Soil Absorption of Septic Tank Effluent

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ABSTRACT

Septic tank effluent is inherently high in sodium ions relative to divalent cations (high sodium adsorption ratio). The disposal of septic tank effluent to the soil will cause the sodium ions to disperse the clay colloids, resulting in a physical blocking of the soil pores. Hydraulic conductivity will be reduced and the effluent will fail to dissipate into the soil profile.

In designing the disposal system for septic tank effluent it is important to account for both the exchangeable sodium percentage of the soil and the sodium adsorption ratio of the effluent. Where high levels of either ESP or SAR are indicated, amelioration of either the effluent or the soil, or both, are required.

Current design parameters and the draft Australian Standard are based upon clean water infiltration. An infiltration demonstration based upon both clean and sodium rich water indicated that a significant loss of infiltration occurred under the latter, reflecting the situation with traditional drainfields.

KEYWORDS: Septic tank; on-site disposal; percolation test; sodium adsorption ratio; hydraulic conductivity; disinfection.

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INTRODUCTION

Septic tanks provide more than 2 million Australian households with an effective, if not efficient, means of removing household domestic wastes away from the living area. Their continued construction in rural residential and fringe urban areas acclaims the communities[1] ready acceptance of septic tanks as something more than a stop gap measure. Almost 47% of Perth residences are unsewered (Whelan and Barrow, 1984), 12% of Sydney's 1977 population of 3 million (Gutteridge *et al*, 1977) and more than 75 000 unsewered premises exist in Melbourne (Day and Willatt, 1982). It is estimated that 130 000 dwellings connected to reticulated mains water in New South Wales rely upon septic tanks to dispose of their household wastewater (Bureau of Statistics, 1987) while a further 120 000 septic systems rely upon rainwater inputs.

There are two Australian Standards, 1546 - 1983 Small Septic Tanks, and 1547 -1973 Disposal of Effluent from Small Septic Tanks (update in draft form) which relate to both the construction of the physical tank and the disposal field in the soil profile. Neither publications is considered of value to the home owner for day to day operation of the septic tank.

In New South Wales the construction and commissioning of septic tanks is controlled under the Health Act and Local Government Act and obscurely by the Clean Waters Act. Two publications, generally accepted by Councils in NSW as guidelines, are currently both out of print. As a result a number of Councils have prepared notes for home owners based upon those publications and local knowledge. These notes vary from valuable to vague.

While these broad guidelines may be in place, the real situation is that there are many septic drainfields which have failed and remain in a poor state of operation simply because the criteria upon which effluent disposal has been based do not address the specific soil conditions. Failure of a soil disposal system is not reported usually for fear that the requirements for repair will be costly. Surfacing effluent, overland flow of partly treated effluent and saturated areas around the disposal field are incorrectly accepted as part and parcel of on-site disposal.

This paper will address some of the misconceptions which lead to failure of a subsoil disposal field. Viable options for the efficient and effective use of domestic septic tank effluent are beyond the scope of this paper. While the problems of high sodium adsorption ratios are similar for both sub-surface disposal and surface disposal from aerated systems, only the former will be treated here.

CURRENT AUSTRALIAN RESEARCH

Most of the research into the disposal of septic tank effluent has been lifted from the United States To date the only recent seminar on domestic wastewater treatment was in Adelaide in June, 1988 (Maakestas & Kayaalp, 1988). Previous research was restricted to a Doctor of Philosophy thesis by Joost Brouwer (Brouwer, 1982) from which a land capability assessment scheme was developed, the thrust of which was that a minimum length of trench required for duplex soils in Victoria was 120 metres for a standard household. Few projects have looked at the reasons for failure and assumed an under-designed length of disposal trench.

Researchers in Perth analysed the effects on effluent percolating through sands (Whelan and Barrow, 1984), a problem specific to the West. Most of New South Wales septic tanks are on heavy clay soils or duplex profiles.

The author is currently researching the soil absorption and treatment of septic tank effluent as part of a Doctor of Philosophy thesis. The thrust of that research is to address the cause of and the prevention of sub-soil hydraulic failure through the amelioration of the septic tank effluent. A number of papers have been published on components of this research.

