DISPERSION OF MICROBES AND POLLUTANTS WITH DISTANCE FROM A FAILED TRENCH

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Abstract

An evapotranspiration-assisted trench system failed after about 10 years of operation. This provided an opportunity to monitor the surface spread of greywater microbial and chemical contaminants and provide further understanding of the buffer distances needed for sandy soils. Despite the system not being build to the design specifications, preliminary results collected in a relatively dry period illustrated the short travel distances the contaminants cover, which challenge the NSW Government Guidelines as being over-conservative for the conditions studied. Possible strategies for lowering pollution risk are also suggested.

Keywords

Bacterial transport in soils, buffer distances, evapotranspiration, on-site treatment, viral transport

1 Introduction

In 1992, an on-site wastewater system was installed to treat the greywater from three lodges and a dining room of an eco-tourist resort near Sydney. It appeared to be coping satisfactorily, until 2002 however, when the trenches failed (seen as surfacing leachate).

The set-back distances recommended in the NSW Government Guidelines for On-site Sewage Management for Single Households (OSSMSH), do not seem to have been based on empirical data. It was therefore thought that studying such a failure could provide a good opportunity to obtain information on faecal indicator microorganisms and therefore potential risk during an actual trench failure. The dual Niimi trench system receiving greywater was in an isolated location well away from any watercourse, so the risk of polluting the aquatic environment during this study was very low.

2 Description of the system

The study site was at a resort that adjoins a National Park on two sides, the downhill boundary being about 50 m from the trench on a slope of about 8%. The nearest watercourse is about 300 m away. The average annual rainfall is about 1,200 mm.

The greywater from the lodges and dining room enters the treatment system into the first of four septic tanks in series. From the septic tanks, the greywater flows into a distribution box. The purpose of the distribution box is to alternate between two Niimi trenches, each 80 m long. A typical cross-section of a trench is shown in Figure 1.

The idea of this design is that it should ensure that the effluent is spread evenly along the trench and encourage capillary flow upwards through the surrounding soil and thus provide a longer path length to the groundwater (Niimi, 1982; Reed *et al*., 1989). Perhaps more important for Australian conditions, is the evapotranspiration provided by the vegetation on top of and adjacent to the trench. There is an impervious liner at the base of the trench, forming a shallow trough to collect excess greywater. Plants then tend to send down their roots to the impermeable layer to assure supply of water and evapotranspire efficiently.

