Domestic Wastewater and On-site Disposal

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Summary

On-site disposal of domestic effluent from septic tanks poses many threats to public health and the environment from poor treatment, hydraulically overload systems, inadequate soil disposal qualities and problems of overflowing effluent with respect to nutrient enrichment of urban runoff water.

While alternative wastewater treatment systems have evolved to combat the problems of on-site disposal, there have been few incentives given to householders to improve the quality of their domestic wastewater and thereby enhance the treatment and disposal potential. While the NSW Government's Phosphorus Action Plan addresses the importance of reducing phosphorus in laundry detergents, nothing is being done to address the reduction of sodium in household products. Many laundry detergents use sodium as a filler and environmental benefits will arise from the removal of these chemicals from the wastewater stream.

This paper addresses the various sources of sodium in household products, including the raw water inputs. The increase in sodium in the wastewater stream from domestic use of sodium rich products is also addressed from the perspective of large sewage treatment works. The impact of sodium rich wastewater on various soil profiles indicates significant reductions in soil hydraulic properties from that source.

With a simple change in household buying patterns a reduction of up to 38% of the current sodium concentrations in domestic wastewater can be achieved at no change in costs to the consumer, at no loss of cleanliness and no negative effect upon current household operations. The benefits to the environment include reduced sodium load to river systems and urban runoff and increased operational efficiency of septic tank drainfields.

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1 Introduction

There is little dispute that since the advent of domestic wastewater collection and removal from the household of human excrete and food wastes that public health in the community has steadily improved. Unfortunately, the agglomeration of large populations reliant upon overcharged sewerage systems and poor disposal strategies is diminishing public health within a community that is now totally reliant upon collection and removal of all domestic wastewater. In areas beyond the economic reach of reticulated systems, on-site disposal allows householders the convenience and improved disposal facilities through septic tank treatment and soil disposal of the effluent.

The terms wastewater and effluent are not synonymous. Wastewater refers to the untreated composite of water and wastes (solids and liquids) collected within the household and moved in the wastewater stream to a treatment plant. Effluent is the liquid emanating from a treatment system after primary or higher treatment and available for further treatment or disposal.

The options available for households not connected to a sewerage scheme are limited to either:

(a) the separation of grey and black water; the grey water to be disposed of with minimal treatment and the black water offered basic treatment before disposal to the soil mantle;

(b) the use of composting toilets in place of total wastewater collection and the minimal treatment of grey water before disposal to the soil mantle;

(c) the use of a conventional septic tank offering primary treatment to all wastewater and disposal of the effluent to subsoil disposal; or

(d) the use of an aerated wastewater treatment system (AWTS) followed by surface disposal of a pre-chlorinated effluent.

This paper addresses concerns for the collection of wastewater from individual households and treatment in a single system with ultimate disposal to the soil mantle. Quantitative data on current wastewater practices will be examined in light of effluent chemistry effects upon the soil mantle. Recommendations for improving the effluent will be discussed and soil treatment mechanisms examined.

2 Current Practices

The individual household of the 1990's is totally reliant upon water for not only personal hygiene but also for the transportation of household wastes to distant treatment systems. Personal hygiene includes disposal of faecal materials and urine, ablutions and clothes washing while general household water use includes washing floors, cleaning and preparing food, washing cooking utensils and flushing unwanted materials away in the wastewater stream. As an essential element of all domestic water use is the consumption of chemicals to assist the washing action of clean water (abrasives, laundry detergents and soaps), bleaches and bactericides as well as the disposal of other chemicals used on the body (powders, make-up, deodorisers, toothpaste) and in the kitchen (detergents, oils and greases, tea leaves). The chemicals which are part of the foodchain decompose in the wastewater treatment system to release nitrates, phosphates and a complex array of other chemicals, alter the pH of the wastewater stream while increasing the oxygen consumption demand during aerobic degradation and finally impinge upon the effectiveness of treatment of the effluent by the soil.

