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On-Site Soil Disposal of Septic Tank Effluent

R.A. PATTERSON
Postgraduate, University of New England
J.R. BURTON
Professor, Resource Engineering, University of New England
D.A. MACLEOD
Senior Lecturer, Agronomy and Soil Science, University of New England

SUMMARY The problems identified with the failure of domestic septic tanks and on-site effluent drainfields are primarily related to inadequate design and lack of correct management. Secondly a failure to take account of the adverse effects of sodium ions on soil hydraulic conductivity results in additional failures on soils previously considered capable of effectively disposing of effluent. It is shown that the increase in sodium ions has a marked decrease in the diffusion of effluent through a disposal field.

1 INTRODUCTION

The contention that the use of septic tanks and on-site disposal of domestic wastewater is but a stop-gap method of sewage treatment (Gilpin, 1980) cannot be substantiated for areas outside the relative densities of metropolitan and urban centres. The use of the soil resource for the treatment of effluent has long been shown to be an efficient use of a natural resource, particularly where less sanitary forms of waste disposal were once employed. In many rural areas the old bush toilet (the deep pit latrine) has been replaced by the septic tank and the inside flush toilet. The fact that septic tank construction continues in peri-urban and rural areas supports both the social and economic viability of the method. Further, 47% of the Perth residences are unsewered (Whelan and Barrow (1984), 12% of Sydney's population of more than 3 million rely upon night soil removal or septic tank treatment (Gutteridge et al, 1977), and more than 75 000 unsewered premises in Melbourne (Day and Willatt, 1982). Gilpin (1980) indicated that 84% of the Queensland Gold Coast was unsewered.

While there are many alternatives available for on-site disposal of wastewaters varying from evapotranspiration beds, Wisconsin Mounds, septic tank pump out systems, and systems reticulating the effluent after septic tank treatment to secondary treatment works,the traditional drain-field is perhaps the most common, but the least understood. In the New England region, the latter accounts for more than 90% of all on-site disposal. Evapotranspiration beds are common in areas such as Ipswich, Queensland, while pump-out systems abound on the Northern Beaches area of Sydney. In the metropolitan and coastal regions where reticulated water is more readily available than reticulated sewerage, there is rarely a policy to exclude the former if the latter is unavailable. Only now are the problems associated with on-site disposal of effluent at urban density being realised. However, the alternatives have become very expensive and remedial action is difficult in the land space available.

While the separation of black water (toilet wastes) and grey water (washing, kitchen, bath-room wastes) is suggested in some localities for individual treatment, joint treatment in a single tank is addressed in this project. It is considered that the bacterial content of grey waters can be sufficient to encourage undesirable risks to the community.

This paper stems from a research project which is attempting to provide alternative guidelines for on-site disposal of septic tank effluent without the inherent problems associated with subsoil failure. The results of the initial part of the project, presented here, identify the major problems encountered in traditional subsoil drainfields in New England. Figure 1 below illustrates the traditional drainfield designed for subsoil disposal of all domestic wastewaters. Variations of length, depth and width often take little account of soil variability or wastewater production rates. Many of the design criteria for septic tanks and drainfields have been borrowed from the United States where soil characteristics and climatic conditions are at variance with the Australia scene.

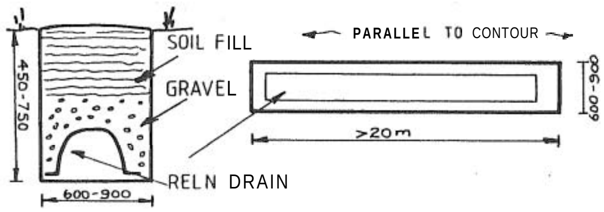

Figure 1. Traditional drainfield for on-site effluent disposal

2 BACKGROUND

The recognised index for assessing the permeability of the soil disposal field has been the various modifications to Ryon's Percolation Test based upon infiltration of a depth of water into a test hole over time. Many variations have been incorporated in the original test in an attempt to obtain a more accurate assessment of a loading rate for effluent drainfields. Winneberger (1984) states that the percolation test is only very crudely precise and lacks the accuracy for replication. Where standards for sizing of drainfields are based upon a percolation test, failure of absorption trenches occurs firstly because of the effects of passing effluent through the soil and secondly because of the variation in effluent quality. The highest rates of failure for drainfields have occurred on sands, where percolation rates take no account of the biological formation of a slowly permeable clogging layer.