SEPTIC TANK EFFLUENT DISPOSAL OPTIONS

A number of alternatives to conventional septic tank systems have evolved. These include the trade names 'Biocycle', 'Envirocycle', "Earth Safe" which utilise multi-chambered tanks for the preliminary treatment and chlorination of effluent prior to surface disposal. Regular maintenance is an important factor in their continued operation as the primary treatment tank is usually less than the daily inflow and the final effluent is treated with hypochlorite for disinfection. Wollondilly Shire has more than 2000 aerated units in use for domestic waste disposal (J.Britton, 1993 pers. *comm.*)

Mounds have been used in experimental situations in Australia but have undergone an intense research program in Wisconsin University, USA. These operate as a mound constructed on the surface of the soil and utilise the higher infiltrative capacity of that horizon to dissipate the wastewater for both soil water and evaporative removal.

Peat bed pre-treatment of septic tank effluent has been documented (Patterson et *al.*, 1986a) as a mechanism by which nitrogen, phosphorus, total solids and a high proportion of the coliforms are removed from the effluent prior to surface disposal. The pre-treatment eliminates the problems encountered with sub-surface disposal by producing an effluent with low organic solids carryover.

Further, with surface application a high proportion of the remaining bacteria is destroyed by ultraviolet radiation and dehydration (Patterson, 1986; 1989). Current research with *Hydrosafe* indicates that considerable removal of faecal coliforms may be affected without the environmental effects of chlorine derived products.

SEPTIC TANK INPUTS

The most important input to the system is the quantity of water used within the home. A sub-surface drainfield has to be designed according to the ability of the soil to dispose of the septic tank effluent as both percolation water (to the soil water and groundwater) and capillary water (to the evaporative cycle). Few Local Government Councils, as approving agencies, are prepared to limit the use of water within a domestic situation. In a recent survey of NSW Shire Councils (Patterson, unpubl.), not one of the 70 respondents placed restrictions on the type of water using appliances within a dwelling. Many Councils permit the unrestricted use of reticulated water supplies to homes served by traditional effluent drainfields.

Reduction in water consumption results in the septic tank effluent having lower total solids carryover to the disposal field. The purpose of the septic tank is to provide primary treatment to the household wastes by allowing sufficient time for the majority of the solids to settle and the less dense materials to float as scum. With insufficient retention time, due to high through flow of water (daily water usage exceeds the liquid capacity of the tank), high concentration of solids carryover is inevitable.

A standard 2050 litre septic tank has the potential for treating approximately 1200 litres of water daily, assuming an accumulation of sludge and scum over a three year period equivalent to 600 mm. This equates to 240 litres per person per day, a value often taken as the average daily consumption. It has been shown, however, that for dwellings connected to reticulated supplies that value is often exceeded by more than 50% (Patterson, 1982). Thus the need to restrict water consumption by the fitting of water restriction devices (low volume shower roses, dual flush toilets) and the lowering of delivery pressure cannot be overlooked in the wholistic treatment of domestic wastewater disposal.

PROBLEMS WITH CURRENT EFFLUENT DISPOSAL

The majority of disposal problems stem from the inability of the soil profile to adequately dissipate the water away from the trench. This results in the effluent surfacing at some point along the trench or blocking the flow of effluent from the tank, in which case the overflow occurs at the tank.
As septic tank effluent flows from the tank, it carries with it a high proportion of suspended solids, often in excess of 150 mg/L (Patterson, 1986). These solids further decay in the anaerobic and aerobic environments within the sub surface trench/soil interface. Many of the solids and some of the soluble materials are polysaccharides which produce a 10 -20 mm clogging layer (dark grey ooze in the anaerobic zone) (Patterson *et* al, 1986b). While this clogging layer is an important functioning environment within the trench, it reduces the hydraulic conductivity of the soil to a about 10 mm m^{-2}. Thus the designed length is usually an underestimation of the potential percolation rate.

While problems with total solids carryover can be prevented, it is often conceived by the householders that a septic tank requires little or no treatment. Unfortunately little education is offered to the home owner to prevent septic tank failure. Of 70 Council replying to a survey on septic tank installations, less than 10 Councils had produced material of an informative nature for home owners. As the New South Wales Health Department's literature is out of print, the majority of home owners could be excused for their ignorance with regards to their treatment of septic tanks.