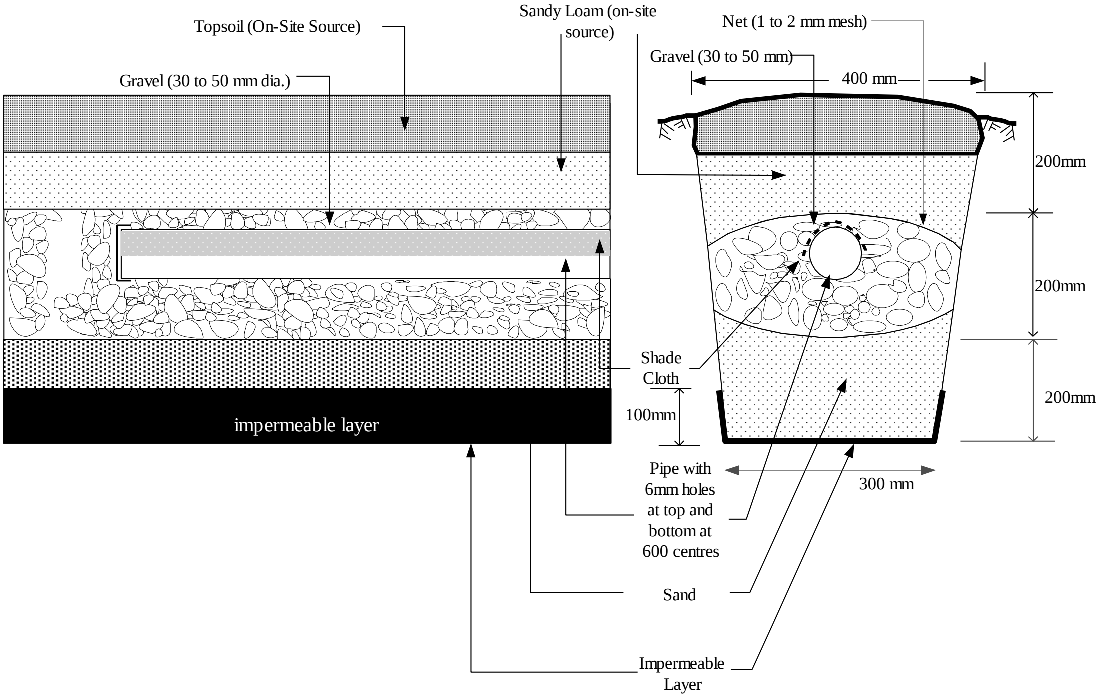

Figure 1 Cross-Section of Niimi trench

At this site, the trenches were laid into a medium grained sandy soil (Medlow Bath Soil, Katoomba Soil Landscape Map) overlying weathered sandstone. The sandy soil contained sandstone floaters at or near the surface down to about 350 mm. Below that, even down to 600 mm or more, the rocks were sufficiently fractured to be easily removed.

Following failure, an investigation of the existing on-site system indicated that it was not installed as designed. The deficiencies found were: -

- The trenches were put in too deep at some sections: the top of the trench was sometimes as much as 300 mm below the surface.
- No humus appeared to be placed at the top of the trench, as required in the design.
- The mesh separating the gravel from the overlying soil may not have been installed throughout the length of the trench.
- The septic tanks were not adequate for preventing excessive amounts of grease from entering the trenches, even though they were designed and operated in accordance with the AS1547-1994 (Australian Standards, 1994). The first writer had not been aware of this after the trenches failed, because the then proprietor pumped the tanks out every six months. This would have overcome any deficiencies of these tanks in allowing too much oil and grease to flow through to the trenches.
- There were two trenches 80 m long instead of four trenches 40 m long, contrary to the advice of the designer. Nowadays, the maximum length of trench that would be installed would be 20 m.
- In contrast to the design, no plants were growing on top of the trench, despite urgings by the writer.

Despite these deviations from the design, the on-site system appeared to the first writer to be working so effectively that in 1999, he applied to Council and received approval for an increased usage of the dining room that supplied greywater to this system.

2.1 Uptake by vegetation

Even though there was no vegetation on top of the trenches, it is quite apparent that the vegetation on both sides of the trench system extended their roots into the trench. The adjoining vegetation seems to have been effective in evapotranspiring some 50% of the average daily flow. At the same time, this vegetation took up some of the nutrients in the trenches, so that it was easier for the microorganisms in the soil to transform what remained. To see this, we can compare the vegetation in Figure 2 with the vegetation in Figure 3.

Figure 2: Vegetation in its natural state

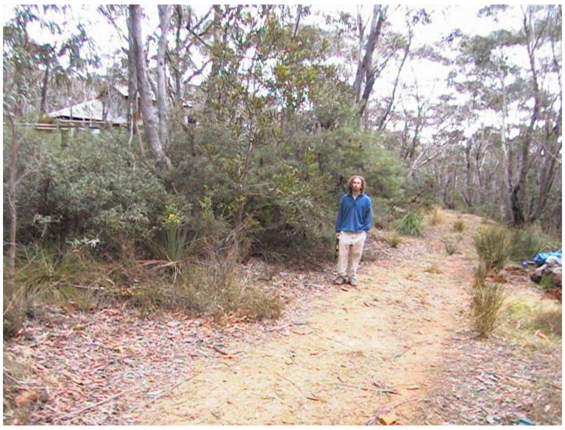

Figure 3: Vegetation adjoining the trenches

Figure 2 shows the native vegetation in its natural state, at a location unaffected by water or nutrients from any on-site system, while Figure 3 shows the native understorey vegetation adjoining the trenches. It can be seen that the vegetation adjoining the trenches is much higher, and when one is on the site it can be observed that the leaves have a deeper hue indicating robust growth. The zone of this enhanced growth is judged to extend to about 8 m from the trenches.

Unfortunately, the improved understorey was only on the southern (uphill) side of the trenches at the time of the photographs. On the instruction of the Council, the understorey vegetation on the downhill side of the trenches was cleared for fire-reduction.