The clogging layer is a 10-20mm layer of polysaccharides and polyuronides caused mainly by the activity of micro-organisms but not a result of solids carry-over in the effluent. The limiting effects of the clogging layer have been described by Otis (1977) and Healy and Laak (1974) who state that the allowable rate of effluent application is insensitive to the soil type or its measured hydraulic conductivity. Simply, the percolation test is performed with clean water over a period of several hours. When effluent is allowed to permeate the soil over a period of months, other factors have to be reconciled, which are independent of the soil characteristics or the frequency or timing of dosing (Kropf et al., 1975). The biomass of the clogging layer is an essential part of the purification process and should be utilised rather than destroyed.

Three common causes of effluent drainfield failure have been summarised by Van de Graaff et al. (1980) as underdesign and overloading; careless installation; and lack of maintenance. The first can be related to inadequate methods of assessing the steady state acceptance rate (hydraulic conductivities) after the formation of the clogging layer as discussed above. However, a sufficient hydraulic gradient must be maintained across the clogging layer to ensure adequate flow through the clogging layer and the sidewalls of the trench. Kropf et al (1975) also suggest that increasing the hydraulic head may increase infiltration but always to a lesser extent than according to Darcy's Law. The installation problems are closely related to smeared soil surfaces, over-compacted fill or impacting by surface traffic during the operational life of the drainfield. The third relates to carry-over of high loading of solids from the septic tank due to an overloaded tank or an excessive water use in relation to tank size. The Australian Standard 1546 - Small Septic Tanks relates the sizing and construction of septic tanks to number of persons and average water use but beyond the outlet does not address tank maintenance or drainfield disposal. The Victorian Wealth Commission (1983) has adopted a code of practice for septic tanks which does address maintenance and drainfield design, a step towards an environmentally sound on-site disposal policy.

De Walle (1981) suggests that only by monitoring satisfactory and unsatisfactory performance of drainfields by soil type can site suitability be determined. This theory supports the need to determine the difference between the percolation rate of the virgin soil and that of the clogging layer. Such research would need to consider also the loading rates, maintenance and design of the drainfields. These variables are among those addressed in this project.

The problems associated with the sodium ion concentration of domestic wastewater and the effects of monovalent cations upon the dispersive qualities of the soil interface within the drainfield have not been addressed in the literature currently available. Problems such as nitrate and phosphate contamination of groundwaters as detailed by Whelan and Barrow (1984), faecal coliform contamination of surface and groundwaters and social problems resulting from smell and wetted areas are covered in various references. It is not uncommon for such articles to neglect the changes in soil physical behaviour due to biological processes (clogging layer), climate (evaporation) or plant/soil interactions (salt tolerance). The understanding of these processes is important for sound on-site planning of domestic wastewater disposal. The sodium in the effluent is derived from human wastes (urine 1800mg/l Na) and laundry powders (up to 60% sodium sulphate fillers).

3 PROJECT METHOD

An initial survey was conducted of traditional drainfields in the Armidale area, for the purpose of determining the rate of failure of effluent drainfields. A failure was considered to have occurred in the septic tank when overflowing was present such that either the wastes backed up through the internal plumbing or sludge or scum overflowed into the drainfield. Drainfield failure produced a wetted area at some point along the drainfield, either at the commencement of the trench due to blocking of the distribution main, or at the lower end where the hydraulic gradient forces the effluent through the surface of the ground. Both types of drainfield failure are common, the former being more consistent with faulty construction, while the latter is indicative of underdesign. Although some malodorous conditions are part of the essential biological activities of the purification system, failures present a nuisance factor to residents and neighbours, while indicating a potential for environmental contamination due to the release of partially treated effluent. The contamination occurs because the overland flows following rainfall remove pollutants (nitrates, phosphates and coliforms) across the landscape and into water courses.

Concurrent with the survey a questionnaire was used to determine the household management strategy for septic tanks. Topics included the rate of' water consumption, the disposal of materials other than kitchen and human wastes into the system and the use of detergents and washing powders.

At each site where drainfields were examined, soil samples were taken at a point unaffected by the disposal of effluent and at several points along the absorption trench. In a system which had a total failure of the absorption system, 10 soil samples were taken at various points in the vicinity of the trench. The dispersion of the soil which is related to hydraulic conductivity was measured by Emerson's Dispersion Test (Emerson, 1977). Dispersibility was then related to the amount of sodium adsorbed by the soil, referred to as the exchangeable sodium percentage.

Hydraulic conductivity of each soil sample was measured as the decrease in volume of effluent passing through a reformed core of the less than 20 micron portion of the soil. Since most of the receiving soils were highly impermeable clays, the fraction used above was considered appropriate.

Effluent from the senior author's septic tank was monitored weekly over a ten week period to indicate the ionic concentrations of calcium, magnesium, sodium and potassium. An initial test for zinc was carried out as the most likely heavy metal contamination in the domestic scene. A comparison with major washing events (use of washing powders in the laundry) was made with the peaks in sodium ion concentrations.