PERCOLATION TESTS

The information available to Local Government bodies suggests that the standard percolation test (Department of Public Health, 1961; Victoria Health Commission, 1983 and AS 1547) should be employed for the design of sub-surface disposal trenches. No percolation test makes mention of soil structural stability, impervious horizons or duplex soil profiles. One criterion that each test has in common is that the water used for the test is clean water. While the test may give some indication of the clean water percolation of the soil, it does not account for the cations within the septic tank effluent which may have a deleterious effect upon the infiltrative capacity of the soil.

The hydraulic conductivity of the soil may be greatly reduced by the presence of sodium ions within the effluent. The sodium ions increase the dispersion of the clay colloids causing a physical blocking of the micropores within the soil. This physical blocking is irreversible through the use of hydrogen peroxide, gypsum or other chemicals. The effects of the sodium ions can be further exacerbated by the ammonium ions in the effluent (from the partial nitrification of organic materials).

It has been shown by a number of researchers that the ratio of the sodium ions to the calcium and magnesium ions (Sodium Adsorption Ratio) can be related to the potential for a water to affect the hydraulic conductivity of a soil. This is more particular for a soil already high in sodium (high exchangeable sodium percentage) and exacerbated by low electrical conductivity. Both these properties have been addressed in irrigation engineering for many years but are neglected when addressing the disposal of septic tank effluent.

Research undertaken by the author (Patterson, 1991) has quantified the changes in hydraulic conductivity for a number of soils, with levels of SAR common in septic tank effluent. All soils tested, as demonstrated with this presentation, reflect a significant decrease in infiltration with sodium rich water. This reduction will occur in both sub-soils and surface soils, thus affecting both traditional drainfields, aerated wastewater treatment plants and future re-use options.

Figure 1 indicates the change in hydraulic conductivity (infiltration) of a grey brown podzolic (duplex) with three simulated septic tank effluents. A typical septic tank effluent with a rainwater input has an outflow SAR in the order of SAR 8. This indicates a reduction of effluent infiltration compared with rainwater infiltration in the subsurface horizon by twenty five times (100 to 4 mm/day). Similar results have been obtained on a range of soils and indicate the lack of correlation between rainwater and effluent in percolation tests.

RETICULATED WATER SUPPLIES

Many reticulated water supplies throughout northern New South Wales have SARs at levels where dispersion of soil colloids may occur from infiltration of treated water through the soil. Without any additional sodium contribution from soaps, laundry detergents or human diet, these waters are unsuitable for traditional drainfield disposal.

Figure 2 indicates the SARs for a number of treated water supplies sampled during the period May - July, 1991. Coastal systems generally have a lower SAR than inland systems. Ballina had an SAR of 1.2, Lismore 2.4 and Alstonville 4.8.

