Evaluating pathogen safety in biosolids treatment and storage in Victoria

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ABSTRACT

We have investigated the inactivation of pathogenic microbial indicators for bacteria and viruses (*Escherichia coli*, *Salmonella*, *Enterococci* and coliphage) in biosolids during the air-drying pan phase and storage of anaerobically digested biosolids. We previously presented preliminary data for enumeration of *E. coli* and coliphage in biosolids from two wastewater treatment plant in Victoria in 2007/2008. Here, we present further enumeration data for four indicators and pathogens: *E. coli*, *Salmonella*, *Enterococcus* spp. and coliphage, in biosolids from a major metropolitan wastewater treatment plant in Victoria, during 2009/2010, and compare the results to the previous study.

INTRODUCTION

Current regulations in the state of Victoria require that digested and dewatered (>10% w/w) biosolids be stored for three years before they can be applied for agricultural and horticultural purposes, for treatment grade T1 products. This storage period is stipulated to ensure that residual pathogenic micro-organisms are reduced to levels unlikely to be a health risk.

In Victoria liquid biosolids from sludge digestion processes are usually placed in lagoons to be air-dried, followed by the storage period. The rate of pathogen die-off during these phases in the treatment process, however, remains uncertain. The question also arises as to whether storage for this extended period of time is actually necessary to protect human health when treated sludge is recycled to agricultural land. Furthermore, extended storage may reduce the agronomic value of the product as a fertiliser and soil conditioner, due to the loss of nitrogen and organic carbon from the biosolids, which discourages its recycling as a soil improver.

In addition, although a process guideline is listed for producing T1 Grade biosolids by anaerobic digestion and pan-drying, there are no recommendations in EPA (2004) to produce restricted T2 treatment grade products by this treatment system. Furthermore, shorter treatment times by this process would only qualify for Treatment Grade T3 status under the current list of prescribed processes in EPA (2004). End-use restrictions apply to T2 and T3 grades, following the multi-barrier approach to minimising risks to pathogens from sludge, by significantly reducing the numbers of enteric organisms by sludge treatment followed by land use restrictions to allow natural attenuation of the residual numbers of pathogens to take place in the soil. The multi-barrier approach is widely adopted and recognised as a safe and acceptable practice for biosolids management and is the principal outlet for treated biosolids in countries such as the US and UK.

As a result of these regulations in Victoria, only about 34% of annual sludge production (82,300 t dry solids (DS)) is used beneficially (Victorian Biosolids Task Group, 2009), equivalent to little more than 28,800 t DS per year. Moreover, currently in Victoria, approximately 3 million t DS of sludge are either stored in lagoons or stockpiled.

During storage, however, the nutrient value of biosolids diminishes owing to the loss of mineral nitrogen (N) by volatilisation of the ammoniacal content and stabilisation of the organic N fraction, reduced solubility of phosphorus (P) and degradation of the organic matter content (Rouch et al. 2009). Over time, this compromises the quality and value of the 'treated' material as a soil improver and fertiliser.

While shortening the storage period has the benefit of increasing the agronomic value of the biosolids, due account must be taken of the implications for the microbiological quality of the sludge. Storage after mechanical or solar/air drying for periods of between 3 to 6 months to meet appropriate microbiological criteria for agricultural application is commonly practised in other countries with climates ranging from temperate (e.g., UK) to arid (e.g., Egypt).

We previously presented preliminary data for enumeration of *E. coli* and coliphages in biosolids from two wastewater treatment plant in Victoria in 2007/2008 (Rouch et al 2008). Here we present further enumeration data for four indicators and

pathogens: *E. coli*, *Salmonella*, *Enterococcus* spp. and coliphages, in biosolids from a major metropolitan wastewater treatment plant in Victoria, during 2009/2010, and compare the results to the previous study.

MATERIALS AND METHODS

Sites

Biosolids samples were taken from the Eastern Treatment Plant (ETP, Melbourne Water Company) in Melbourne, Victoria, which services 42% of Melbourne city. The processes in this plant include anaerobic digesters, air-drying pans, and stockpiling.

Biosolids sampling and analysis

Samples were taken from the anaerobic digesters, air-drying pans and stockpiles, with different ages of biosolids in pans and stockpiles. On a day of sampling, triplicate samples were taken from the pump output of anaerobic digesters and three composite samples were taken from air-drying pans. Stockpiles were sampled three times at a depth of 0.4-0.6 m, to avoid any surface post-treatment contamination (Rouch et al., 2008). Samples were stored at 4 ^{o}C and analysed within 72 h for the presence of *Escherichia coli*, *Salmonella*, *Enterococci* and coliphages.