For soil disposal of effluent, sodium has been widely reported as reducing the saturated hydraulic conductivity by dispersing the soil clay minerals, reducing porosity and increasing the risk of poor movement of water through the soil. Although the hydraulic capacity of the soil is considered important is dealing with on-site effluent disposal, the resultant failure of the soil system during continued loading leads to chemicals in the effluent reaching the broader environment. The chemicals which can escape include nitrogen, phosphorus and sodium salts. Bacterial contamination of the surrounding environment is also a consequence of the hydraulic failure.

3 Wastewater Quality

An indicator of water quality for disposal of effluent to soil is the sodium adsorption ratio (SAR) of the infiltrating water and the exchangeable sodium percentage (ESP) of the soil to which the effluent is applied. The sodium adsorption ratio is a comparison of the concentration of sodium salts that affect dispersion to a combination of the calcium and magnesium salts, the latter ameliorate dispersion (causes flocculation), although high concentrations of magnesium may also cause dispersion with some clays. The ESP is the proportion of sodium ions on the exchange sites on the colloidal materials (clays and organic material), soils high in exchangeable sodium(ESP > 6) are more likely to disperse than soils below that value. There is, however, a complication caused by the impact of electrical conductivity (EC) on the dispersion factor which will be discussed later.

3.1 Clean water inputs.

Treated water from town water supplies, rainwater and groundwater are often neglected in the mass balance of the chemical loading for domestic water.

Town water is available to a large proportion of the population of New South Wales and is the primary supply of water to the wastewater stream. While guidelines for drinking water quality are currently in use in Australia (NHMRC, 1994), the variation across northern New South Wales gives an indication of the expectation of water quality from "clean water" sources. That clean water is a definable quality for the purposes of estimating impact of water on the soil is not supported by data presented in Figure 1. There was a significant difference in water quality from coastal to inland river systems, additional salts in inland water systems reflecting the lower rainfall and higher geological salts in the environment

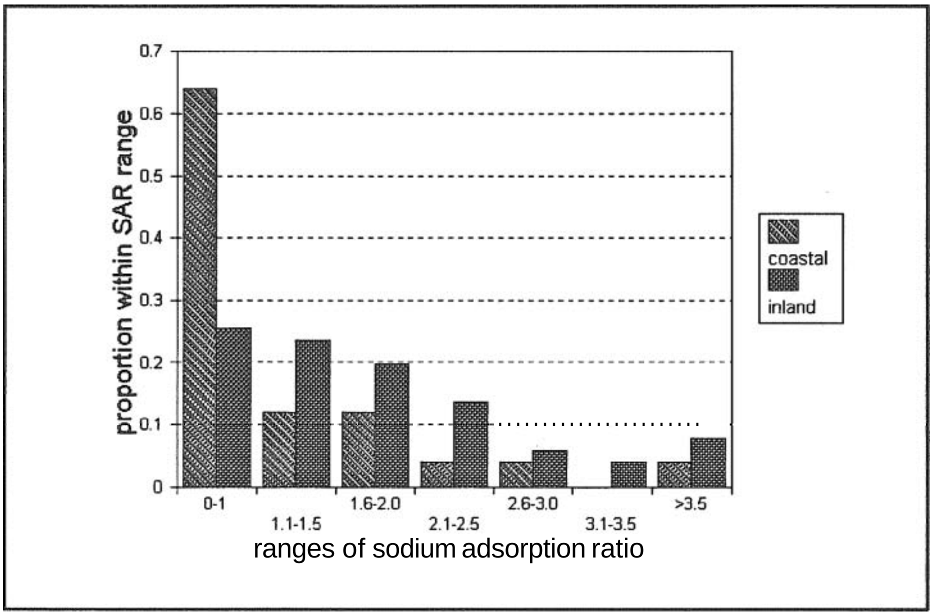

Figure 1. Variation in sodium adsorption ratios in town water across New South Wales as at July, 1991 (62 town supplies). (Source: Patterson, 1994)

The SAR values averaged 1.1 ± 0.2 (CV 85%) and 2.2 ± 0.5 (CV 177%) for the coastal and inland supplies, respectively. Seven inland samples exceeded SAR 3 at which soil hydraulic conductivity problems are likely to arise. It has been shown from discussions with participants at Wastewater Disposal Training Courses, that few Councils have any records of the SAR of the town water supply or the impact of treatment on the raw water supply with respect to sodium additions. Thus this important contribution of sodium into the environment through the wastewater disposal is poorly appreciated.