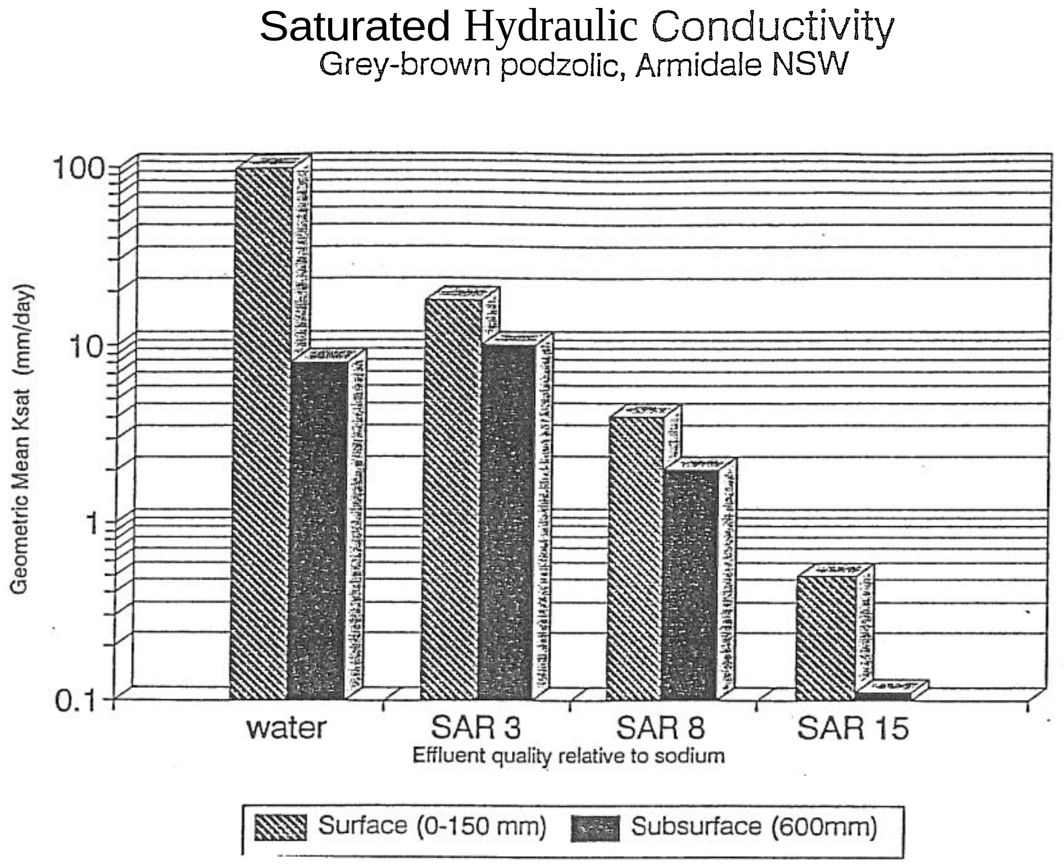

Figure 1. Loss of infiltration capacity with increasing SAR

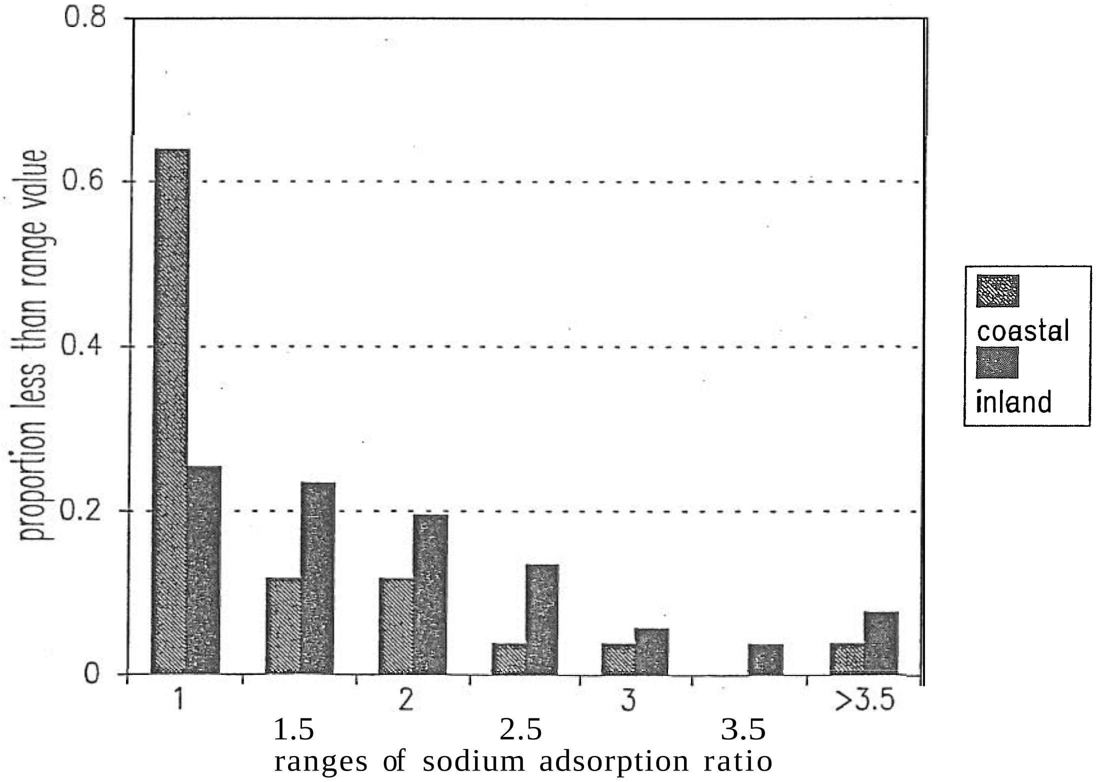

Figure 2. Range of SAR in reticulated town water supplies (NSW)

SODIUM INCREMENTS FROM DOMESTIC USAGE

A survey of a number of sewage treatment works was undertaken to indicate the increase in sodium ion concentrations consistent with urban usage. Figure 3 below indicates the input water from a treated reticulated supply and the outflow from the final treatment pond. As all sodium salts are soluble, there is no mechanism for removal of the offending sodium ions. Sodium Adsorption Ratios (SAR) greater than 3 to 5 have the potential for soil dispersion. These values, while lower than septic tank effluent reflect the alteration of water quality through domestic consumption.

