IMPORTANCE OF SITE CHARACTERISTICS IN DESIGNING EFFLUENT DISPOSAL AREAS

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Abstract

This paper discusses a research project on on-site sewage treatment undertaken in the Brisbane area. The primary objectives of the project were to relate treatment performance to site and soil conditions. The field study consisted of sixteen sites in the Brisbane urban fringe with the subsurface effluent disposal area located on a number of different soil types. A householder survey was used to collect information relating to the sewage treatment system. This included its history, householder maintenance practices adopted and usage. The effluent quality was monitored prior to entry to the disposal field and at the exit. Detailed soil analysis was undertaken to evaluate soil physico-chemical characteristics at the study sites together with a comprehensive evaluation of site and landscape factors. The study found that site factors, physico-chemical characteristics of the disposal area and householder maintenance practices play a crucial role in effluent treatment, or renovation.

Keywords

effluent disposal, effluent renovation, on-site sewage treatment, septic tanks, soil chemistry

1 Introduction

On-site treatment of sewage and effluent disposal is common in rural and urban fringe areas where reticulated wastewater collection systems do not exist. In the past, on-site treatment of wastewater did not merit much attention as their density was relatively low and they were seen as an interim measure. Despite the spread of urbanisation and more intensive development of semi urban areas, it is unlikely that reticulated sewage collection systems will be provided in some areas in the near future. Consequently, on-site treatment is seen as an attractive alternative because of its simplicity and relative low cost. Despite the seemingly low technology of these systems, failure is common. Failure can lead to adverse public health and environmental impacts, which are well documented. A major concern associated with these impacts is their insidious nature. Often, the detrimental consequences are not immediately apparent, but become obvious after a relatively long period of time. The effluent disposal area is most prone to failure.

To safeguard public health and environmental values in an area, careful consideration must be given to the design and location of on-site sewage treatment and disposal systems. It requires an understanding of the factors that influence treatment performance and the development of a predictive strategy for performance evaluation. This translates to a paradigm shift from the common prescriptive strategies for the design and location of on-site sewage treatment to a more performance-based approach such as advocated in AS/NZS 1547:2000 'On-site domestic wastewater management'.

Subsurface effluent absorption systems are the most common form of effluent disposal for on-site sewage treatment and particularly for septic tanks. Location-specific parameters such as topography and subsurface characteristics play a significant role, even in the case of surface disposal of effluent and must be considered in designing subsurface effluent disposal systems.

2 Importance of Site Factors

Septic tanks are the most common form of on-site sewage treatment and the available subsurface effluent disposal area is a crucial part of the treatment train. It is essentially the 'last line of defence' to prevent the contamination of surface and groundwater sources by sewage. Unfortunately the disposal area is the component most susceptible to failure, resulting in unacceptable surface and groundwater contamination. Most failures can be attributed to two primary factors – poor system maintenance and inadequate consideration of site and soil characteristics. Landscape features and subsurface characteristics at the site play a crucial role in the design of a subsurface disposal area.

The most valuable information for designing and siting an on-site treatment system is derived by soil characterisation and terrain evaluation, particularly geomorphologic features affecting drainage – flow of surface water through the site, flood potential and discharge of surface and ground water. Geary *et al* (1999), in their study at Dodges Ferry, Tasmania, found groundwater pollution at the bottom of drainage areas below catchments containing high densities of on-site systems. They also found that both surface and subsurface drainage flowed towards clusters of development where elevated concentrations of pollutants occurred.

A site assessment for effluent disposal must also consider seasonal changes in "true" and perched water tables, area available for disposal, and the presence of environmentally sensitive areas such as aquatic habitats and water supply wells. A comprehensive site assessment should define the limitations of a site, taking into consideration other related factors such as:

- topography - drainage and aeration of soil, whether there is soil movement down slope
- climate such as temperature, rainfall, transpiration and evaporation - these factors influence profile development through leaching and weathering
- parent material - exerts the primary control on soil development
- native vegetation - reflects the nutrient status and water availability
- biological activity - can impact on infiltration and water storage in the soil

This assessment can be supported by the observation and description of colour, texture and structure of the soil which may be used to qualitatively assess the hydrology of the soil profile whilst the physico-chemical soil data can provide an insight into soil stability and its ability to absorb applied nutrients.