Sodium salts are used in the treatment system to improve pH (sodium hydroxide), coagulate calcium and magnesium to reduce hardness (sodium carbonate) for the addition of fluoride (sodium fluorosilicate) and the ion exchange removal of heavy metals (sodium aluminosilicate or zeolite).

Sodium (sodium chloride) is used to reverse flush ionic exchange units as a recharge mechanism. Because most sodium salts are soluble in cold water, sodium is an ideal carrier of anions for precipitation of nuisance colloids.

Variations in rainwater quality are not significant, the greatest variation being for salt inputs along the seaboard and from additional calcium salts leaching from new concrete water storage tanks. In the majority of tank water samples analysed by the author, rainwater quality varied by less than 0.05 dS m^{-1} with an average total dissolved salt (TDS) content of less than 10 mg L^{-1}. The input to wastewater quality from this resource in minimal.

Groundwater varies significantly in quality depending upon the geology of the aquifer. As an example, Table 1 indicates typical chemical components of three aquifer types in the New England Tablelands. The use of groundwater for domestic purposes is more pronounced during extended dry periods when it is used to supplement scarce rainwater reserves. During periods when sufficient rainwater is available for normal domestic purposes, groundwater is used for gardening, toilets and outside purposes.

TABLE 1
Water quality from aquifers in sediments, granites and basalts in New England Tablelands (Source: Patterson 1994)

Parameter	Sodium mg L^{-1}	SAR	TDS mg L^{-1}	Hardness mg L^{-1}
SEDIMENTS				
median	26	0.9	363	132
range	2 to 203	0.1 to 5.2	34 to 2418	6 to 518
GRANITES				
median	67	1.6	861	358
range	9 to 143	0.5 to 3.2	135 to 1870	31 to 535
BASALTS				
median	49	0.8	982	454
range	9 to 181	0.7 to 2.7	220 to 2650	80 to 1403

3.2 Cumulative effects of domestic inputs

The data in Figure 1 and Table 1 above indicate the SAR of the water before it is used within the household. The impact of chemicals used within the household must then be added to the input water quality. There are two indicators of the cumulative effects of households on the sodium content of domestic wastewater. Firstly, the quality of septic tank effluent where rainwater provides the clean water input and secondly, from the quality of sewage treatment works (STW) effluent where the increase in sodium from the clean water to the effluent is a measure of the sodium additions. Table 2 indicates typical septic tank effluent where small volumes of wastewater are produced each day from households reliant on rainwater with some support from additional resources during periods of drought.

TABLE 2
CHEMISTRY OF DOMESTIC SEPTIC TANK EFFLUENT
All values are in milligrams per litre unless otherwise shown

Variables	Mean ± SE	Range	Coeff. Var. (%)
Calcium	33337	7-166	79
Chloride	182316	48-506	61
EC (dS m^{-1})	1.4 ± 0.1	0.5-5.0	55
Hardness	131 ± 17	29-217	90
Magnesium	12 ± 2	2-1.9	143
pH	7.1 ±0.1	6.4-8.7	5.1
Phosphorus	14.4 ± 0.8	3.7-30	38.6
Potassium	35 ± 4	14-180	78.2
SAR	3.6 ± 0.3	0.7-9.6	48.9
Sodium	84 ± 6	26-318	53.4

SE = Standard error, upper and lower ranges equivalent to 95% confidence interval

Where the clean water input to the household above is from a resource other than rainwater, the cumulative effects of that water and that from the above table should be taken into account. The variations in chemical composition of the STE are due to use of different chemicals within the home and the different dilution factors as determined by the quantity of water consumed per day.