The graph indicates that most outflows have the potential for creating soil infiltration problems and the increase is attributable to urban consumption.

LAUNDRY DETERGENTS

The largest single contribution to sodium ions in septic tank effluent is from laundry detergents. Sodium salts are used because of their high solubility and are generally not a problem where wastewater is disposed of to ocean outfalls. Where outfalls are to clean river systems or soil absorption, the potential for sodium problems is significantly increased.

Figure 4 below indicates the frequency of SAR levels measured from a full 200 litre washing machine cycle using 40 brand name liquid and powder detergents. In some brands more than 40% of the powder is sodium sulphate, used as a filler and of dubious value in wash performance. Where septic tank effluent is to be disoposed of by sub-soil infiltration, selection of low sodium detergents should have a high priority. Unfortunately this information is not readily available for the consumer. The author has examined 41 popular brands and concluded that only five are suitable for septic tanks.

DEMONSTRATION

Three sets of duplicate samples of soil were placed in glass tubes and arranged in a rack. A flask was mounted to maintain a constant head of 10 mm liquid over the soil (typical of drainfield operation). One sample of each was infiltrated with clean water while the duplicate was infiltrated with washing machine water. An equivalent amount of a laundry powder had been dissolved in water to simulate the SAR from a full 200 litre wash cycle (that is, wash, spin, rinse and spin dry).

The three soil samples represented a duplex soil (yellow solodic), a gradational soil (Krasnozem from Alstonville) and a heavy clay (Black Earth). The results are given in Table 1 below and are for demonstration purposes only, A direct quantitative comparison cannot be made, only a indication of loss of infiltrative capacity with sodium rich effluent. This reflects what occurs in a sub-surface drainfield when sodium rich septic tank effluent is percolated through the soil. Scientific results require infiltration of various strength effluents through undisturbed soil cores (Patterson, 1991).