The effluent analysis was conducted according to the following procedures:

(a) sodium and potassium - flame photometry;

(b) calcium and magnesium - atomic absorption spectrometry; and

(c) pH and E.C.(as a measure of total dissolved solids) as electrical resistivity of specific electrode.

The effluent qualities with relation to Biochemical Oxygen Demand (BOD), Total Suspended Solids (TSS), nitrate, ammonium and phosphate concentrations were not required for this initial survey, since the failure was rated simply as a system failure within the septic tank, or a hydraulic failure within the drainfield.

4 RESULTS

The results of daily analysis of septic tank effluent collected from the senior author's septic tank over a ten week period were used to estimate the values used in Table I below. Comparison of analyses of other effluents surveyed indicated the typical nature of the data used. The cation characteristics of that analysis of septic tank effluent, given in mg/1, are presented in Table I along with the values of total annual weights of cations. A previous study by Patterson (1985), conducted in the Armidale area, indicated that the internal consumption of water averaged 1000 litres per household per day. That data formed the basis for the annual production rates calculated below.

Electrical conductivity of 140 milliSiemens per metre are typical at a pH of 7.0-8.0. Sodium absorption ratios (SAR) were calculated at a value of 11. Ratios of this order are suitable only for moderately tolerant to tolerant plant species because of the effects of SAR on the physical properties of the soil. The electrical conductivity value is within limits for irrigation use. It is therefore, the monovalent to divalent ion ratio which limits plant productivity, although the use of the effluent by plants is of minor importance other than the production of saline conditions within a soil.

TABLE I

CATION CONCENTRATION OF SEPTIC TANK EFFLUENT AND ANNUAL PRODUCTION RATE

Cation	Daily (mg/1)	Annual (kg)
Sodium	150	54.7
Potassium	35	12.8
Calcium	10	3.6
Magnesium	5	1.8
Zinc	0.3	0.1

The cation exchange values of the soil from the survey points within the failed system indicate that high levels of sodium ions within the effluent are flushing divalent cations (calcium and magnesium) from the exchange positions. The increase in sodium ion concentration resulted in an increase in the dispersion of the air dried soil aggregates to a level of total instability (Class 1). The unaffected soil was of Class 3 generally, that is dispersion occurs only after remoulding the soil and repeating the test.

Table 11 indicates the changes in cations of the soil samples for the failed system as a percentage increase to that at the unaffected sites within the system. Position 1 was situated at the lower end of the drainfield , 300mm outside the physical end of the trench, position 2 was adjacent to and mid length along the downslope side of the trench, while position 3 was a further 200mm out into the undisturbed soil. Position 4 was a site 20 metres downslope at which the effluent ponded on the surface. As a result of the drainfield failure the effluent had been directed from the end of the trench (position 1) to flow through an open channel on the surface of the soil. A period of less than 15 months resulted in the high levels of sodium observed.

TABLE II

CATION EXCHANGE AS EFFECTED BY EFFLUENT DISPOSAL

	Soil horizon					
	A1		A2		B	
	Na	Ca	Na	Ca	Na	Ca
1	+0.3	-0.9	+3.3	-0.9	+6.8	-0.9
2	+2.8	-1.5	na	na	+1.5	-0.9
3	+4.0	0	na	na	+3.6	+1.1
4	+6.3	-0.5	+2.1	-0.5	+1.9	-0.7

(all values as ratio increase (+), decrease(-) of control column)

It can be seen from Table 11 that around the trench (positions 1,2,3) the increase in sodium is in the B horizons since diffusion is within the trench. At position 4 where the effluent has saturated the surface, sealing as a result of dispersion has prevented the downward movement of sodium, hence the lower level in the B horizon at this position. This was supported by the reduced moisture level measured in the B horizon which was 17% relative to 23% in the A horizon. At other sites the surface horizons were 12-14% while the B horizons were 26-32%.

The reduction in hydraulic conductivity was measured as the increase in time required for a given volume of the effluent to pass through a sample of the soil, packed to a similar and uniform bulk density. The increase in time as a ratio to that for the solution passing through the unaffected soil varied from 3.0 for the B Horizon at position 1 to 14.6 for the A horizon of position 4. This indicated the loss of permeability the soil suffered as a result of the sodium ion concentration alone. In the subsoil situation an additional complication of the biological clogging layer would further reduce permeability as described above. Thus increases of between 3 and 15 times the measured percolation rate may be required. However, in view of the cost involved in constructing a drainfield to cope with these values, the figure of 5 times the present requirement may provide a more favourable disposal field with failure only during wetter periods.