Some simple calculations based on average rates of evapotranspiration and average daily flow suggest that clearing this understorey vegetation might have reduced effluent uptake by some 25% of the average daily flow. This assumes that the understorey accounts for 50% of the total evapotranspiration, and that the average rate of evapotranspiration is 5 mm/day.

In other words, even recognising that the calculations could be refined further, it would seem that the adjoining native vegetation had provided sufficient evapotranspiration and removal of nutrients to overcome the deficiencies in the installation. When the understorey was removed on the northern side, this would have reduced the overall capacity of the system to treat the greywater, which probably contributed to the trenches failing.

Vegetation is now returning to the downhill side of the trenches, as well as being allowed to grow strongly on top of the trenches. Furthermore, growth around the effluent plumes that have surfaced can be expected to reduce, if not eliminate, this failure in time. The resort has cabins with grease traps instead of septic tanks, and these have only short greywater trenches. The difference is that they are wholly within natural bush that would be evapotranspiring effluent very effectively. These have operated for years without sign of failure.

3 Monitoring

Probes for sampling pore water (Soil Moisture Equipment Corporation, Goleta, Ca, USA) were installed in two sets, on 30th August 2002 and 15th November 2002. Their layout is as shown in Figures 4 and 5.

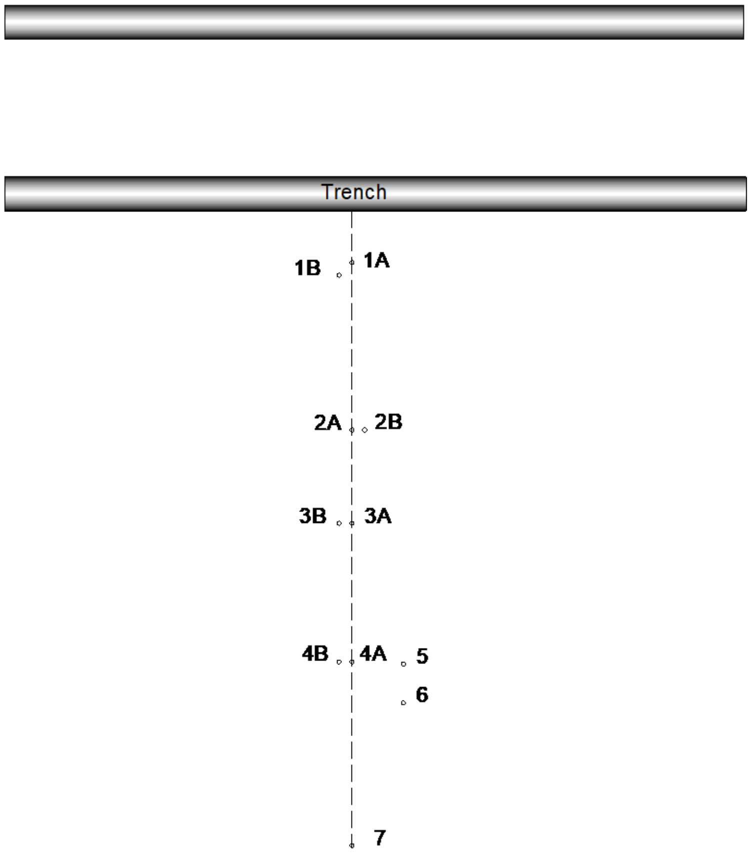

Figure 4 Plan of soil moisture probes (aligned down slope through the zone of failure)

The first set of seven probes, 1A, 2A, 3A, 4A, 5, 6 and 7, had ceramic ends with a maximum pore size of 1.3µm, which are probably too small for *E. coli* to readily pass through, unless the cells enter the ceramic end-on. *E. coli* is rod shaped and about 0.5 µm wide x 1.8 µm long, so if it strikes the ceramic side-on, it will not get through. To overcome this deficiency, another four probes, 1B, 2B, 3B and 4B, were installed, with a maximum pore size of 6µm.

Moisture content was measured with seven ECHO (Decagon Devices, Pullman, Wa, USA) soil moisture sensors, installed as close as practicable to the ceramic cups of the pore-water samplers.