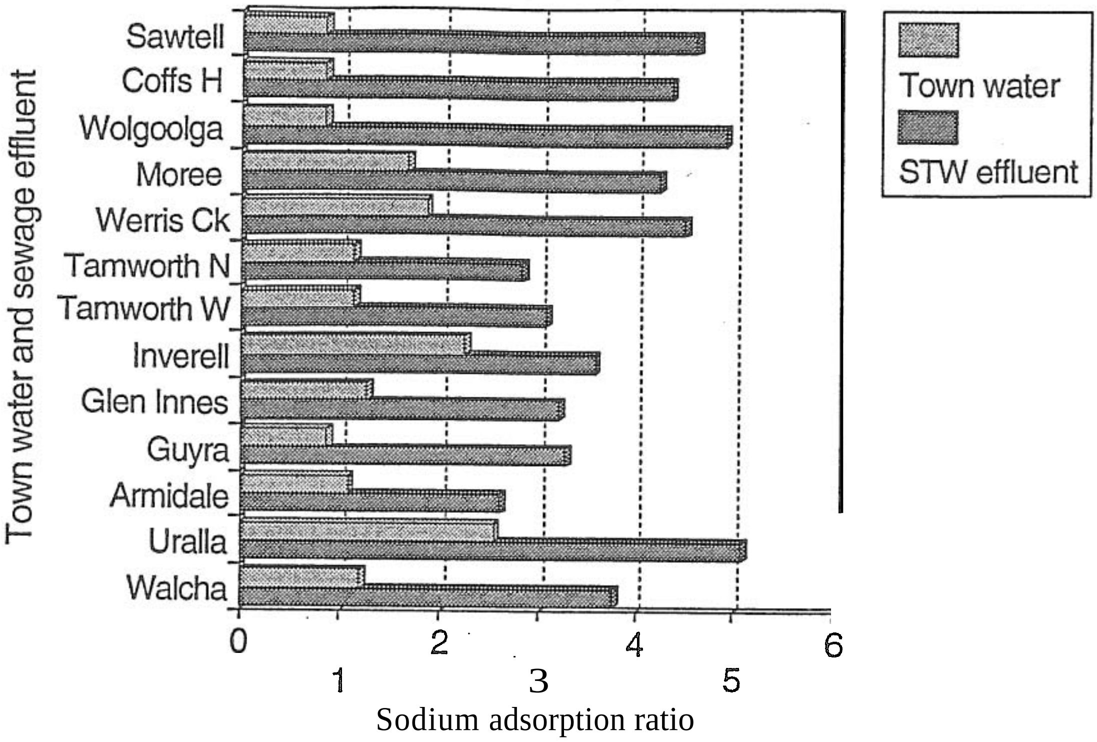

Figure 3. Change of SAR in selected towns due to urban consumption

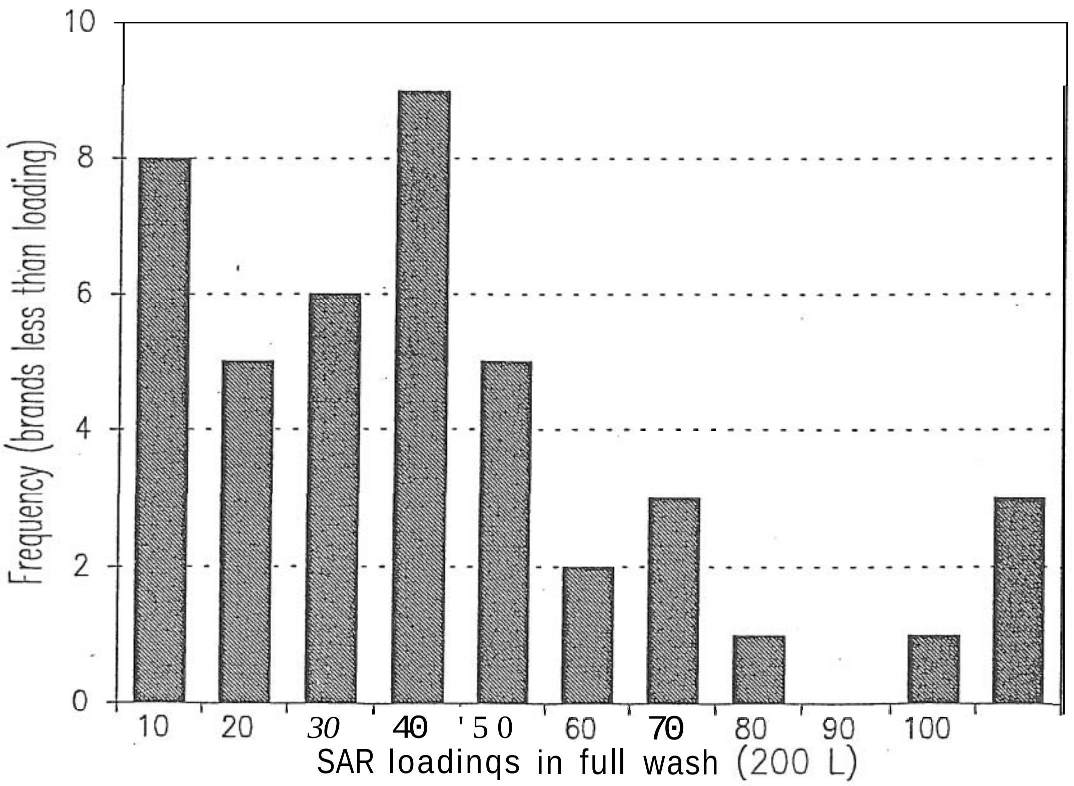

Figure 4. Frequency distribution of popular brands of laundry detergents.