The treatment of wastewater from large scale residential development results in STW effluent being either released back into the river system or available for irrigation on land. STW effluent and the clean water inputs to those town supplies were analysed for 14 towns in northern NSW. The results for the sodium adsorption ratios are shown in Figure 2 below. The change from the shorter bar to the longer bar with respect to each STW is the impact of the additions and removals of sodium, calcium and magnesium.

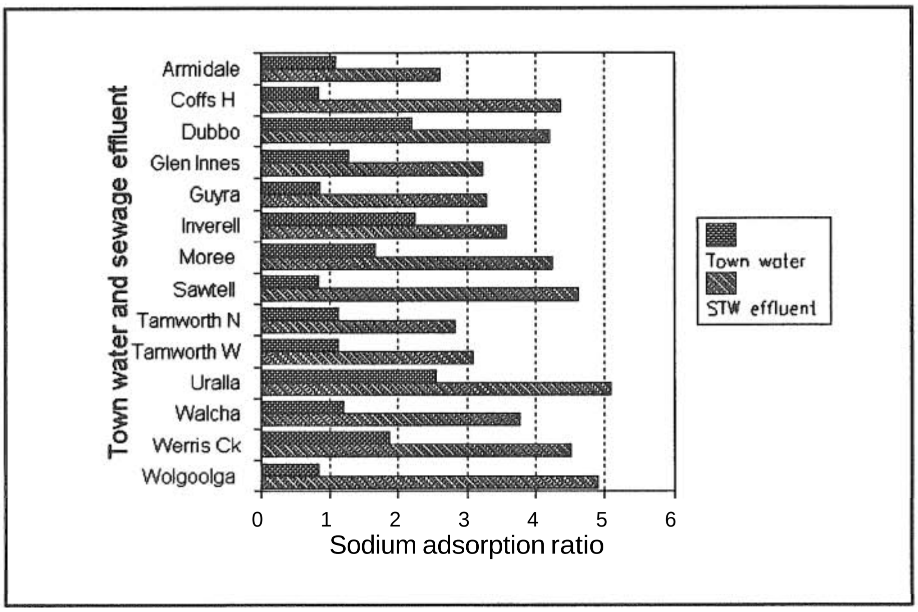

Figure 2. Comparison of SAR for selected STW effluents

The environmental effects of the sodium in the STW effluent will lead to an increase in sodicity in the river system or impinge upon the physical and biological properties of the soil to which it is disposed. The scale of sodium additions is shown in Table 3 below, indicating the sodium loads in tonnes per day from each 5 ML effluent per day for the selected works. The total contribution from the town must be equated with the actual volume of discharge. Armidale is currently (November, 1995) discharging about 9 ML per day.

TABLE 3
CONTRIBUTION TO SODIUM BUDGET FROM DOMESTIC SOURCES
(tonnes NaCl equivalent per year for 5 ML discharge per day)

Location	Town water supply	STW effluent	Domestic Input
Coffs Harbour	32	**338**	306
Armidale	127	**330**	203
Moree	148	**394**	246
Dubbo	**283**	589	306

3.3 Sources of Sodium

Sodium in the household is derived from foodstuffs, cooking additions and numerous chemicals which utilise the high solubility of sodium salts. The amounts of common salt used in the human diet are but small contributors to the overall sodium budget and it is doubtful that large reductions in common salt use within the home will lead to significant changes to sodium in wastewater discharges. A significant source of sodium is from the laundry detergents, particularly the standard, non-concentrated powders which use various sodium salts as active ingredients and as fillers. The fillers provide very little worthwhile contribution to the wash but may provide up to 40% of the sodium salts in the wastewater.

