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The importance of site assessment 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 and will evaluate the treatment performance of on-site effluent disposal systems (septic tanks with absorption fields) and relate them to site and soil conditions. 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 performance-based approach to domestic wastewater management introduced recently across Australia will result in a process in which site characteristics establish performance objectives for treatment and disposal. In designing and siting an on-site treatment system valuable information is derived not only by soil characterisation and terrain evaluation, but also observing geomorphologic features that are significant in relation to drainage. Soil chemistry can also add value in evaluating difficult sites. The results obtained confirmed the strong site specific nature of effluent renovation.

Keywords: on-site sewage, effluent disposal, septic, effluent renovation, soil characteristics.

1. INTRODUCTION

Approximately 12% of the Australian population, or more than two million people, are not serviced by reticulated sewerage facilities (Whitehead and Geary 2000) and rely wholly on on-site systems for the treatment and disposal of domestic wastewaters. 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 forms the 'last line of defence' along with buffer zones to prevent the contamination of surface and groundwater sources by sewage. Despite the seemingly low technology of the systems, failure is common. In many cases this can lead to adverse public health and environmental consequences. Most failures can be attributed to two primary factors, poor system maintenance and inadequate consideration of site and soil characteristics.

In the interest of safeguarding public health and environmental values in an area, it is important that careful consideration is given to the design and location of on-site sewage treatment systems. This 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" (Standards Australia, 2000).

On-site domestic wastewater renovation systems have traditionally relied on physical, chemical and biological properties of the soil to remove contaminants as effluent percolates through the soil. Soil has been found to be an excellent renovation medium provided the duration of effluent/soil contact is sufficient. However the ability of the soil to purify effluent is not completely understood. Reneau et al (1986) provided a comprehensive review of treatment achieved by soil based renovation systems and concluded that removal of pollutants such as phosphorus and microbial pathogens is adequate as long as travel times through the soil are of a satisfactory duration.

2. REGULATORY ENVIRONMENT

Domestic wastewater regulation in Australia is administered by local authorities, although policy advice and the approval of treatment and disposal systems is the responsibility of State Government departments. Some local authorities have developed their own guidelines and requirements resulting in wide variations in approach to site assessment and system design of on-site systems. While local knowledge is important, the poor understanding which exists between soils and their effluent disposal capabilities, and the lack of standardised procedures has led to many inconsistencies in approach, system sizing, and performance.

The prescriptive approach of the previous Standard AS 1547:1994 (Standards Australia, 1994) was based on the presumption that a scientifically rigorous and exact approach to septic tank effluent disposal field design and implementation is possible. It is clear that this belief is questionable and the use of a prescriptive approach has not achieved sound environmental outcomes. This previous Standard only briefly referred to the importance of land capability criteria in siting disposal areas, and the characteristics of the soil type were not adequately addressed in the design of the disposal system.

Both AS/NZS 1547:2000 and some recently rewritten State guidelines including the Queensland State Government Code of Practice (DNR 1999) have moved away from the prescriptive approach to site assessment and system design, and adopted a performance-based approach. The new Standard focuses on outcomes i.e. desired results that are needed to achieve sustainable public health and environmental performance and the processes needed to achieve these objectives. This is illustrated by the key performance objectives stated in the new AS/NZS1547-2000 Section 2.2.1 which states, "The key performance objectives for any on-site domestic wastewater management system shall be:

- to protect public health
- to maintain and enhance quality of the environment
- to maintain and enhance community amenity"

Otis and Anderson (1994) pointed out that "performance standards define the acceptable environmental impacts of onsite wastewater treatment systems by specifying measurable performance requirements". The performance-based approach would result in a process in which site characteristics would establish performance objectives for treatment and disposal.

3. IMPORTANCE OF SITE ASSESSMENT

The most valuable information for designing and siting an on-site treatment system is derived not only by soil characterisation and terrain evaluation, but also observing geomorphologic features that are significant in relation to drainage, flow of surface water through the site, flood potential and discharge of surface and ground water. This is supported by Geary et al (1999) in their study at Dodges Ferry, Tasmania. They noted groundwater pollution at the bottom of drainage areas where catchments above contained high densities of on-site systems. They further established that both surface and subsurface drainage flowed towards the clusters of development where elevated concentrations of pollutants occurred.