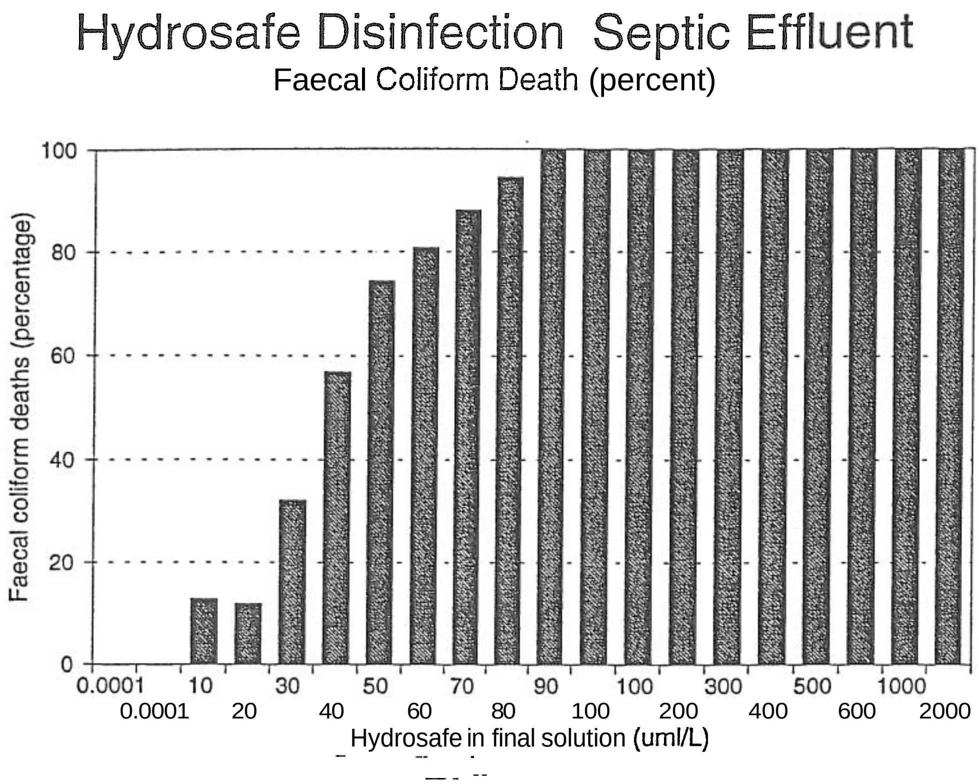

Figure 5. Hydrosafe disinfection of faecal coliforms with concentration

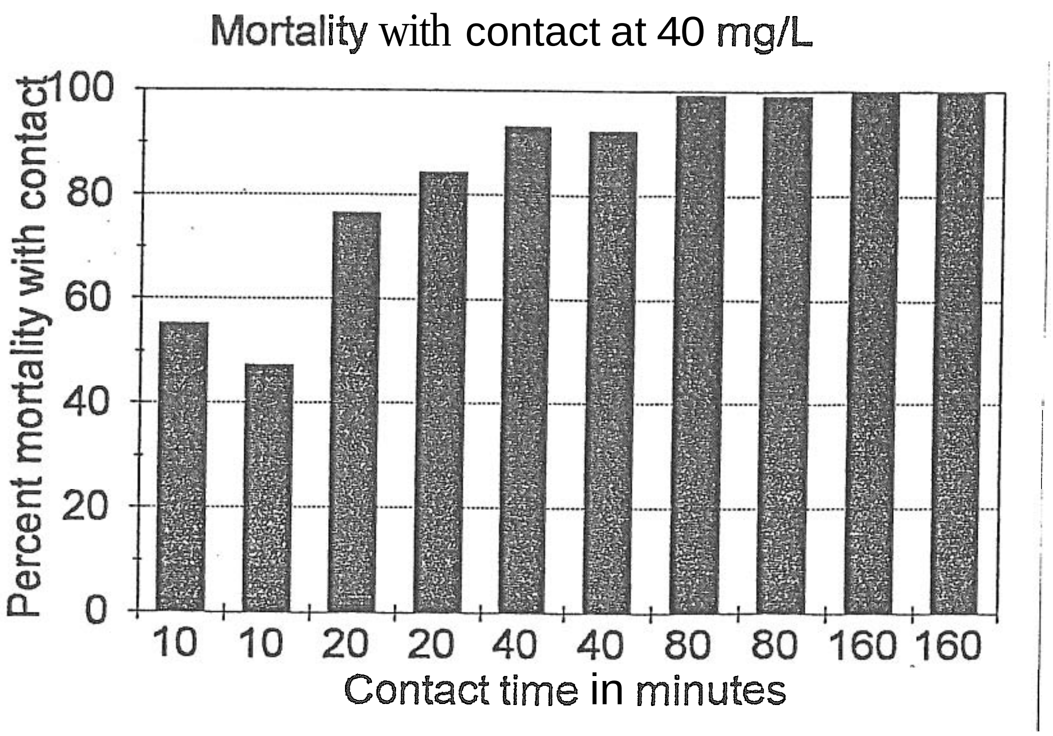

Figure 6. Hydrosafe disinfection with contact time at 40 mg/L

TABLE 1.

