, will cause a decrease in Ksat of the soil into which the effluent is to be disposed. Where drainfields fail from a loss of Ksat, the effluent which surfaces and enters the surface drainage system via run-off will carry phosphates, nitrogen products and faecal coliforms into the environment.

For satisfactory absorption of effluent by soil it is imperative that sodium loadings in domestic wastewater are decreased and so remove the need to rejuvenate drainfield and irrigation areas after they fail. The least cost solution to decrease the environmental consequences of failed drainfields is decrease the quantities of sodium products entering the wastewater stream before treatment.