Enumeration by membrane filtration of *E. coli* and confirmation were by methods modified from those detailed by the Environment Agency for England and Wales (EA, 2002a, 2003). Coliphages were enumerated using the *E. coli* HS(pFamp)R host by standard methods (ISO, 1995). Detection of *Salmonella* and *Enterococci* were based on the membrane filtration methods of the Environment Agency for England and Wales (EA, 2002b, 2002c, respectively).

Due to the focus on pan air-drying, brief details of the air-drying processes at ETP are given. The drying pans had aggregate bases, and were filled over 5-8 weeks, decanted and air-dried from about 5-11 months, depending on the time of year when started. In addition, sludge pans were regularly mixed or turned during the drying phase. Both the SDP33 pan (started 6-2-07) and SDP23 pan (started 13-3-09) ran for about 12 months, from one summer season to the next summer, while the SDP41 pan (started 31-8-09), ran from the spring season to summer, about 7 months.

RESULTS AND DISCUSSION

The results indicated similar values in reducing the presence of *E.coli* and coliphage during the air-drying pan phase across the two seasons investigated. An approximately 10^2 cfu g^{-1} dry solids (DS) reduction of *E .coli* occurred during the anaerobic digesting phase. In contrast, in the air-drying pan phase the prevalence of *E. coli* was reduced by $>10^5$ cfu g^{-1} DS compared to sludge entering the pan, due to destruction related to retention time and drying of the sludge. With the dates of phases in air-drying pans, and the sampling data, trend lines were calculated for the reduction of *E. coli* (Fig. 1). Data for SDP33 was taken from Rouch et al. (2008). Time 0 represents completion of anaerobic digestion and of the start of filling the pans. At ETP the T2 grade limit was reached in both SDP33 and SDP23 by about 31 weeks drying/storage, while the T1 grade limit was reached by 42 weeks drying/storage. In the case of SDP41, which was started at the beginning of the drying season, the T2 grade limit was reached more swiftly, after 21 weeks drying/storage. Destruction of coliphages (not shown) followed a similar pattern to that to that observed for *E.coli* in both SDP33 and SDP23, with the reduction of prevalence by $>10^4$ pfu g^{-1} DS in stockpiles compared to primary sludge. No coliphages were detected in harvested sludge lifted from the drying pans or in the stockpiles. For SDP41, numbers of coliphages declined relatively more quickly than the other two pans, as did numbers of *E. coli*.

The consistent removal of *E. coli* and coliphages during pan–drying for both years of monitoring is shown by the results for SDP 33 (07-08) and SDP 23 (09-10). This suggests that removal of indicators is robustly reproducible, despite the difference in environmental conditions across different years. In addition, SDP 41, which was started at the beginning of the drying season showed higher removal rates of indicators.

In stockpiles from harvest time to 12 months storage age no *E. coli* or coliphages were detected (limit 20 cfu/g DS or pfu/g DS).

The results indicate $>10^4$ cfu g^{-1} removal of *E .coli* during the air drying phase due to destruction related to retention time and drying of the sludge. Moreover, in the stockpiles the prevalence of *E. coli* was reduced by $>10^6$ cfu g^{-1} dry solids (DS) compared to primary sludge entering the plant. This would comply with the enhanced treatment requirements for agricultural use of biosolids prescribed in the UK Safe Sludge Matrix.

Completion of air-drying in pans reduced the survival of *E. coli* to below detectable limits (2 x 10^1 cfu g^{-1}) exceeding Victorian and international requirements for unrestricted or enhanced treatment status for biosolids. The Victorian Guidelines for Environmental Management: Biosolids Land Application (2004) require $<10^2$ *E. coli* MPN g^{-1} DS for Treatment Grade T1. The USA EPA pathogen reduction criteria for Class A biosolids for unrestricted use and UK enhanced treatment status require $\leq 10^3$ cfu g^{-1} DS. The UK also specifies a $\geq 10^6$ cfu g^{-1} reduction of *E. coli* to achieve enhanced treatment status to allow the most flexible end-uses for treated biosolids.

Coliphage numbers also decreased substantially during the air-drying phase, indicating that enteric viruses are also likely to be destroyed during this phase.

The levels of *Enterococcus* spp. decreased during pan air-drying, but at a slightly slower rate than for *E. coli* and may prove a more robust indicator for pathogen removal than *E. coli* (not shown). A range of *Salmonella* serotypes, such as *Salmonella* Typhimurium, were detected at low levels in a number of samples from anaerobic digesters, but not in drying pans or stockpiles (not shown).