Figure 4 shows that Probes 5 and 6 were not lined up along the original centreline that ran from Probe 1 to Probe 7. At the time of installing the first set of probes, there was a plume of effluent running from the trench along an axis from Probe 1 to Probe 7. However, by the time it reached Probe 4, the plume was quite narrow, less then a metre wide. Excavation at the edge of the plume showed that there was a nearly vertical discontinuity between the saturated soil within the plume, and unsaturated soil outside it. It was felt that it would be of interest to monitor around this discontinuity. Accordingly, Probe 5 was placed approximately level with Probe 4A, but at the discontinuity about half a metre to one side of the axis. Probe 6 was placed downhill from Probe 5, putting it just outside the plume. Probe 7 was placed about a metre downhill from the furthest tip of the plume. The idea was that this probe should provide a baseline of the conditions in the soil unaffected by the plume.

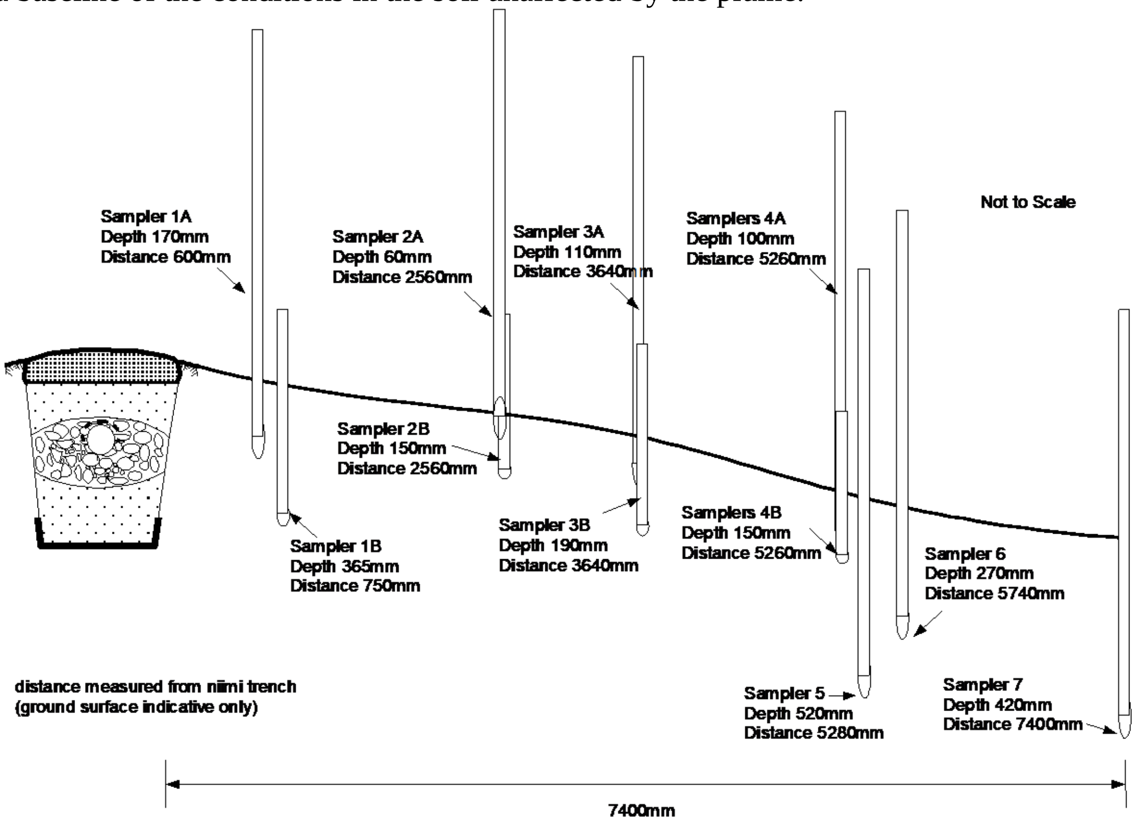

Figure 5 Long section of soil moisture probes

3.1 Results

Sampling so far has not been as thorough as one would wish. Although the probes were all installed by mid-November 2002, sampling could not start straight away. Not only had there been a drought, but also a bushfire passed close to the resort in late November. Although the resort was spared, few visitors came until Christmas. As a result, the trenches had very little effluent running through them, and there was no soil water for the probes to sample until early January 2003.

