Soil Absorption and Treatment of Septic Tank Effluent

by Robert A. Patterson
Department of Resource Engineering
University of New England, Armidale

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.

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

Invited paper presented to Seminar "Engineering the Environment", Institution of Engineers Australia, Newcastle Division-Northern Group. University of New England, 28-29 June, 1990

INTRODUCTION

Septic tanks provide more than 2 million Australian household 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' 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 in New South Wales rely upon septic tanks (Bureau of Statistics, 1987).

There are two Australian Standards, 1546 - 1983 Small Septic Tanks, and 1547 -1973 Disposal of Effluent from Small Septic Tanks which relate to both the construction of the physical tank and the disposal field in the soil profile. The former contains detail for manufacturers of septic tanks more than homeowners while the latter gives very broad dimensions for absorption trench, transpiration bed and collection well design. Neither publications is considered of value to the home owner for day to day operation of the septic tank.

The Victorian Health Commission has developed a "Code of Practice for Septic Tanks" and leads the rest of the states in the publication of a comprehensive document for the community and includes a section on septic tank maintenance. 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. Depending upon the method of disposal of the effluent the State Pollution Control Commission's guideline for use of recycled water (SPCC, undated) and design guide for land application of wastewaters (SPCC, 1989) may be applicable.

Two publications which are being used by Councils as guidelines in NSW 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.

While these broad guidelines may be in place, the real situation which exists is that there are many septic tanks which have failed and remain in a poor state of operation simply because the criteria upon which effluent disposal has been designed 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 and give some viable options for the efficient and effective use of domestic septic tank effluent.

CURRENT AUSTRALIAN RESEARCH

Most of the research into the disposal of septic tank effluent has been lifted from the United States where much time and effort have been given to solving environmental and social problems related to failed disposal fields. The reliance of rural and peri-urban American communities on septic tanks is increasing. This is obvious as the American Society of Agricultural Engineers holds a biennial conference on On-Site Treatment which in 1987 attracted over 40 papers and 260 delegates (ASAE, 1987). To date the only recent seminar on domestic Wastewater Treatment was in Adelaide in June, 1988. Previous research was restricted to a Doctor of Philosophy thesis by Joost Brouwer (Brouwer, 1982) and associated research as part of that program. (A land capability assessment scheme resulted from that thesis, 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 works have looked at the reasons for failure other than 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.

The author is currently involved with research into the soil absorption and treatment of septic tank effluent as part of a Doctor of Philosophy thesis. The thrust of that research is into the prevention of sub soil failure through the amelioration of the septic tank effluent. This material will be treated in more detail later.

SEPTIC TANK EFFLUENT DISPOSAL OPTIONS

A number of alternatives to conventional septic tank systems have evolved. These include the trade names 'Biocycle', 'Envirocycle', which utilise multi-chambered tanks for the preliminary treatment and chlorination of effluent prior to surface disposal. These systems require a licensed plumber to be available for routine and regular maintenance. 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.
The separation of black water (toilet wastes) from other domestic wastewater (shower, laundry, kitchen) and the disposal of partially treated black water into evaporation beds is also used in some Local Government areas. The grey waters are untreated except for a grease trap on the kitchen wastes and the wastewater is disposed of by surface spreading. The majority of local government areas prefer treatment of all wastes in a single tank of 2050 litres.

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 groundwater and evaporative removal.

Peat bed pre-treatment of septic tank effluent has been documented 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 are destroyed by ultraviolet radiation and dehydration (Patterson, 1986; 1989).

The author has successfully operated a 18 square metre peat bed in a domestic situation for almost four years. The pre-treated effluent has less than 1 mg/L suspended solids and is suitable for irrigation. The effluent has no offensive odour and is virtually colourless. The system, capable of being constructed on a domestic block is essentially maintenance free.

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 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, not one of the 70 respondents placed restrictions on the type of water using appliances within a dwelling. Several Councils made veiled statements as to the need to conserve water but none offered constructive advice to home owners on the potential for reducing water consumption. Many Councils permit the unrestricted use of reticulated water supplies to homes served by standard 2050 litre single chambered septic tanks.

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 that value 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 planned treatment of septic tank effluent.

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 water 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. By the time the problem becomes obvious, the damage caused to the disposal field is usually beyond repair. The need to construct another disposal field is seen as the obvious alternative, however, as this is viewed in economic terms the construction is often delayed. This additional economic burden is often offered as the excuse for failing to notify the Council of the problem. Councils have indicated that they only inspect septic tanks systems when a serious failure is reported. It is often suggested that revitalisation using hydrogen peroxide is useful (Gutteridge <u>et al</u>, 1985), but neglects to suggest it is both costly and dangerous.