The change of household laundry detergents from those which contribute large quantities of sodium to the wastewater stream will reduce the impact of the effluent on its receiving environment. That sodium salts are difficult to remove once placed in the wastewater stream requires that efforts to prevent their entry are the most important measures for reducing environmental impact. Figure 3 indicates the range of laundry products examined by the author. The detergents were mixed with an amount of water equivalent to a full load of a top loading automatic washing machine. The SAR value was derived for rainwater inputs. The lower the SAR value, the less impact the effluent has upon the soil physical properties.

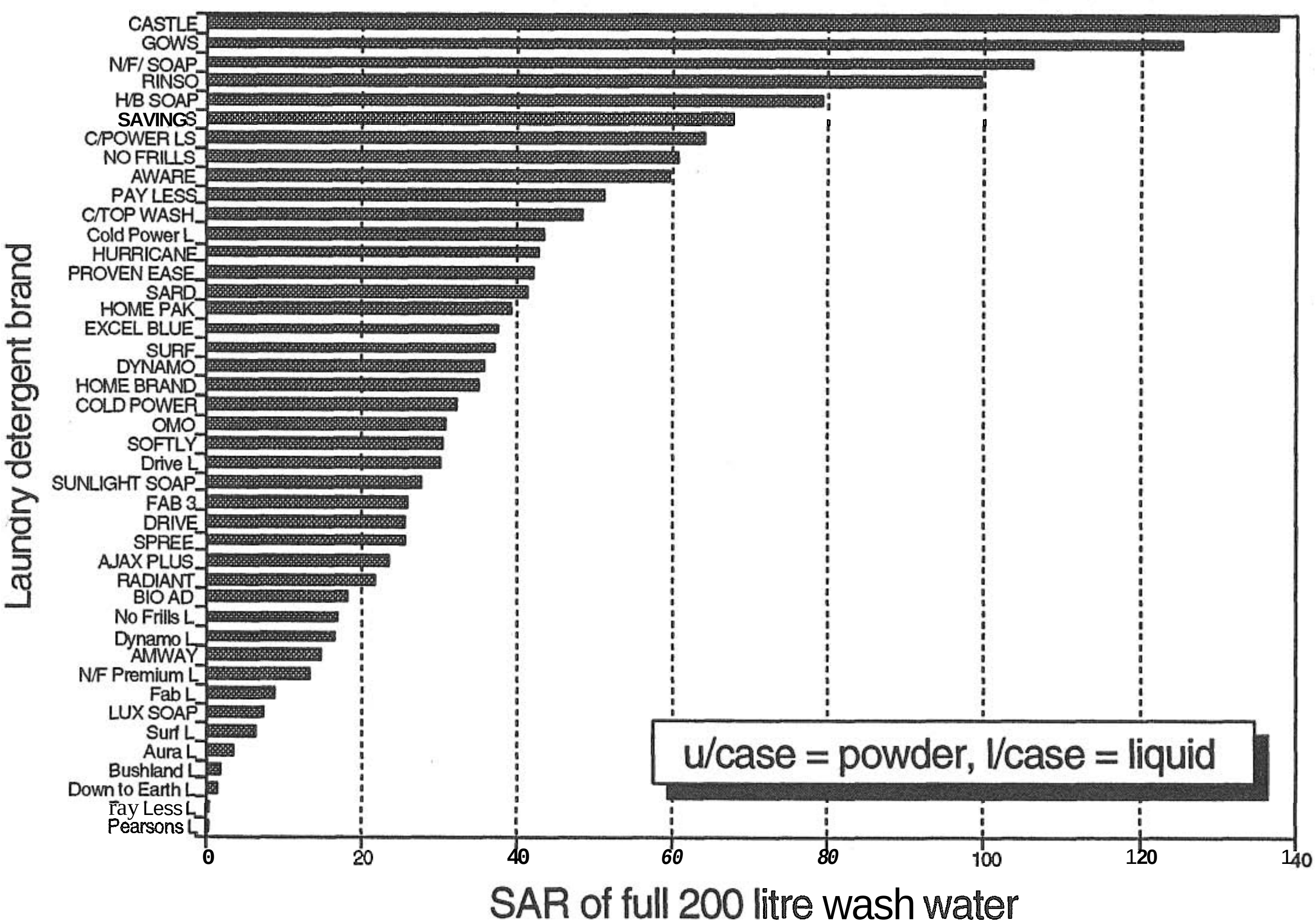

Figure 3. Sodium adsorption ratio of laundry detergents tested

A demonstration conducted in conjunction with this lecture displays the short term loss of hydraulic conductivity on four soils using water of a chemical nature similar to the full water load from an automatic washing machine. Where soils are dispersed, colloidal material moves with the effluent into the flask below the soil. In the field, the movement of these colloids contributes to the physical blocking of soil pores and the loss of hydraulic conductivity.

4 Environmental impact of sodium

Sodium is an essential biological chemical which takes part in processes maintaining osmotic pressure in living cells, plant and animal. An excess of sodium disturbs the critical balance and in humans excess salt (sodium chloride) intake has been linked to heart disease and high blood pressure. In plants, excess sodium leads to a perceived drought effect and plants will show a "burnt edge" effects and eventually die. Salt tolerance is a characteristic of many plants but for agronomic purposes, and that includes landscaping, significant loss in plant quality and production arise from increased sodium in the plants' environment.

Animals are tolerant to larger concentrations of sodium. It is common for sheep and cattle to eat soil, scraping the hard soil with their teeth, along gully lines where salt extrusions occur. Many animals will also prefer salty groundwater to clean rainwater. Soils, however, behave in a typical manner with respect to increases in sodium.