INFILTRATION DEMONSTRATION - SIMULATED EFFLUENT

	Number of flasks infiltrated over approximately similar time period	
	Rain Water	Na^+ rich water
Yellow Solodic	4	2
Krasnozem	3	0.3
Black Earth	0.25	0.1

NOTE: (a). Soil density less than in-field bulk density but not quantified

(b), values refer to 250 ml flasks over a similar although not controlled time period.

CAUTION: the values are for demonstration purposes only

DISINFECTION

The effluent disposed of to the environment is required to meet a low level of faecal coliform contamination. In aerated systems this is controlled through the use of hypochlorite tablets to maintain a residual chlorine level in the wastewater. In the sub-surface drainfield a strong reliance is placed upon the soil bacteria, aeration and dehydration to eliminate coliforms from the effluent.

In the peat bed operation mentioned above, the wastewater has a low level of faecal coliform contamination after peat treatment, consistent levels of 2000 colonies per 100 ml has been achieved over a six year operation. However an additional reduction is necessary to satisfy Public Health. Hydrosafe, a stabilised hydrogen peroxide has been used in laboratory tests with peat bed effluent. With concentrations as low as 90 mg L^{-1}, 100 percent kills of faecal coliforms have been obtained. Figure 5 indicates the kill rate attained for a 5 minute contact period. Since the by-products of hydrogen peroxide are oxygen and water, considerable environmental benefits are likely, rather than the effects of residual chlorine on soil bacteria.

Figure 6 indicates the variation in faecal coliform destruction with contact time.

FUTURE DIRECTIONS

That septic tanks will continue to be an important part of both rural and peri-urban developments cannot be overstated. The problems associated with disposal of septic tank effluent will continue while ever there is little or no education of the home owners, poor standard trench dimensions with respect to soil type and lack of understanding by local authorities of the specific effects of sodium upon that soil. The failure of the draft revised Australian Standard to address effluent quality is deplorable and is not encouraging for sustainable peri-urban developments.

The need for conservation of water use within the home cannot be overstated and must be considered through stipulation of water conservation appliances and restrictions on reticulated supplies.

The effects of sodium on the majority of Australian soils is underrated in most guidelines for the disposal of wastewaters to a soil profile. The exchangeable sodium percentage at which Australian soils tend to disperse is as low as 6 units (Northcote and Skene, 1972) while American soil scientists use 15 as a cut off. The current edition of guidelines for land application of wastewaters (SPCC, 1990) does not mention the ESP levels for suitable disposal. Rather it suggests an SAR of 8 for suitable irrigation water. While this may be suitable for low sodium soils it would be devastating for high sodium soils.

Other statutory authority guidelines fail to differentiate between clean water and sodium rich water in determining hydraulic conductivity in percolation tests. Until acknowledgement is made of the contribution of sodium ions to soil dispersion, the failure of traditional drainfields will continue.

CONCLUSIONS

The need for the effects of sodium upon soils used for the disposal of wastewaters cannot be too highly stressed. Whether the effluent is disposed of to sub-surface (absorption) trenches or the surface soils (irrigation), the effects of sodium on hydraulic conductivity are pronounced.

In quantifying wastewaters for disposal to a soil it is imperative that both the exchangeable sodium percentage (ESP of the soil) and the sodium adsorption ratio (SAR of the wastewater) are clearly indicated. Where either the ESP or SAR are unsuitable, amelioration either of the effluent or the soil will be required. In any circumstances soil percolation tests using clean water are unsuitable and will inevitably lead to incorrect designs.

Septic tank effluent has an inherent high SAR and must be ameliorated prior to subsurface disposal. Surface disposal from aerated systems and re-use options create less of a problem as the soil can be ameliorated more easily to overcome the effects of high SAR wastewater but the long term effects may be the same.

Disinfection of final wastewaters must address the potential environmental problems of chlorine and the effects upon the soil biota. Hydrosafe is a suitable alternative with low environmental hazard.

Solutions to the above disposal problems are achievable at the domestic level and within simple economic terms. However a wholistic approach by a number of government instrumentalities is required for guidance.

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