GROUNDWATER CONTAMINATION FROM ON-SITE DOMESTIC WASTEWATER MANAGEMENT SYSTEMS IN A COASTAL CATCHMENT

P.M. Geary, J.H.Whitehead*

ABSTRACT

A catchment management and groundwater monitoring program has been undertaken in several small coastal communities approximately 35 km south east of Hobart, Tasmania, Australia. Domestic wastewater disposal is on-site with absorption systems in sandy soils, while the shallow groundwater is increasingly being used in the community for non-potable uses. Lot sizes are typically less than 800 m^2. The coastal waters are commonly used for primary contact recreational activities such as swimming and surfing in the summer months and bathing water quality during this period is of some concern.

This paper presents the results from part of the groundwater monitoring program. Low levels of bacterial indicators have been identified in groundwater samples from 50 mm domestic wells. Some high nitrate concentrations have been recorded, usually associated with clusters of houses and, from this, several high-risk areas have been identified. In particular some linkages between on-site systems and effluent contaminated seeps along the beachfront have been confirmed.

Whilst it does appear as though the failure of on-site systems is affecting, to a limited degree, the quality of shallow groundwater in the area, a clearer picture is emerging of the capacity of this area to adequately treat the effluent load from the relatively high lot density. The results from this study will afford the local council and planning agencies some useful guidelines for the future planning of developments.
Keywords. On-site sewage disposal, Groundwater contamination, Nitrate leaching, Aquifer pollution.

INTRODUCTION

In non-sewered urban and rural residential developments, domestic wastewaters are usually treated and disposed of on-site. The traditional method of treating wastewaters is an all-purpose septic tank where partial treatment of the raw waste occurs followed by a soil absorption or absorption/transpiration system with the effluent from the tank disposed of primarily below ground into the soil. Aerobic wastewater treatment (AWT) systems which provide extended aeration to domestic wastewaters prior to surface or subsurface spray or drip irrigation of the treated effluent are becoming a popular alternative. Dry or wet composting systems are also increasingly being used, while other systems which utilise the substrate properties of soil or rock materials for filtration and nutrient removal are being investigated.

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For many people, on-site wastewater treatment systems, which were initially intended as short term alternatives prior to the provision of reticulated sewerage, have become more permanent features as the long promised reticulated systems have not been provided. The proportion of the population relying on on-site wastewater management systems in Australia is likely to rise as greater numbers of people move to rural and urban margin locations. Surveys of system performance have indicated that a large number of on-site systems fail. Inadequate effluent disposal due to failing systems may have serious environmental health implications and contribute to nutrient related water management problems. These public health concerns have been brought to the fore in the last few years with an outbreak of *Hepatitis A* in 1996 which was linked to the consumption of oysters from Wallis Lake (NSW) and the 1998 occurrence of *Cryptosporidium* and *Giardia* in the Sydney water supply. On-site system failure and contamination by human waste was considered to be an important factor in both of these major public health incidents.

GROUNDWATER IMPACTS FROM ON-SITE SYSTEMS

The fate and transport of biological and inorganic contaminants from on-site systems have been summarized by Reneau et al., 1989) and many studies report impacts to groundwaters and discuss contributing factors (Yates, 1985; Scandura and Sobsey, 1997; Arnade, 1999; Rose et al., 1999; Gold et al., 1999). In general, most concern appears to be related to nitrate nitrogen (N), viral, and bacterial contamination of aquifers in areas with sandy soils and high on-site system density. High nitrification rates occur with well-drained soils, and small lot sizes with higher urban densities typically occur in coastal locations. As urban density and areal extent of unsewered development increases, dilution capacity decreases and aquifer concentrations can exceed regulatory limits for aquifer beneficial use.

Anderson et al., (1987) estimated that the high density of on-site systems and typical subdivision sizes in Florida would cause the 10 mg/L nitrate-N in groundwater standard to be exceeded at allowable housing densities for a 50 acre subdivision. Winter et al., (1999) also suggested that in many unsewered urbanizing coastal watersheds, nitrate concentrations increased in proportion to increased housing density. Bechdol et al., (1994) in investigating the risk of contamination of drinking water wells by viruses from septic system discharges in the coastal area of Rhode Island predicted that wells in coarse grained stratified drift aquifers were at risk of viral contamination when septic systems were located 30 metres upgradient. Scandura and Sobsey (1997) in their investigations in sandy coastal aquifers of Northern Carolina demonstrated that virus detection was positively associated with proximity to septic effluent distribution lines.