Many Australian soils have "duplex" profiles, which have impermeable 'B' horizons. When they occur in an undulating landscape, these can develop perched water tables, which predisposes to reducing conditions and gleying and mottling in the profile. This is a common phenomenon in "duplex" soils on the lowers slopes and foothills of the Great Dividing Range in south-eastern Australia (White 1997). Sites of this nature can be problem sites for effective effluent disposal, and need characterising carefully by a combination of site factors along with chemical and physical criteria.

Generally in undulating landscapes on permeable material, the soils near the top of the slope tend to be free draining with the watertable at depth, whilst the soils at the valley bottom are poorly drained with the watertable at or near the surface. The succession of soils forming under different drainage conditions on relatively uniform parent material comprises a hydrological sequence. This is illustrated in Figure 1. As the soil drainage deteriorates, the oxidised soil profile is transformed into the mottled and gleyed profile of a waterlogged soil.

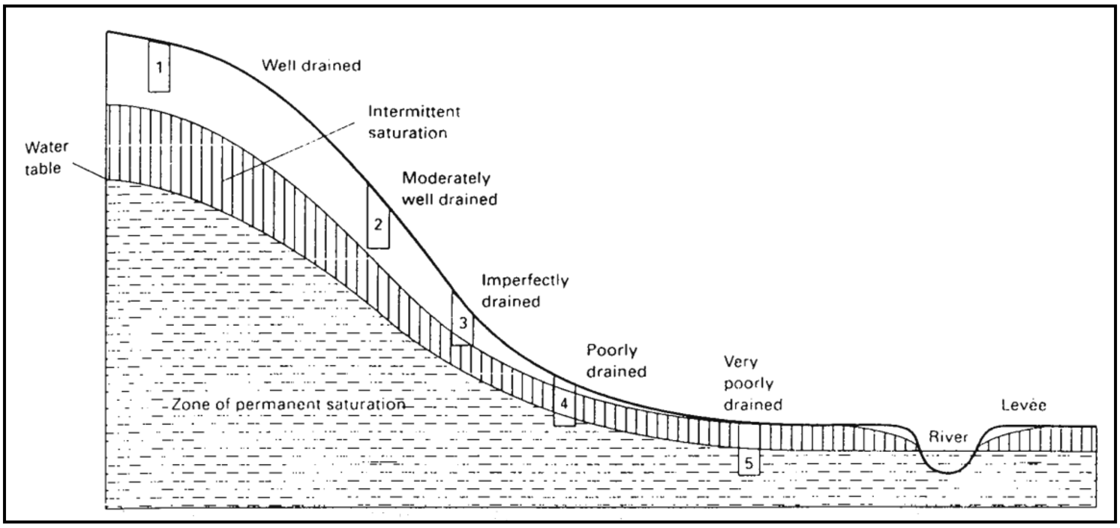

Figure 1 Hydrological Sequence in a Landscape Catena (Adapted from White 1997)

There is continuing dependency on practices found to be inadequate in assessing soil absorption system behaviour, particularly the use of the percolation test. Van de Graaff *et al*. (1999) found that intermittent soil waterlogging does not inevitably lead to absorption failure, and that the maximum level to which a perched water table may rise in a soil profile has no bearing on the soil suitability for on-site effluent disposal. They also concluded that permeability tests should be used exclusively for determining soil permeability in sizing disposal systems but not in assessing soil water regimes. Goonetilleke *et al.* (2000) point out the possible misleading nature of the standard percolation test in assessing site suitability for effluent disposal.

3 The Project

The research project was undertaken by Queensland University of Technology, School of Civil Engineering on on-site sewage treatment in the Brisbane urban fringe and included mainly septic tanks with absorption trenches and a small number of aerobic wastewater treatment plants (AWTS). The project evaluated the treatment performance of on-site sewage systems and related performance to site and soil conditions. This involved investigating the influence exerted by soil parameters on the removal of various pollutants in sewage effluent. A more detailed evaluation was subsequently formulated and implemented to enable an in-depth understanding of the role played by soil physico-chemical properties and landscape factors in the renovation of effluent.

3.1 Sampling Strategy

To better understand and define the performance of sub-surface effluent disposal systems, it is important to understand the crucial role played by the soil. Soil is an excellent medium for the removal of physical, biological and chemical contaminants in effluent. However the ability of soil to purify effluent is poorly understood. The sub-surface characteristics of the disposal area are among the most important parameters governing the performance of effluent treatment processes. The sampling strategy was to specifically focus on these factors.

