



# Using Biofilters to Reduce the Greenhouse Impact of Small to Medium Sized Landfills

## CASE STUDY

When organic materials break down in the absence of air in landfills, methane is produced and slowly released into the atmosphere, contributing to global warming. For large landfill sites, a number of gas extraction and recovery systems are available, but few options exist for small to medium sized landfills due to their scale or design.

The University of NSW and GHD Pty Ltd received funding from the Department of Environment and Climate Change NSW to evaluate passive drainage and biofiltration as a method for managing landfill gas. This involved the installation of 'gas drainage trenches' into the cap of a landfill, which direct the landfill gas into a layer of material consisting of compost and shredded wood and timber, referred to as a 'biofilter'.

The project found that greater than 90% of methane and 97.5% of odour can be removed from landfill gas.<sup>1</sup> The study also found that recycled materials such as compost and crushed concrete and brick aggregate can be used successfully in the passive drainage and biofiltration system.<sup>1</sup>

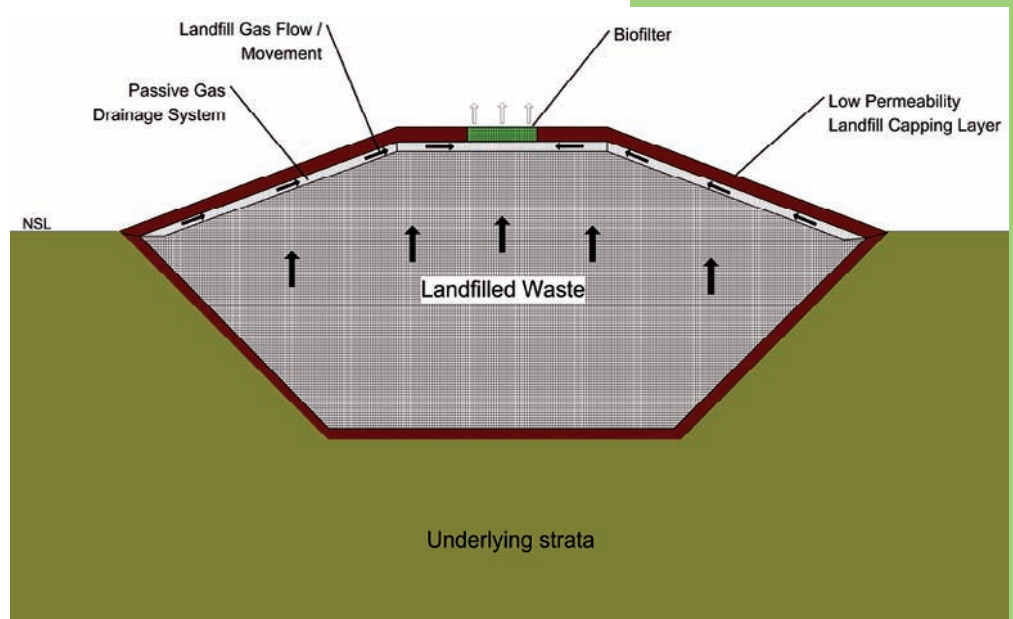
This sustainable and low-cost technique can help to reduce the greenhouse impacts of small to medium sized landfills as well as potentially increasing markets for a number of recycled materials across NSW.

### Why are Landfill Gas Emissions a Problem?

All landfills that contain organic waste generate landfill gas. Landfill gas contains methane (45–60%), carbon dioxide (40–60%), and small quantities of other gases and compounds including nitrogen, oxygen, sulphides, ammonia, hydrogen and carbon monoxide.<sup>2</sup>

Methane in landfill gas presents a number of problems. It is potentially explosive and is a significant contributor to greenhouse gas emissions. Methane has 21 times the greenhouse impact of carbon dioxide and the Australian Greenhouse Office<sup>3</sup> reports that emissions from landfills amounted

Figure 1. Concept drawing of a passive landfill gas drainage and biofiltration system.