A site assessment for effluent disposal also needs to take into consideration 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 good site assessment should define the limitations of a site, taking into consideration other related factors such as:

- topography - drainage and aeration of soil and whether there is soil movement downslope
- climate such as temperature, rainfall 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, transpiration 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. These are soils which have impermeable ‘B’ horizons and when they occur in an undulating landscape can develop perched water tables, which predisposes to reducing conditions and gleying and mottling in the profile. It is sites of this nature which can be problem sites for effective effluent disposal, and need characterising carefully by a combination of site factors along with chemical and physical soil 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.

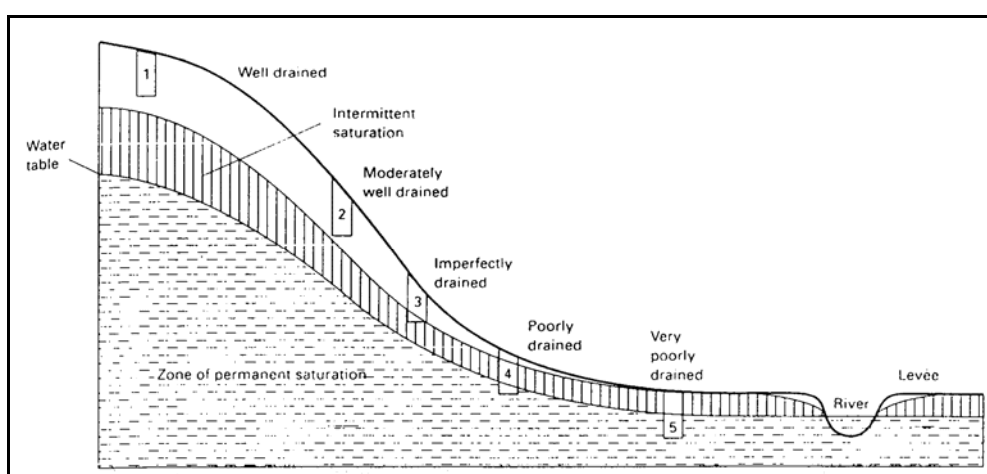


Figure 1 Hydrological sequence in a landscape catena (Adapted from White 1997)

There is continuing dependency on practices, which have been found to be inadequate in assessing soil absorption system behavior. This particularly refers to the use of the percolation test which assesses soil characteristics at a particular location at a particular time and is of limited value unless considered in the context of the site characteristics summarised above. van de Graaff and Brouwer (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.

4. FIELD STUDY OF TREATMENT PERFORMANCE

This project evaluated the treatment performance of on-site effluent disposal systems and related them to site and soil conditions. The research project undertaken by Queensland University of Technology, School of Civil Engineering in the Brisbane urban fringe included mainly septic tanks with absorption trenches (16 sites) and a small number (6) of aerobic wastewater treatment plants.

Acquisition of factual field information during wet and dry periods, from existing operating on-site sub-surface disposal systems led to an insight into what extent contact with soil changed the properties of the effluent along with the extent of travel of pollutants from sub-surface disposal fields. Chloride concentration was used as an indicator of effluent movement because it is highly mobile in soil systems and undergoes limited soil adsorption and no biochemical transformation.

Table 3 – Effluent and soil parameters measured

Parameter	Effluent sample		Soil sample		Reasons for selection
	Piezometer	Distribution box	Piezometer site	Control site	
pH	x	x	x	x	Possible indicator of soil chemical properties, effluent travel, ability of soil to renovate effluent
Electrical Conductivity	x	x	x	x	
Total nitrogen	x	x			To determine the nutrient uptake by the soil.
Biochemical oxygen demand	x				To correlate with total organic carbon data.
total organic carbon	x	x			Possible indicators of effluent travel and ability of soil to renovate effluent.
total dissolved solids	x	x			
phosphorus			x	x	
faecal coliforms	x	x			Possible indicators of effluent travel, ability of soil to renovate effluent and health indicators.
nitrate concentration	x			x	
chloride concentration	x		x	x	
Calcium, Magnesium Sodium, Potassium ion concentration		x		x	These are possible indicators of damage to the soil structure due to effluent discharge.
moisture content			x	x	Possible indicators of the ability of the soil to renovate and percolate effluent through the soil horizon.
soil texture and structure			x	x	
clay content			x	x	

Electrical conductivity was also evaluated as a possible indicator of effluent travel. Soil sampling (including detailed profile descriptions) and monitoring at sub-surface effluent disposal systems was employed as a convenient method for evaluating renovation efficiency and to obtain an understanding of renovation mechanisms. The advantage of using soil parameters as indicators is that they are less weather dependant and can be measured at any time. Comparison of soil water quality of samples collected at piezometers located 1 and 3m downstream from the edge of the subsurface disposal area and prior to entry into the disposal field can indicate the degree of treatment of the effluent moving through the soil.