The sampling strategy to determine the "zone of influence" of a sub-surface disposal field included the collection of physical and chemical characteristics of the effluent entering the disposal system. A detailed soil evaluation directly downstream of the disposal field provided an insight into the extent of effluent travel, ability of soil to renovate effluent and nutrient uptake by the soil. It was assumed that where pollutant levels emanating from disposal fields were not discernible from background levels, adequate purification had taken place.

Soil sampling and monitoring at existing sub-surface effluent disposal systems was employed as a convenient method for evaluating renovation efficiency and in understanding the renovation mechanisms. The advantage of using soil parameters as indicators is that they are not weather dependant and can be measured at any time. In conjunction with soil sampling, a comparison of quality parameters of soil water samples collected at the soil interface provided information relating to the degree of change in quality experienced by the effluent moving through the soil.

Soil parameter selection was based on the suite of tests generally carried out in land resource evaluation by Agricultural Chemistry Branch of Queensland Department of Natural Resources (Rayment and Higginson 1992). These tests have been developed through extensive agricultural research and are designed to distinguish between deficient, adequate and toxic supply of elements in soil and between degraded and non-degraded soil conditions. The chemical parameters measured were exchangeable cations, Ca:Mg ratio, pH, electrical conductivity, chlorides, nitrates, phosphorus sorption, Exchangeable Sodium Percentage, and Effective Cation Exchange Capacity. The effluent parameter selection was based on standard parameters currently required for approval by the Department of Natural Resources (DNR 1999) and accepted by industry as an adequate measure of a domestic on-site plant's treatment performance. Results were used to determine the change in effluent properties due to contact with the soil.

In the initial phase of the project, chemical indicators such as electrical conductivity (EC), pH and chloride concentration were employed as indicators to investigate the extent of effluent flow and to understand the processes of effluent renovation by soil. In the later detailed soil investigations, selected profiles were analysed for their physical and chemical properties. These were interpreted and employed as quantitative information needed for confirmation and to support the field descriptions.

3.2 Field Study

The field study consisted of sixteen sites in the Brisbane urban fringe with the sub-surface disposal area located on a number of different soil types. The effluent quality was monitored prior to entry to the disposal field and at the exit. Detailed soil analysis was undertaken to evaluate soil physico-chemical characteristics at the study sites together with a comprehensive evaluation of site and landscape factors. Additionally a householder survey was employed to collect information relating to the treatment system. This included its history, maintenance practices and usage.

The field monitoring and sampling program consisted of the following tasks:

1. Installation of monitoring wells or piezometers at 1m and 3m downstream from the edge of the subsurface disposal area or surface spray area for sampling of the soil water percolating through the subsurface. See Figure 2
2. Mapping of soil horizons at the piezometer installation sites.
3. Collection of soil samples to a depth of about 1.2m from a control site which has not been disturbed by landscaping or contaminated with effluent, to determine background soil parameters.
4. Collection of soil water samples from the piezometers and effluent from the distribution box, to determine the quality characteristics of the effluent prior to and after disposal into the soil.
5. Collection of background data relating to the site and sewage treatment system. This included system details such as its history, usage and maintenance undertaken and site conditions such as topography, slope and drainage.

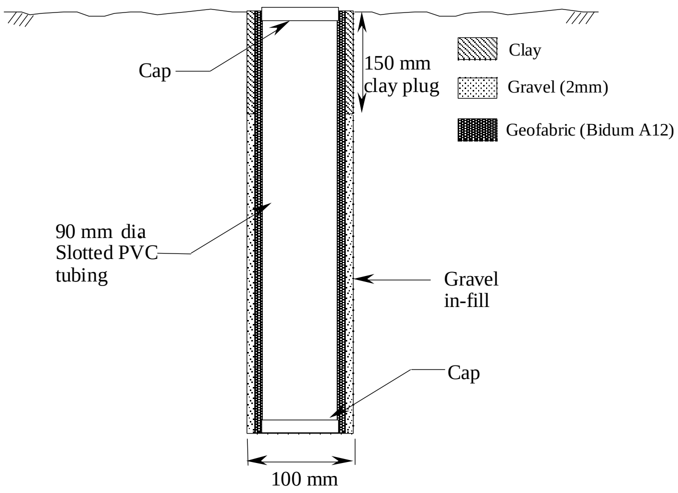

Figure 2 A typical Piezometer Installation

4 Results

4.1 Site-specific Information

Significant site-specific observations were made during the field investigations which may impact on the performance of on-site effluent disposal systems and their ability to effectively renovate effluent. These included:

A Ongoing Maintenance of Treatment Systems

In the case of septic tanks, most house owners seem unaware that sludge removal needs to be undertaken regularly. AS/NZS1546:1998 recommends sludge removal to be undertaken every three to five years. None of the older septic systems surveyed had undertaken this essential maintenance activity. Even in the case of the relatively newer systems, the householders did not appear to consider regular maintenance as important for the satisfactory functioning of septic systems. The on-site systems ranged in age from 1.5 to 19 years.

B Lateral Flow of Effluent

In most sites, the soil profile at the piezometer installation sites indicated the presence of a shallow highly saturated soil layer. In a number of sites, the 'B' horizon showed signs of mottling, which indicates a perched groundwater table during wet periods. These factors suggest significant lateral percolation of effluent through the soil profile. It is logical to expect that this phenomenon will be even more pronounced during rainfall periods. Under these circumstances, flow of effluent into surface water bodies is a distinct possibility.

4.2 Effluent

Generally, the improvement in effluent quality appeared to take place within the initial 1m of travel. Further improvement in quality was not apparent between the 1 - 3m distance. This finding is similar to that of other studies (for example Brouwer and Bugeja 1983). An improvement in Total Nitrogen was comparable to studies by Brouwer *et al*. (1979) and Gerritse *et al.* (1995). In most cases, pathogen testing proved inconclusive. It is important to note that these findings only relate to the quality improvement obtained. This does not mean that the quality that is obtained is satisfactory. Some sites in flat, poorly drained areas show an appreciable improvement in a number of other parameters (eg: TOC, Faecal Coliforms).

Whilst AWTS may provide effluents of higher quality, after 1-3m of travel through the subsurface it was not possible to distinguish significant differences in quality between effluent originating from septic tanks and from AWTS. It is not implied that the use of AWTS does not serve a useful purpose. The decision to install an AWTS instead of a septic tank would be based on other considerations.

As expected, the well-drained sites generally had lower chloride and TDS concentration and electrical conductivity values compared to the sites with heavier clay soils. In summary, the results obtained imply that in a significant majority of the sites investigated, the quality that is achieved within the initial 1m of travel is the final quality. This hypothesis could be interpreted to mean that while the concentration of pollutants may be expected to decrease with distance due to dispersion and dilution, the total quantity percolating into a water course or aquifer may be determined by the processes occurring in the initial few meters.

4.3 Soil

A number of chemical indicators such as EC, pH and chloride concentration were employed to investigate the extent of effluent flow and to understand how soil renovates effluent. The soil profile, especially texture, structure and moisture regime was examined more in an engineering sense to determine the effect of movement of water into and through the soil.
Comparing the electrical conductivity and chloride concentration values at the two boreholes downstream of the disposal area, there were instances where the value at the second site was higher than the first. This is probably due to effluent percolating through the 'A' horizon in dilute pulses from the absorption trenches during periods of saturation (Brouwer and Bugeja 1983). Saturated conditions will initially form closest to the trench and the effluent will move through the soil profile forming fronts of elevated parameter levels.

Detailed chemical analyses were utilized to determine possible indicators of likely deterioration of the soil structure due to effluent discharge. Influential soil parameters were identified and possible correlations and linkages between these parameters evaluated. These include effective cation exchange capacity (ECEC), dominance of exchangeable Ca or exchangeable Mg over exchangeable Na concentration, Ca:Mg ratio and dispersiveness (ESP or Emerson test). Clay content and type of clay can also have significant influence on these parameters (Bell 1993). Soils with moderate to high ECEC, Ca:Mg >0.5, dominance of exchangeable Ca or exchangeable Mg over exchangeable Na concentration and thus low ESP have the ability to renovate effluent without major soil structure deterioration. In some cases moderate to high exchangeable Na concentration was offset by the presence of swelling clays (ECEC>40 me/100g) and co-dominance of exchangeable Ca and exchangeable Mg concentration. This aids the absorption of cations at depth.

Soils that exhibit low Ca:Mg ratio (<0.5), generally imply a high ESP and high exchangeable Na, indicating poor soil conditions for effluent disposal. Clay content in these soils is generally high, and in these cases even low ESP can have significant effect on soil stability (Baker and Eldershaw 1993).