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 <u>et al</u>, 1986b). While this clogging layer is an important functioning environment within the trench, it reduces the hydraulic conductivity of the soil to a level well below its measured potential. Thus the designed length is usually an underestimation.

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) should be employed for the design of sub-surface disposal trenches. There are several variations of the test available, as to whether the test hole is round (100 mm round in Victoria) or square (300 mm square in NSW), as to whether the soil moisture conditions are monitored or as to the homogeneity of the soil type over the distance of the trench. No percolation test makes mention of soil structural stability, impervious horizons or duplex soil profiles. One criterion that they have in common is that the water used for the test is clean water. While this 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 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). The ammonium ions displace divalent and trivalent cations which tend to cause flocculation (the opposite to dispersion).

While the effects of surface salinity are currently gaining the attention for the potential to cause land degradation, no notice is being paid to the effects of the high use of sodium salts within the household on the disposal of domestic wastewater. For example, water supplied by Armidale City Council enters the household at approximately 35 mg/L. The average household effluent leaving the Armidale sewage treated works is in the order to 48 mg/L, an increase of 37%. Water leaving a septic tank is in the order of 160 mg/l, an increase of 360%. (Patterson et al, 1986c) The difference in the two final effluents is that in the case of the Armidale Sewage Treatment Works, the water is added to the receiving waters of Commissioner's Waters and diluted as local stream flow conditions allow, The effluent leaving the septic tank is immediately associated with its disposal medium - the soil and the high level of sodium ions has a pronounced effect upon the hydraulic conductivity.

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). Both these factors have been employed in irrigation engineering for many years but have been neglected when addressing the disposal of septic tank effluent.

Research by the author (Patterson et al, 1986c) showed that soil treated over a twelve month period with septic tank effluent had an increased exchangeable sodium percentage (ESP). This had the potential for increasing dispersion and reducing hydraulic conductivity. Further research is being undertaken to quantify the changes in hydraulic conductivity, for a number of soils, with level of SAR common in septic tank effluent.

The current indications are that the septic tank effluent requires amelioration with calcium ions prior to soil disposal.

SOIL DISPOSAL OF EFFLUENT

Given that the use of household soaps, washing powders, human excrements and kitchen wastes have a high concentration of sodium ions relative to the water supply (reticulated or rainwater), it is an important to consider the effects of that water upon the disposal medium.

Where effluent is disposed of to the sub-soil, any failure within the micropores, brought about by sodium aggravated dispersion, sets in train an irreversible process. Effluent likely to cause soil dispersion problems should be ameliorated before it leaves the septic tank. This can be done effectively by raising the SAR through the addition of calcium ions. Lime is an effective source of calcium ions as well as providing a flocculating environment within the tank (reducing solids carryover).

Treatment of the newly constructed trench with lime or gypsum may assist in initial stages but its effectiveness over time will be reduced. The effects of the lime upon the anaerobic environment are not well understood and may be detrimental to the functioning of the trench as a treatment mechanism.

Effluent may be successfully disposed of as surface applied water, either by overland flow or sprinkler application. The larger surface area over which the effluent may be disposed reduces the concentration of sodium ions but permits natural leaching with rainfall. Surface application of lime or gypsum may be used to alleviate any potential sodium problems, or the lime may be mixed in the septic tank. The advantage of surface application is that the disposal area is quickly moved to a fresh site should a problem be noticed. The disadvantage with the system is that the effluent has a high coliform count and a particular odour which may be obnoxious. The residual nitrogen and phosphorus compounds are available to the plant community and not a problem for runoff.

Pre-treatment of the effluent to remove the odours and reduce the eoliforms are essentially the operations of the systems such as 'Biocycle' and 'Envirocycle". The peat bed pre-treatment (Patterson et al, 1986a) is effective in reducing both odour and total solids although the coliform destruction is variable, although within acceptable limits. However, ultraviolet light and desiccation will provide a substantial reduction in coliform levels with surface application.

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 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 is suggests a 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 sodium adsorption ratio and exchangeable sodium percentage, failing to take notice of the inherent properties of the soil and the potential for greatly reducing hydraulic conductivity as a result of unsuitable irrigation waters for the soils available. The design of septic tanks suffers the same symptoms and manifests in the numerous failed sub-surface disposal systems across the country.