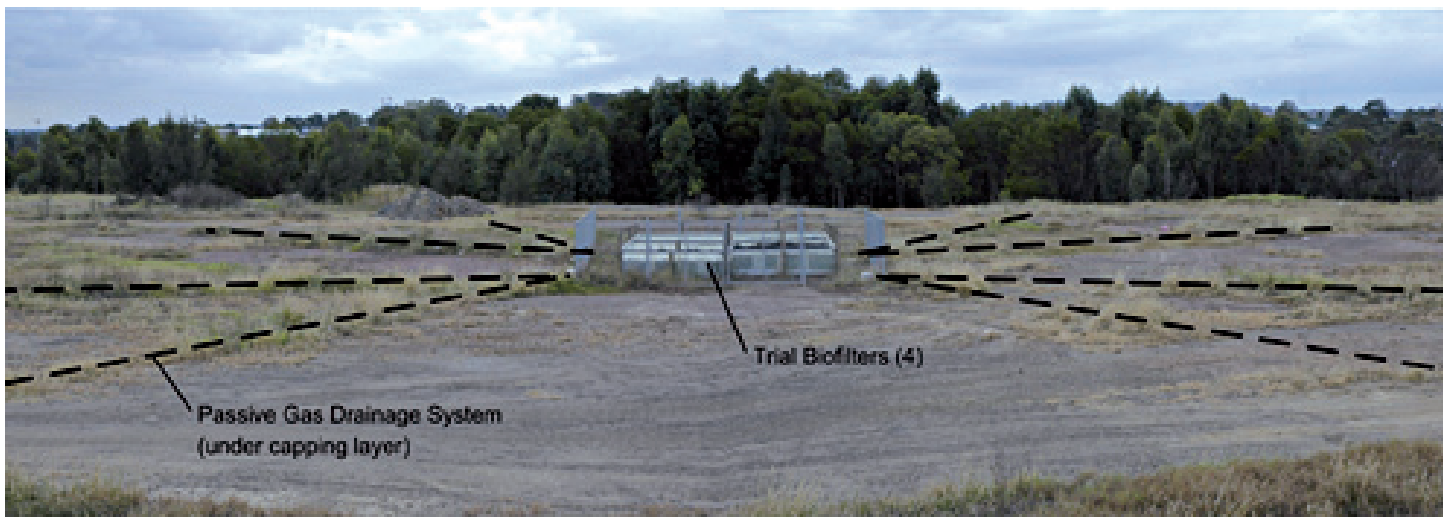


Figure 2. Kelso Waste Depot trial, showing the layout of the gas drainage field and the position of the biofilter beds.

to 15 Mt (CO<sub>2</sub>-e) in 2004, representing approximately 2.7% of Australia's net national greenhouse gas emissions. Landfill gas emissions can also be highly odorous.

## Using Microorganisms to Treat Landfill Gas

Methane 'loving' microorganisms (methanotrophs) are able to convert methane in the presence of oxygen to energy, carbon dioxide, water and cell material.<sup>4</sup> These microorganisms are commonly found in the natural environment, where oxygen and methane both occur.<sup>4</sup> They are fairly adaptive organisms but only achieve high methane consumption rates when the pH, soil porosity, temperature, water content, nutrient supply, oxygen supply and methane supply are suitable, and where levels of inhibitory substances are low.<sup>5</sup> Substances that can inhibit the process include ammonia, nitrite, and various salts.<sup>5</sup>

Microbial oxidation of methane in landfill gas has been demonstrated in both laboratory and field studies, and is well documented in the literature.<sup>5-9</sup> Studies have found that microbial methane oxidation is affected by many factors including moisture content, temperature, nutrient supply, including availability of oxygen and methane, and the movement of gas (oxygen and methane) to and from the microorganisms.

Consequently, the effectiveness of microbial methane oxidation depends upon many site-specific environmental conditions, including the characteristics of the media in which the process is occurring, local climatic conditions and the quantity of methane to be oxidised.

## Passive Landfill Gas Drainage and Biofiltration Trial

A trial passive gas drainage and biofiltration system was constructed at Bankstown City Council's Kelso Waste Depot. The trial system comprised the following:

- A 6m x 6m biofilter structure, which was subdivided into four (4) separate 3m x 3m biofilter beds;
- A 1.2m thick layer of biofilter media in each bed. Four different biofilter media were trialed:
  - Media A: composted garden organics plus an additional 10% shredded wood (kg/kg, dry mass basis). Note, the garden organics mix (prior to composting) comprised approximately 65% (v/v) shredded garden organics and 35% (v/v) shredded wood/timber;
  - Media B: composted municipal solid waste plus 20% shredded wood (kg/kg, dry mass basis);

- Media C: composted garden organics (see above — media A); and
- Media D: composted municipal solid waste plus 10% shredded wood (kg/kg, dry mass basis).

- A 0.5m thick gas distribution layer, located under the biofilter media, which included a pipe distribution network located within the drainage layer (to improve the distribution of landfill gas across the full area of the biofilter). Two different sizes of recycled brick and tile aggregate were used in the gas distribution layer (10–20mm and 70mm);
- A layer of non-woven geotextile to separate the biofilter media and the gas distribution layer aggregate;
- A passive landfill gas drainage system for each biofiltration bed. Two different types of recycled aggregate were used in the trial gas drainage systems; crushed concrete in two different sizes (20–40mm and 70mm), and crushed brick and tile in two different sizes (10–20mm and 70mm).