In Australia concern is increasing that effluent from on-site wastewater disposal may impact on groundwater quality. While some studies have been undertaken (Hoxley and Dudding, 1994; Ivkovic et al., 1998; Whitehead and Geary, 2000), relatively little is published about the nature and extent of on-site wastewater impacts on groundwater. Geary and Gardner (1998) commented on this, and in examining the sustainability of on-site systems, recommended that lot sizes be sufficiently large to prevent impacts to both surface and groundwater systems.

A project undertaken for the Rural Water Corporation in Victoria investigated the impact of septic tank effluent on groundwater receptors in the Murray Basin (Hydrotechnology, 1993). This study identified septic tank effluent as the cause of groundwater nitrate-N levels in excess of the World Health Organization and U.S. drinking water standard. Nitrate in elevated concentrations above the maximum level of 10 mg/L nitrate N can cause methemoglobinemia in infants and contribute to cancer in adults (Plumb and Morrisett, 1988). In this Victorian study, septic tank density of 15 tanks per km^2 was cited as the primary cause for the high levels of contamination.

A further study at Venus Bay, Victoria (Hoxley and Dudding, 1994) reported on the condition of a shallow aquifer which provides water supply for and receives septic tank effluent from a community of up to 3000 during the peak holiday season. House lots are small, on average about 800 m^2, and each house typically has both a septic tank and a well, often within 10 metres of each other. No significant pollution of the aquifer by nitrogen was found, with nitrate-N levels not exceeding 8 mg/L. The shallow aquifer was, however, contaminated with significant levels of fecal bacteria and the high concentration of failing septic systems was thought to be responsible for fecal contamination some 500 m distant from the area of septic tanks.

More recently, a study of groundwater quality from 42 wells in the Piccadilly Valley, South Australia (Ivkovic et al., 1998) identified groundwater nitrate levels above background levels, though only in one case exceeding the 11.3 mg/L nitrate-N (Australian) National Health and Medical Research Council (1996) drinking water guideline. An increase in nitrate concentration in 54% of the wells has been observed over the period 1979 to 1994; though changing patterns of landuse make accurate interpretation of this data more difficult. Fecal indicator bacteria were detected in 19% of the wells and leaking septic tanks were thought to be the most probable source of contamination. Rural residential development is occurring preferentially on the higher elevations around the margins of the Piccadilly Valley coinciding with the areas of greatest recharge which appear most vulnerable to groundwater contamination from leaking septic tanks.

GROUNDWATER MONITORING

In 1998 a three-stage catchment management and groundwater monitoring program commenced in four small unserviced communities in and around Dodges Ferry, approximately 35 km south east of Hobart, Tasmania (fig.1). Domestic wastewater disposal in these communities (where lot sizes are typically less than 800 m^2) is on-site where the absorption systems are in sandy soils. The program was commenced because of the potential for ground and surface water contamination and the increase in the density of the systems associated with development. The area is along the coastal zone and is commonly used for primary contact recreational activities such as swimming and surfing, particularly in the summer months.

The aim of the study was to identify any impacts arising from on-site wastewater disposal systems in relation to groundwater quality. The most detailed investigation has been in Dodges Ferry itself (Study Area 1) and this is reported here. Dodges Ferry is a holiday "shack" area that has recently become more permanently occupied. A recent unpublished survey of recreational water quality at swimming beaches at Dodges Ferry reported higher than desirable levels of indicator organisms, not always associated with rainfall events. The survey also examined the microbiology of nearshore beach water quality after three rainfall events of between 11 and 15 mm and found indicator levels per 100 mL of between 4500 – 8000 fecal coliforms and 800 – 64000 fecal streptococci; however, the source of the microbiological contamination was unclear. Stormwater runoff and failing on-site systems were considered contributing factors.

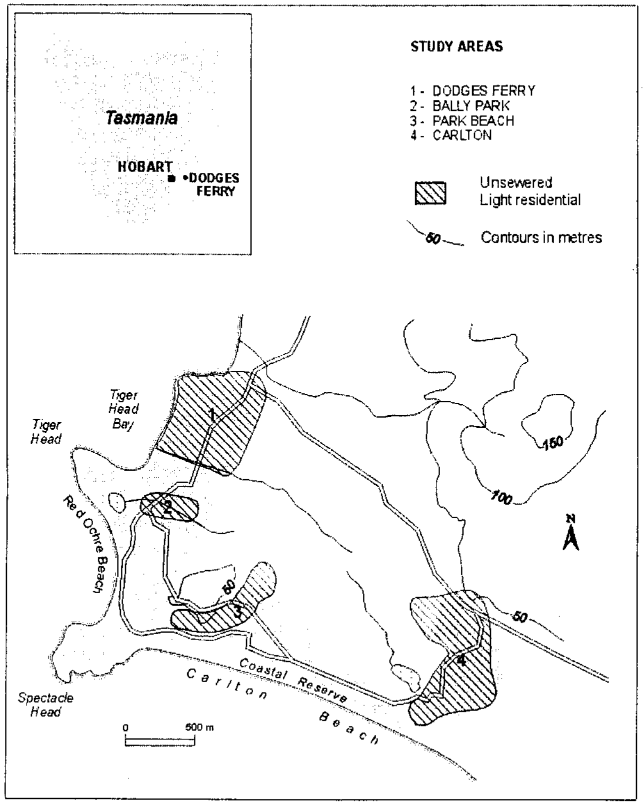

Figure 1. Location of Study Area.