4.1 Field study

The field study consisted of twenty two sites in the Brisbane urban fringe representing a range of common soil groups and geological settings in the non-sewered area of Brisbane. The effluent quality was monitored prior to entry to the disposal field and at the exit. Detailed soil analysis at control sites and downstream of the disposal field (1 and 3m) was undertaken to evaluate soil physico-chemical characteristics together with a comprehensive evaluation of site and landscape

factors (Goonetilleke et al 2000). Additionally a householder survey at each site collected information relating to the treatment system. This included its history, maintenance practices adopted and usage. In several cases a correlation between the maintenance practices and the observed treatment performance of the disposal system in efficiently renovating effluent to a safe level for discharge to the surrounding environment was found.

Although not generally used in effluent disposal design, soil parameter selection was based on the suite of tests generally carried out in land resource evaluation by the 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. A constant supply of nutrients, organic matter, salts and metals are dumped into the soil by effluent altering the physico-chemical characteristics of the soil and its ability to assimilate wastewater. The chemical parameters measured were exchangeable cations, Ca:Mg ratio, pH, electrical conductivity, chlorides, nitrates, phosphorus sorption, Exchangeable Sodium Percentage (ESP) and Cation Exchange Capacity (CEC). 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 wastewater treatment plants performance.

4.2 Results

4.2.1 Effluent Renovation

Generally the improvement in effluent quality appeared to take place only within the initial 1 m of travel. An appreciable further improvement in quality was not apparent between the 1 - 3 m distance (Figure 2 shows effluent results for well drained sandy loam site with 4 year old septic tank).

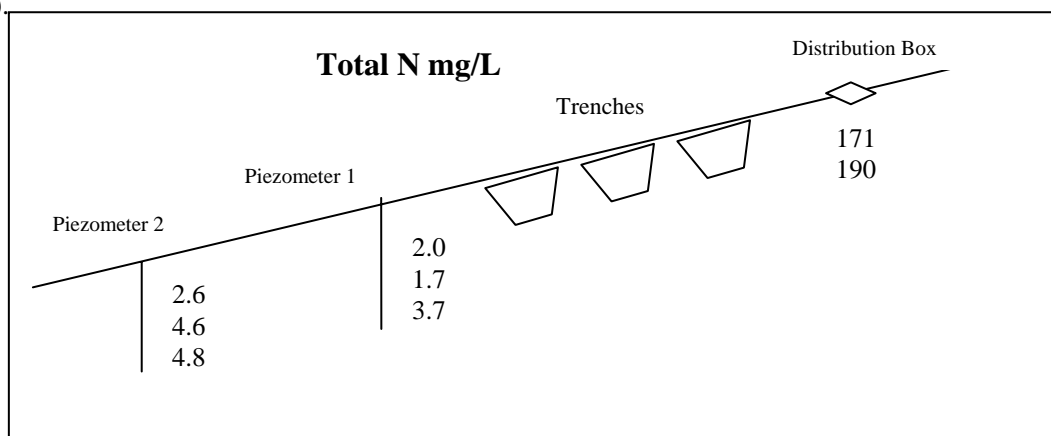


Figure 2 Site 1 Effluent sampling for Total Nitrogen

As expected, the well-drained sites generally had lower chloride and TDS concentration and electrical conductivity values when compared to the sites with heavier clay soils. In summary, the results obtained imply that in a majority of the sites investigated, the quality that is achieved within the initial 1 m of travel is close to the final quality. This finding 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 metres. This calls into question the value of adopting setback distances from sensitive water bodies. However this argument should be tempered with the fact that only a small number of effluent samples were analysed thus results obtained preclude drawing statistical significant conclusions.