DEMONSTRATION

The simple demonstration to accompany this presentation is designed to indicate the potential for greatly reducing soil hydraulic conductivity with the introduction of washing machine waste water (distilled water and "Rinso").

A sample of approximately 21 g of air dried sieved (2 -5 mm) grey brown podzolic has been placed in a glass tube. The sample has been pre-wet with distilled water and allowed to freely drain. The macropores in the soil (the quality imparting hydraulic conductivity) are visible and continuous from top to bottom. The soil peds are freely and randomly arranged and are intended to represent an open structured friable soil profile.

One sample is subjected to a static head percolation test using distilled water. The resulting effluent has a mild dispersion of clay colloids, but the sample appears to retain an undisturbed macroporosity. The second sample is treated with a liquid equivalent to wastewater from a domestic washing machine ("Rinso" is the detergent used). The sample runs freely at first but then slows to about half the pace of the clean water. The resulting effluent is highly coloured with a large quantity of dispersed clays. The sample also appears to have dispersed and the macroporosity is being lost. The hydraulic conductivity has been greatly reduced with less than 100 mm of equivalent irrigation.

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 the 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 creates less of a problem as the soil can be ameliorated to overcome the effects of both ESP and SAR.

REFERENCES

American Society of Agricultural Engineers, 1988 On-Site Wastewater Treatment Vol 5. Proceedings of the Fifth National Symposium on Individual and Small Community Sewage Systems

Australian Bureau of Statistics, 1987 Domestic Water Use: New South Wales Aust Bureau Statistics, Sydney.

Brouwer, J., 1982 Septic Tank Effluent Absorption Systems near Melbourne, Victoria: Land Capability and Design Thesis, School of Ag. La Trobe University, Melbourne

Day, K and Willatt, S.T., 1982 Evapotranspiration as a Method of On-Site Household Wastewater Disposal in Victoria. School of Ag., La Trobe Uni, Vic.

Gutteridge, Haskins and Davey, 1977 Planning for the Use of Sewage Dept.Environ. Housing and Development, A.G.P.S., Canberra

Gutteridge, Haskins and Davey, 1985 Sewerage Facilities for Fringe Communities Office of Local Government A.G.P.S. Canberra

Health Commission of N.S.W., 1973 Septic Tank Installation: Advice for the Home Owner. Government Printer, Sydney

Health Commission of Victoria, 1983 Code of Practice for Septic Tanks Health Commission of Victoria

Maakestas, M and Kayaalp, M., 1988 Proceedings from Seminar on Domestic Wastewater Treatment and Disposal Options for Unsewered Areas Aust.Water and Wastewater Association, S.A. Branch

New South Wales Department of Public Health, 1961 Domestic Septic Tanks Government Printer, Sydney

Northcote, K.H. and Skene, J.K.M. (1972) Australian Soils with Saline and Sodic Properties C.S.I.R.O. Aust.Soil Publ. No 27

Patterson, R.A., 1982 Hydrologic Parameters: A Strategy for Subdivision Honours thesis, B. Nat. Res. University of New England, Armidale

Patterson, R.A., 1989 Re-Use of Septic Tank Effluent. Proceedings of Conference on Effluent Re-Use Water Research Foundation of Aust., Wollongong

Patterson, R.A., Burton, J.R. and MacLeod, D.A., 1986a Peat Treatment of Septic Tank Effluent Prior to Soil Absorption. Proceedings Conf. Ag Engineering, Adelaide . Inst. Engrr. Aust. Publication No.

Patterson, R.A., Burton, J.R. and MacLeod, D.A., 1986b On-Site Soil Disposal of Septic Tank Effluent Proceedings Conf. Ag Engineering, Adelaide. Inst. Engrr. Aust. Publication No.

Patterson, R.A., Burton, J.R. and MacLeod, D.A., 1986c Sodium as a Source of Water Pollution. Hydrology and Water Resources Symposium Brisbane, Inst. Engrr Aust. Publ No

Standards Association of Australia, 1973. AS 1547 - 1973 Disposal of Effluent from Small Septic Tanks SAA, North Sydney

Standards Association of Australia, 1983. AS 1546 - 1983 Small Septic Tanks SAA, North Sydney

Whelan, B.R. and Barrow, N.J. (1984) The Movement of Septic Tank Effluent through Sandy Soils near Perth 1. Movement of Nitrogen. Aust. J. Soil Res./ 22, 293-302