Sodium in many Australian soil is inherently high. A measure of soil sodium is exchangeable sodium percentage, the percentage of all exchange sites which are held by sodium ions. ESP values above 6 are considered sodic, although ESP 15 has been adopted inappropriately from USA data. Where domestic effluent is disposed of on soils with ESP values above 6, loss of hydraulic conductivity is expected to occur. Similarly, where the disposal of effluent leads to an increase in ESP to 6 or higher, hydraulic conductivity losses will also occur.

Thus the need to prevent sodium entering the soil profile is of greater importance than amelioration after the event. For the subsurface disposal of septic tank effluent, the loss of hydraulic conductivity is pronounced and surfacing effluent is the result. Once the subsoil interface is dispersed and physically blocked with dispersed colloids, the remedial action is replacement of the trench. The surfacing effluent carries with it a high bacterial population, nitrates and phosphates which are free to enter surface water supplies and impinge on adjacent areas.

5 Measuring soil hydraulic conductivity

Several methods are employed for measuring the infiltration capacity (hydraulic conductivity) of a soil horizon. The percolation test as designed by Ryon in USA has been used in Australian up until recent times even though the Americans discontinued its use more than 20 years ago. It was seen as an easily replicated test with some simple conversions to long term acceptance rates (LTAR). The percolation test should not be used in relation to septic tank disposal field design.

A disc permeameter as designed by CSIRO is a useful tool for short term investigative research into the behaviour of saturated hydraulic conductivity of soils. Using the device it is difficult to limit the movement of water to a vertical profile and care must be given to site selection, setup and a limitation place upon the duration of tests. Unfortunately subsurface discontinuities may render many of the results worthless.

Well permeameters are used to equate hydraulic conductivities in soil profiles. The major problem with such equipment is that the smearing of subsoil surfaces is difficult to avoid, surfaces may be compacted and changes in horizon characteristics may affect results.

Undisturbed cores are expensive to obtain and usually beyond the resources employed in septic tank design. It is usually that only for research purposes are undisturbed cores equilibrated with effluent of differing types and strengths.