Study Methodology

A desktop study collated and reviewed available geological, hydrogeological and groundwater quality data along with records of drilled and dug wells. The field investigation involved locating and sampling approximately 40 of these wells and surface seeps in the broader study area. In discussion with property owners, information on well history, usage, performance and water quality was gathered and recorded on a database for later use.

Water Quality Parameters

Some water quality parameters were tested at the time of sample collection, while other samples were stored for later analysis, always within 24 hours of collection. Water samples for chemical analysis were collected in clean polyethylene sample bottles from the wells with pumps after approximately five minutes of continuous pumping. The water samples for microbiological examination were collected in sterile glass bottles according to standard procedures and techniques for this type of testing and transported to a microbiological testing laboratory on the day of collection. On several occasions, shallow wells without pumps had to be sampled with hand bailers. The same procedures were followed for these samples as for the pumped well samples.

Water quality parameters which were tested in the field with a Horiba multiprobe were; pH, electrical conductivity, turbidity and temperature. Samples collected from each location were later analysed for nitrate-N using the Cadmium Reduction Method, while analyses for fecal coliforms and *Escherichia coli* were conducted by a registered microbiological laboratory.

RESULTS

Groundwater samples were taken on three occasions in February 1998, January 1999 and December 1999 at approximately 40 drilled and dug wells and seeps located within the broad study area. The water quality results of seven bores and a beachfront seep from within a small catchment in Dodges Ferry are presented in Table 1. The selected results are of a transect from Tiger Head Bay beachfront (Study Area 1 in fig. 1) to the eastern upper part of the catchment.

Geology and Soils

The study area is largely underlain by Triassic sandstone, comprising well-bedded quartzitic sandstone with minor mudstone horizons. The Triassic rocks have been intruded by Jurassic dolerite which is harder and more resistant to weathering and hence forms headlands such as Tiger Head and Spectacle Head. The gently sloping coastal plain is draped with a mantle of Quaternary windblown sand. The soils of the area reflect the underlying geology and the drainage regime. Deep sandy soils occur on the recent windblown sand deposits. Podzols, comprising a deep sand horizon with an iron or humus accumulation at depth and a clay accumulation below, develop on the Triassic sandstone. More clayey soils develop on dolerite and in areas of poor drainage the soils are typically clayey.

Table 1. Water Quality Data.

Well No.	Well Depth(m) (Standing Water Level m)	Mean pH	Mean EC (uS/cm)	Mean Nitrate-N(mg/L) (Range)	Fecal Coliforms (colony forming units cfu/100mL)	E.coli. (colony forming units cfu/100mL)
37	36.0 (30.0)	6.87	3530	0.5		
35/36	30.0 (25.0)	6.50	11150	1.4 (0.8-2.0)	<1	<1
31	42.0	6.31	9366	0.6 (0.1-1.4)	<1	<1
5	42.0 (13.6)	7.64	3150	57.5	<2	<2
6	29.3 (9.1)	6.47	6320	12.4 (7.8-23.6)	<1	<1
23	28.0 (2.4)	6.23	4560	0.6 (0.3-0.9)	<1	<1
9	30.5 (6.0)	6.75	2660	3.8 (2.6-7.4)	<1	<1
Beach Seep	2.0 above Sea Level	7.64	1404	8.9 (6.7-10.2)	<1	<1

Hydrogeology

In some areas of Dodges Ferry, shallow wells access perched water table aquifers in the windblown Quaternary sands at depths of only a few metres. Immediately below the unconsolidated sands, the upper horizons of the Triassic sandstone are, in places, weathered to a depth of some few metres. Beneath, the Triassic sandstone extends under most of the area, and in some places is intruded by igneous sills. Jointing in the sandstone and the presence of mudstone horizons and the igneous intrusions all have a bearing on transmissivity and are commonly identified at or about the depths at which high yields are realized.