Figures 2 and 3 show the installed trial system and Figure 4 shows a typical section of one of the trial biofilter beds.

The trial system was monitored on a regular basis from October 2004 to July 2006. This involved monitoring and evaluating the climatic conditions at the site; behaviour of the trial gas

Figure 3. Trial biofilter beds, Kelso Waste Depot.

drainage systems, including landfill gas flow and composition; and behaviour and performance of the trial biofiltration beds, including the landfill gas loading, gas composition profiles through the biofilter, media temperature, moisture content and emissions (methane, carbon dioxide, odour) from the surface of the biofilters.

## Trial Results

Microbial oxidation of methane was identified in all four trial biofilters. The performance of the four trial biofilters (at oxidising methane) was found to be dependent on the methane loading rate (see Figure 5). The rate of methane oxidation in the passive biofilters was found to be limited by the diffusion of atmospheric oxygen into the biofilters, which was influenced by the gas loading rate.

Methane oxidation rates greater than 90% were measured, however, this varied with the methane loading rate and landfill gas generation.

Methane emissions from the trial biofilters depended on the landfill gas loading rate and the performance (oxidation rate) of the biofilter.



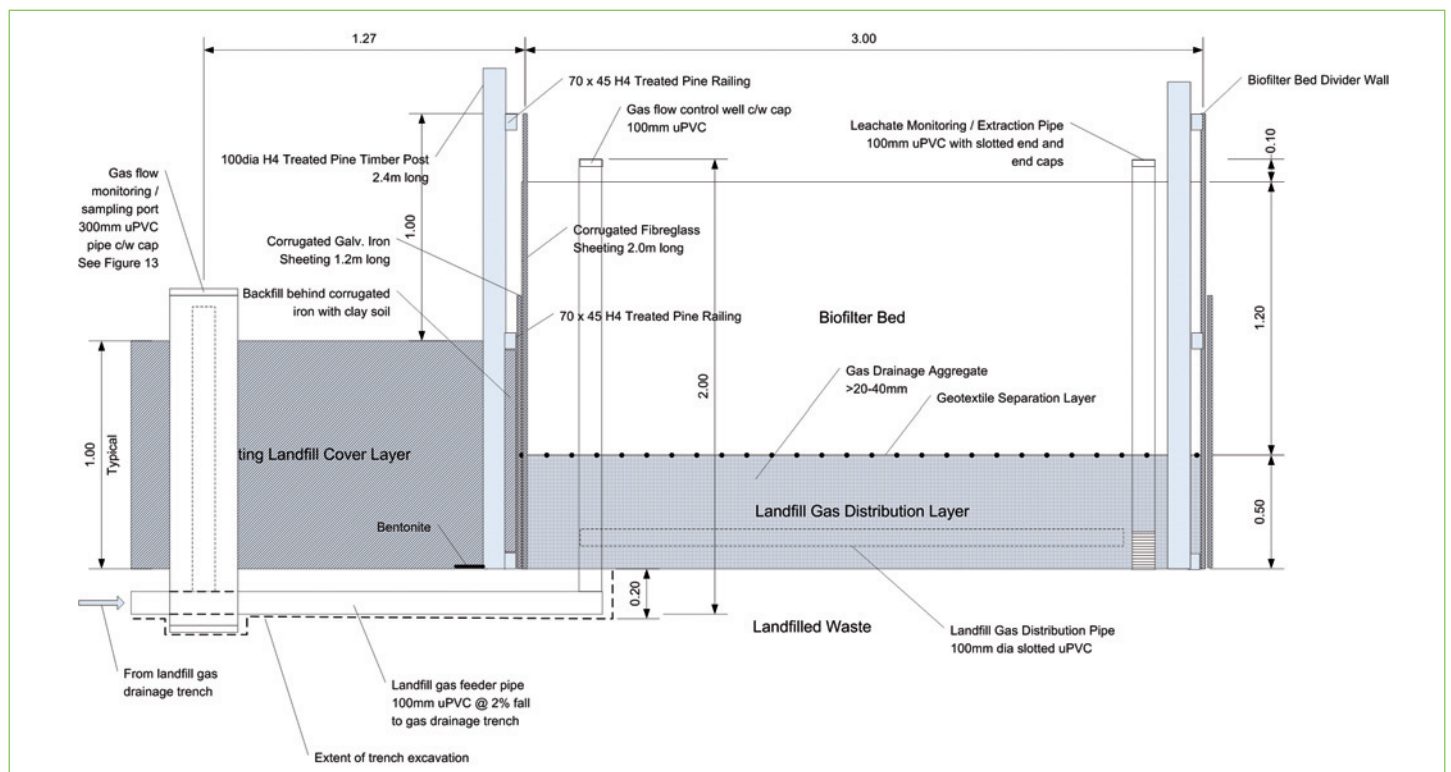
Local climate had a number of effects on the biofilters, including bed temperature and moisture content. The temperature profile of the biofilter was found to be a good indicator of microbial activity.