The most useful technique for determining soil hydraulic conductivity is to describe the soil profile in the disposal field and assign conductivity rates to the soil consistent with a number of soil parameters. While the method employs a degree of subjectivity, it leads to a more thorough description of the soil profile and examines the texture and structure of the soil which influence hydraulic conductivity. The examination of horizons, boundaries and other discontinuities may assist in more accurately assigning consistent disposal rates to similar soils.

6 Loss of Soil Hydraulic Conductivity

Research undertaken by the author indicated that saturated hydraulic conductivity is reduced when effluent of SAR as low as 3 is disposed of on a number of NSW soils. The problem presented with STE is that SAR 3 effluent is accompanied by low electrical conductivity (EC). Figure 4 indicates the loss of hydraulic conductivity with increasing SAR for a chocolate (clay loam) soil. The losses are statistically significant.

The implications for septic tank effluent disposal are that the higher the SAR of the effluent, the shorter the life of the drainfield because of the rapid loss of hydraulic conductivity. Because loss of hydraulic conductivity is related to soil dispersion, the problem is chemically irreversible and a new disposal field is required. Where surface disposal of effluent is performed, loss of hydraulic conductivity may be reversed by physically disturbing the dispersed layer and incorporating chemical ameliorants.

The critical factor for avoiding loss of hydraulic conductivity is to prevent the sodium salts from reaching the disposal field or reducing their impact by chemical alteration of the effluent SAR before reaching the soil. In economic terms, reduction of the use of sodium salts in the household is the most effective and efficient prevention.

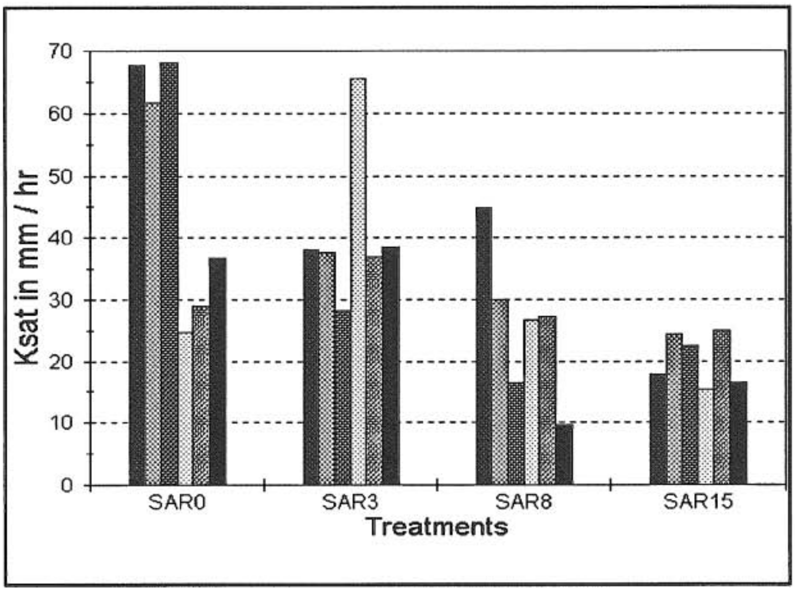

Figure 4. Saturated hydraulic conductivity for surface chocolate soil using disc permeameters.

7 Conclusions

The impact of sodium on wastewater management is critical to ensuring that both the aquatic and soil environments are protected from increasing sodicity and effects of sodium salts on biological well-being and soil physical properties are either prevented or ameliorated. The development of salt tolerant species in disposal areas is but a short term response to a problem whose solution is one of reduction. By reducing the quantities of sodium salts used in the household, the life of safe soil disposal fields is lengthened.

There is strong evidence that sodium is an environmental hazard and that significant losses of soil hydraulic conductivity will occur from even short term disposal to current suitable soil profiles. Measuring soil hydraulic conductivity with clean water and inferring a disposal strategy under a dirty water regime is inviting failure of the soil system. Where soil disposal, either subsurface or surface, is proposed, the effects of the effluent must be evaluated with respect to the SAR and EC of the effluent together with the ESP, soil texture and soil structure of the soil profile.

References:

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