The importance of good drainage is vital even in the case of surface irrigation of treated effluent due to the possible accumulation of salt on the surface. Where salt is continually added to the soil by the effluent, good drainage of the site is essential in order to allow the continuous movement of water and salt through the profile. Without this continuous leaching, salt may build up to levels that may be harmful to the landscape and vegetation. Figure 3 shows a typical example of this high accumulation of salt at the A/B horizon interface at two piezometer locations when compared to the control site. The treatment system was a 4 years old septic tank, located on poorly drained soil.

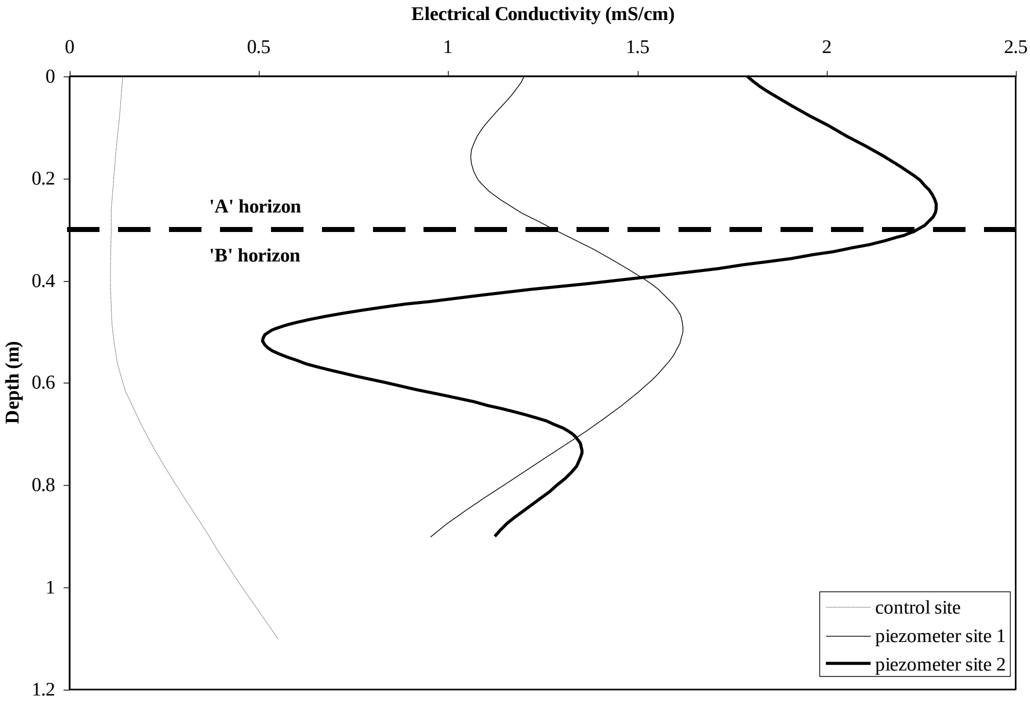

Figure 3 Typical Salt Profile

5 Conclusions

The results confirm the location-specific nature of the treatment performance of effluent disposal systems. Site factors and physico-chemical characteristics of the disposal area play a crucial role and together exert a strong influence on land suitability for on-site effluent disposal. With some soil types, applying effluent to a subsurface disposal field produces effects similar to in-situ weathering.

The quality of effluent being discharged and the soil characteristics are important in defining disposal area behaviour. Additional travel distance was found to be beneficial for the further improvement of effluent in sites with poor soil conditions. The results of the study highlighted the need to undertake soil investigations to a minimum depth of 1.2m to enable improved site evaluation.

Soil chemistry can be used as a valuable predictive tool in conjunction with physical soil characteristics and site factors for evaluating site suitability for effluent disposal. However soil chemistry does not necessarily add value to a site suitability assessment in the case of a well-drained, upper position site. Its importance is in the case of soils in the lower position in the landscape which exhibit poor drainage and need further evaluation to assess their suitability for effective effluent disposal.

The design approach to on-site disposal should include a detailed evaluation of the soil including physical and chemical characteristics in conjunction with site factors such as drainage characteristics, climate and topography. This will help to determine design strategies to be adopted to mitigate the adverse impacts resulting from the constant addition of solutes and salts to the soil and to ensure the long term performance of the disposal area in effluent renovation.

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