The fluctuation in sodium ion concentration in the effluent produced from the senior author's home corresponded with the advent of a normal washing day. Increases of up to 30% were not uncommon even though the household was considered a low consumer of laundry powders. The majority of households surveyed used laundry powders at or above the manufacturers specifications, while less than 10% dissolved the powder before using in the washing machine, a strategy designed to minimise use of powders. Automatic washing machines were used in 50% of the households, although this could not be correlated with the effluent characteristics. It would be expected that the annual production of sodium ions would differ little from homes with automatic washing machines to those with semi-automatics or manuals. In the case of the former, a greater volume of water is consumed for the same physical wash, while in the latter it is the rinsing water which is conserved. Thus higher concentration with lower overall volumes of the latter would equate with lower concentrations and higher volumes of the former.

The survey revealed that local councils in New England have accepted standard trench lengths for effluent drainfields. Dumaresq Shire considers a 20 metre long trench to be adequate for disposing of the typical domestic wastewater volumes while the neighbouring Uralla Shire with a greater proportion of solodic soils requires a minimum trench length of 30 metres. However, neither accepts that the performance of effluent drainfields is of a high standard, but hesitates at altering the requirements in the absence of alternate codes acceptable by the public health authority. The Inverell Shire Council has recently opened an urban subdivision on a black earth landform, of slope less than 5%, and offered residents reticulated water. Sewage disposal is by traditional drainfield following septic tank processing. The failure of those fields has occurred in less than a month during a period of relatively low rainfall. The problem of redesign and resiting will be expensive, while the community disbenefits will be large. In this instance, failure was a direct result of inadequate percolation and trench area. Other failures which result from septic tank carry over of solids and biological materials did not have time to occur in this instance. All drainfields were correctly oriented to the contour and since council inspection before backfilling is required, it was assumed that the distribution pipe or troughing and gravel were correctly installed. It could not be assumed that smearing of the bottom or sidewall areas had been avoided.

Of 20 drainfields examined in the Armidale area, only one was successfully disposing of all effluents to the subsoil field. That occurred because the loading rate was less than one-fifth of the average loading for a similar field on the same soils. Using that example, it could be said that drainfields should be approximately 100 metres in length. A calculation using climatic data and loading rates for similar soils, based upon research by Brouwer (1982) indicates that a length of 80 to 100 metres would be required. A suggestion to Health Inspectors that such a length is required would bring comments connected with economics rather than effective disposal. The senior author encountered such comments during a similar project at Grafton recently.

Residents stated that they did not consider the reduction in domestic use of water as an important strategy for the safe disposal of septic tank effluents. None of the sites sampled was connected to a reticulated water supply, however, the consumption of water was not restricted other than by the physical limitations of stored water capacity. Where minimum rates were applied (based on householder's information) the drainfields had smaller failure zones and were reported to have less problems with overflowing septic tanks.

Maintenance of septic tanks was not given high priority by householders, only being undertaken when overflowing or clogging occurred. Three tanks had not been pumped out within the last ten years and it is believed that only a water conservation policy in each household and careful screening of wastes prevented the systems from failing. Each, however, had exceeded the designed storage capacity of scum and sludge. Discussions with the local pump-out contractor suggested that blockages result from the abuse of the system. The questionnaire indicated that items such as tea leaves, sanitary napkins, baby nappy liners, facial tissues and out dated medicines were disposed of down the toilet into the septic tank. The survey revealed that the resident generally lacked a basic knowledge of the workings of either the tank or the drainfield. The misinformed opinion that septic tanks are maintenance free was held by the majority.

5 DISCUSSION

The survey has revealed the general lack of understanding of the maintenance required for an efficient septic tank such that restrictions are placed upon the types and quantities of wastes disposed to the system and that pump-outs are required at regular intervals other than when failures occur. The general misconceptions have resulted in overloading of the drainfield with carry over of solids, further aggravating the under-design problem. The drainfields examined were constructed within the dimensional requirements of the local councils yet failure was at a high level. The occurrence of failure due to high carry-over of solids was not able to be assessed, however, high water consumption and lack of maintenance are conducive to septic tank and drainfield failure.

The adverse effects of sodium ions upon a soil absorption trench must now be addressed in depth to determine the mechanisms by which their impact may be minimised, if not eliminated. The loss of hydraulic conductivity by a possible factor of up to 15 imposes severe limitations on the design of drainfields in soils adversely affected by sodium. This, however, includes most of the soils in eastern Australia and in particular those considered to have a dispersion problem, such as solodics.

The aim of this project was to identify the major problems encountered when septic tank drainfields failed. It has been successful in that while maintenance and internal water use will impinge upon the design of drainfields, a further consideration must be given to the effects of sodium. This must be approached from two angles; the amelioration of the adverse effect upon the disposal field and the reduction in hydraulic conductivity; and the reduction in amounts of sodium ions flushed into the system as washing soaps, detergents and wastes. Further research into these aspects is continuing.

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