The moisture profile of the biofilter media was found to be particularly important. The biofilter must contain sufficient water (between 10 and 30% v/v), at the right location for microbial methane oxidation to occur. Microbial activity within the biofilter also varied with oxygen levels, landfill gas loading rate and the physical properties of the media.

To ensure good methane oxidation the media should have the following properties:

- High level of nutrients and organic matter (C:N ratio ~ 15:1);
- High level of stability and low respiration levels;
- Low levels of ammonia and nitrite (ammonia < 350ppm and no nitrite);
- High porosity and high gas conductivity — to allow movement of gas through (into and out of) the biofilter;
- Moderate water holding capacity;
- Good drainage to avoid saturation of the biofilter media;
- Well mixed and relatively homogeneous — to minimise short circuiting of landfill gas through the biofilter media layer; and

Figure 4. Typical section of a trial biofilter bed.





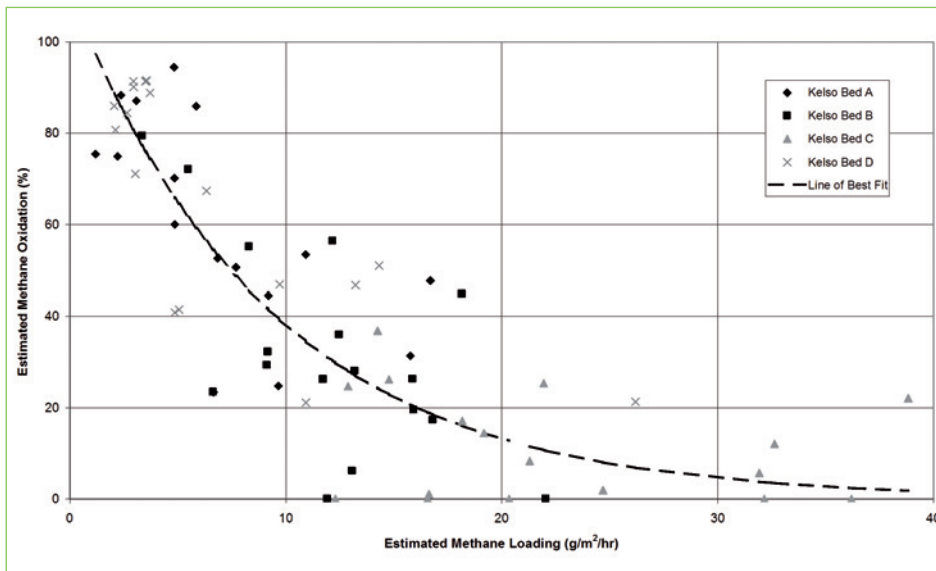


Figure 5. Performance of the biofilter beds at removing methane from landfill gas at different gas loading rates. Note that the results are preliminary and the subject of ongoing research.

Contain material that provides a structural skeleton for the biofilter media, which is suitable for biofilm establishment and minimises settlement of the biofilter media – thus maintaining high porosity and high gas conductivity.

Recycled aggregate used in the trial system showed no significant signs of physical or chemical deterioration over the duration of the trial (approximately two years).

The trial biofilters removed more than 97.5% of odour from the raw landfill gas and odour emissions from the surface of the biofilter were relatively low.

Rainfall infiltration and drainage through the biofilter beds over the duration of the trial was relatively low, equivalent to 10–12% of the rainfall received at this site.

## Conclusions

Passive drainage and biofiltration of landfill gas can be an effective and viable option for reducing methane emissions at small to medium landfill sites. It may be used to complement gas recovery measures or be used if gas recovery is not a practical option. Methane oxidation rates greater than 90% (of input methane) can be achieved.

Composted garden organics, composted municipal solid waste, and shredded wood can be used to make biofilter media

that achieves a high level of methane oxidation (>90%).

A passive biofiltration system should be designed considering landfill gas generation, the gas loading rate on the biofilter (and its variability), local climate and the properties of the biofilter media.

Recycled aggregate (concrete and brick and tile) may also be suitable in a passive landfill gas drainage system, depending on the conditions within the landfill.

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