Samples were collected in sterilised 250 mL glass Schott bottles and analysed for inorganic chemical concentrations (usually in the field) with a Hanna C200 Multiparameter Photometer. The accuracies of such measurements were low, but judged adequate for our purposes.

For the microbiological analyses, *E. coli* and enterococci were enumerated by MPN using Quantitray2000™ and Colilert™ and Enterolert™ reagents respectively as recommended by the manufacturer (IDEXX, Portland Maine, USA). Somatic coliphages present in 10 x 1mL of sample were incorporated into the upper agar layer with the host bacterium (*E. coli* strain CN, ATCC 700078) of a double agar Petri dish as described by ISO method 10705-2 (ISO, 2000). When no plaques were obtain in 10 mL of sample, reagents were added to 100 mL of sample along with the host, and after 24 hours incubation at 37°C, spot tested onto double agar overlay plates with host as described by Grabow (1993); and scored positive in 100 mL if a plaque formed.

Further, the range of concentrations for the different parameters varied, and sometimes the chemical concentrations dropped below the range of the photometric chemicals being used. The volumes obtained were sometimes so low that the sensitivity and accuracy of the micro-biological testing were constrained. For example, if the volume was very low, the laboratory might only be able to test for presence or absence rather than analyse for concentration.

Nevertheless, where feasible, values have been assigned wherever their approximate magnitude could be inferred from the available information. For example, where there was no water in the probe, it was assumed that there would be no ammonia, nitrate nor faecal indicators. Graphs using such data carry a note to state that some of the values are indicative only.

Figure 8 shows that the moisture content had decreased uphill of the edge of the plume by mid-November, and has continued to be lower. Nevertheless, the zone at which the moisture content becomes low seems to have remained at the same distance, namely after about 5.25 m from the trench. As well, it is worth noting that the moisture content at the edge of the plume was generally lower than along the centreline. In fact, these probes either produced no sample, or samples with no indications of microbiological contamination.

Figure 6 shows the concentrations of nitrate ion, while Figure 7 shows the results for enterococci. Please note the concentration of 1 enterococci/100 mL at the last probe (Probe 7) at 7.4 m. The results for *E. coli* and somatic coliphages are similar to the results for the enterococci, except that no detection was obtained at 7.4 m. Enterococci are more numerous in the trench influent than coliphage (though less hardy), so it is possible that the positive enterococci at 7.4 m originated from contamination by the plume of greywater. However, since this is the only positive result obtained from this probe, it may have come from external contamination or cross-contamination during sampling or testing.