4.2.2 Soil Chemistry as a Predictive Tool

Detailed chemical analyses including exchangeable cations, Ca:Mg ratio and ESP were employed

to determine possible indicators of likely deterioration of the soil structure due to effluent discharge. Influential soil parameters were identified (exchangeable Na and Ca:Mg ratio) and possible correlations and linkages between these parameters and landscape factors evaluated (Goonetilleke et al 2000). Sites were categorised, initially by their landscape position along with sub-surface drainage, vegetation and climate factors. If the soil profile evaluation supported the drainage characteristics of the site, as favourable, no further detailed chemical analysis was considered necessary. In the case of poor drainage, detailed soil chemistry can be a valuable tool in predicting site suitability for effluent disposal. Very poorly drained sites can be deemed unsuitable for on-site sewage disposal especially in small lot developments, without further analysis. An example was a “duplex” soil that lay mid-slope and was thought to be a moderately drained soil with initial investigations supporting this. Detailed soil profile evaluation at the control site described initially as sandy loam revealed the presence of a clay-enriched zone at the top of the ‘B’ horizon at 0.6m. Subsequent soil chemistry revealed low Ca:Mg ratio and high exchangeable Na, low CEC and exchange capacity dominated by exchangeable Mg indicating that poor soil conditions for effluent disposal existed. A standard percolation test would have yielded misleading favourable results. It was subsequently found that the owner had replaced a failed septic system due to constant overflowing of the disposal trenches.

The importance of good drainage is crucial, 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 continuous movement of water and salt through the profile. Without this, continuous leaching salt may build up to levels which may be harmful to the landscape and vegetation. Figure 2 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 year old septic tank, and located on poorly drained soil (Goonetilleke et al 2000).

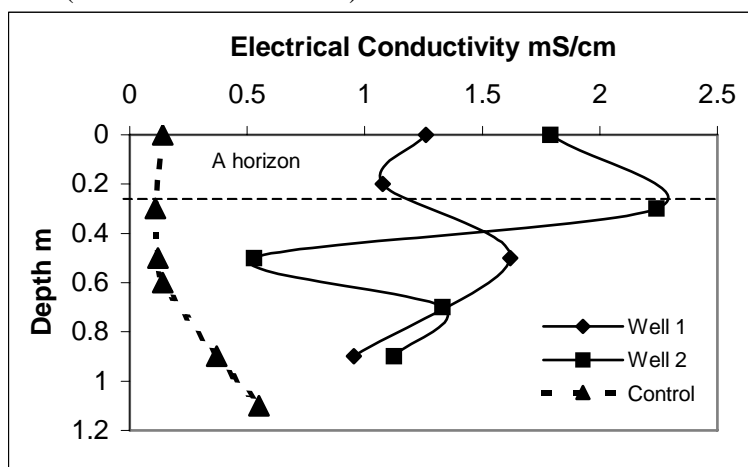


Figure 3 Typical Salt Profile

4.2.3 Conclusions

The conclusion that effluent quality improvement occurs within metres of the trenches is similar to that derived by other studies (Brouwer and Bugeja 1983). An improvement in Total Nitrogen was comparable to studies by Brouwer et al (1979), Sherman and Anderson (1991) and Gerritse et al (1995). It is important to note that the above conclusions relate only to the degree of quality improvement that is obtained. This does not mean that the quality that is obtained is satisfactory. Additionally in the case of some sites in flat, poorly drained areas, there is an appreciable improvement in a number of other parameters (TOC, Faecal Coliforms). Therefore it can be concluded that the additional travel distance may be beneficial for the further improvement of effluent in sites with poor soil conditions. In most cases pathogen testing proved inconclusive.

5. DESIGN IMPLICATIONS

Design approaches to on-site effluent disposal need to be more “big picture” and focus on the

whole system rather than single parameter design methods. This is supported by Lott et al (1999) who found the critical determinant for safe on-site disposal of wastewater is not a single parameter but a balance between hydraulic loading, waste loading versus net removal or loss of nutrients from the system and continuance of a stable soil chemistry. This research project compared the health and performance of several on-site systems based on field observations, soil and effluent data and householder survey information, with control soil characteristics. Collection of this information improves the understanding of the relationship between site conditions and effluent renovation within a given environment. The results obtained confirmed the strong site specific nature of effluent renovation. It showed that effluent renovation is primarily influenced by a combination of various soil physico-chemical parameters and landscape factors. In some cases soil chemistry could be used as a valuable predictive tool in conjunction with physical soil characteristics and landscape factors, for assessing site suitability for on-site effluent disposal.

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