CONCLUSION

The results suggest alternative processing options are possible to produce biosolids suitable for use on land, compared to producing and storing stockpiles for 3 years. In the reported cases across two different years microbial safety of treatment T1 grade, based mainly on *E. coli* data, was reached before the end of the air-drying phase. This would save over three years storage for producing T1 grade biosolids in Victoria, compared to current guidelines. It is additionally suggested that air-dried biosolids with treatment T2 and T3 grades are also suitable for direct use on agricultural land, following a standard regime of land-use restrictions, without the need for an extended storage period. To sustain these conclusions it will be necessary to also assess the removal of parasites and enteric viruses in treatment processes. Also, across Victoria the metropolitan and regional wastewater plants have a range of different process sequences, for example, some do not have anaerobic digesters, which may lead to some variation in removal of pathogens. It is therefore, considered important to assess the removal of pathogens by each type of plant.

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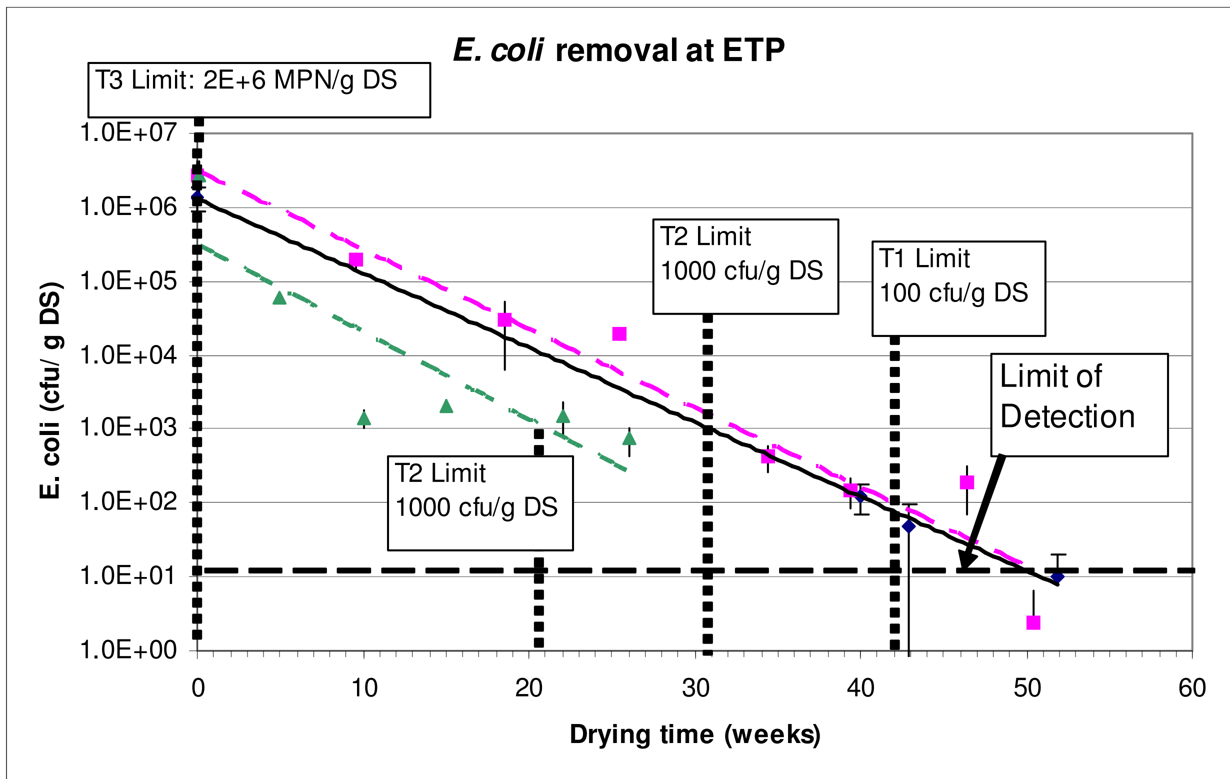

Fig. 1. Effect of air-drying processes on removal of *E. coli*, ♦, SDP33 (6-2-07 to 4-2-08), y = 1E+06e$^{-0.23x}$, R^2 = 1.0; ■, SDP23 (13-3-09 to 1-3-10), y = 3E+06e$^{-0.25x}$, R^2 = 0.95; ▲, SDP41 (31-8-09 to 1-3-10), y = 3E+05e$^{-0.27x}$, R^2 = 0.72: for the T3 limit MPN/g DS is equivalent to cfu/g DS.