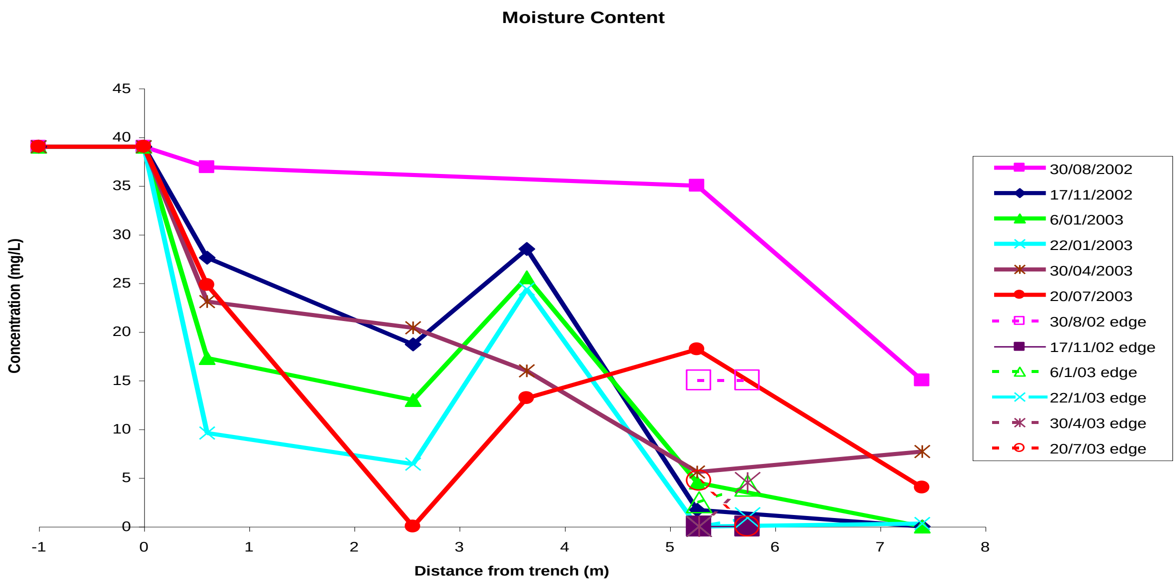

Figure 8. Moisture content vs distance down slope from trench from 30/8/02 to 20/7/03

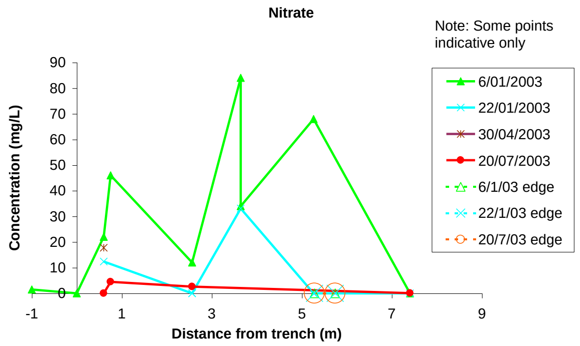

Figure 7. Nitrate vs distance

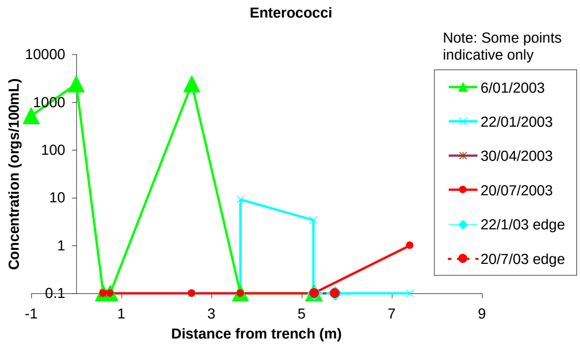

Figure 8. Enterococci vs distance

4 Discussion

In sandy soil (Medlow Bath Soil, Katoomba Soil Landscape Map) at least, the risks of effluent spreading across a slope or uphill are small. Further, on the downhill side, it would seem that the buffer distance in sand could be less than the currently specified 12 m (NSW Government (1998), noting however that our results were collected during a relatively dry period.

Thus, provided the flow of the groundwater follows much the same direction as the slope of the ground, in the absence of macropores and fractured parent rock near the trench, there does not seem to be a need for such large buffers for absorption trenches treating greywater.

Furthermore, provided there were permanent and sustainable mechanisms for evapotranspiring or otherwise removing effluent from a failed trench, it would seem reasonable to accommodate periods of trench failure without the need to provide a further safety distance. Viruses are often considered to be the pathogen group with the highest capacity for groundwater transport, yet removal by several $\log_{10}$ are expected within metres of transport in sandy aquifer materials (Schijven and Hassanizadeh, 2002). Hence, in unsaturated soil, virus removal would be even higher.

Confirmation of appropriate buffer distances not only depends on the results of the rest of this study (hopefully when the weather is not so dry), but also other investigations of on-site systems using spiked influent to raise the initial microbial concentrations (so that a greater level of reduction can be demonstrated). In addition, modelling of microbial transport and risks of infection are also required to generalise these findings, as being undertaken by Charles *et al.* (2003).

5 Conclusions

A preliminary conclusion from our on-going research program is that the current buffer distances set out in the NSW Guidelines are probably excessive for absorption trenches treating greywaters in sandy soils. It is suggested that based on further independent research, tolerable risks may well be achieved with the following changes in buffer distances for sandy soils receiving greywater from absorption trenches: -

- Uphill from the trench: from 6 m to 2 metre;
- Across the slope from the trench: from 6 m to 3 metres;
- Downhill from the trench: from 12 m to 10 metres.

Acknowledgements

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