Unconfined aquifers in the Quaternary windblown sand deposits and underlying Triassic sandstone recharge from rainfall and surface waters and are susceptible to contamination from a number of surface and near surface sources. Amongst the potential contaminant sources are poorly performing septic trenches, particularly if overloaded by heavy usage at peak periods (if inundated by heavy rain), or where present in high density, the latter resulting in locally elevated effluent loading. A number of contaminated seeps and springs have been noted along the coast, where clay and sandy clay horizons hold up perched water tables. The deeper aquifer in the Triassic sandstone is less variable in yield but is appreciably more saline than the shallow perched water table aquifer. This former aquifer provides a plentiful supply for some well users, but usage is limited to toilet flushing, occasional laundry use and for garden watering of the more salt tolerant plant species. Overpumping and pumping for prolonged periods in wells located close to the coast results in saltwater ingress and deterioration of water quality with time.

Groundwater Quality Results

The quality of groundwater samples collected is variable and related to the local geology. To assist with the interpretation of the data, the hydrogeologic and topographic data for the wells in the Dodges Ferry transect have been plotted in fig. 2. The transect is easterly from the Tiger Head Bay beachfront through Study Area 1 to the upper part of the catchment. Standing water levels in the bores are shown and the hydraulic gradient for the bores on the western side of the transect is towards the beachfront. The variability in salinity is due to the aquifer depth and the residence or contact time of groundwater with the parent material. The more saline groundwaters are those from the deeper bores. The presence of nitrate in waters, particularly groundwaters, can be used as an indicator of contamination by sewage effluents. Given the permeable nature of the sediments in the area and the mobility of the nitrate ion, it is logical to assume that effluent may reach the shallow aquifers when systems fail.

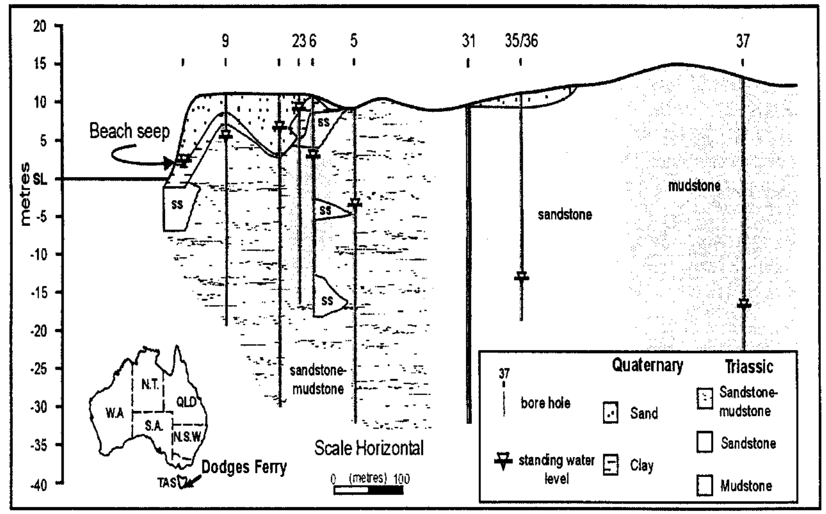

Figure 2. Hydrogeology Dodges Ferry Transect.

In general, the deeper wells exhibited low or background concentrations of nitrate. The shallower wells closer to the beachfront (9, 23, 6 and 5) had significantly higher concentrations of nitrate-N, and several of the samples exceeded drinking water standards. The beachfront seep which is present even during the drier summer months also contained elevated concentrations of nitrate-N. The samples from wells 5 and 6 were sited close to on-site disposal systems and contamination of the aquifer appeared to result from effluent percolating through the porous media below the system or, if the well was poorly sealed, by leakage down the side of the casing. Given the number of on-site systems near the beach front area and the elevated concentrations of nitrate-N, a connection is evident between the disposal of effluent on-site and the beachfront contamination.

The results for this study for fecal coliforms and *Escherichia coli* are shown in Table 1. At all locations the results have been reported as less than 2 cfu/100 mL for both bacteriological indicators. These results indicate that the organisms were not found according to the method of detection for all sites in the transect. No association was found between nitrate-N and the bacteriological indicators possibly due to substantial residence time of these waters and the potential for bacterial die-off.

CONCLUSIONS

The testing of groundwaters has indicated that other areas are at risk of groundwater pollution as well as the Dodges Ferry area. It is not possible, however, on the basis of these limited results, to quantify the nature of the risk. A connection is evident between the quality of shallow groundwater aquifers in specific areas and the practice of disposing domestic wastewaters on-site, particularly where houses are in close proximity to each other. The groundwater in the Dodges Ferry area, with a high density of residences on typically small lots, contained the highest nitrate concentrations found in the study. Whilst concern has been expressed that high densities (15 systems or more per km^2) of on-site wastewater systems with in-ground disposal of treated effluent might be contributory to groundwater contamination in coastal areas, further studies are needed to clarify the picture more widely throughout Australia.

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