The efficacy of Richmond Valley Council's Food and Garden Organics Collection scheme

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Abstract

On the thirteenth of June of 2016, Richmond Valley Shire Council in northern New South Wales introduced the Food and Organics collection scheme. This scheme was first implemented in the Casino district on that date, and then other parts of the shire such as Evans Head, Coraki and Woodburn on the twentieth of June.

The scheme was introduced as a response to perceived wastages and environmental concerns disposing of organic waste in normal landfilling. It was decided that these wastes would be of better service to the community if they were composted, returning the product to the soil as mulch and compost. This composting is performed at the Lismore Recycling and Recovery Centre.

To facilitate this scheme, the shire council delivered to each resident a small kitchen caddy and a roll of biodegradable liner bags. When filled, the bags are then placed in a green-coloured recycle bin (a "wheelie" bin) for pickup by the council's garbage disposal service. This larger bin is for all organic waste, namely grass clipping, leaves, cardboard and other compostable products.

The aim of this paper is to examine the efficacy of the collection and composting process in comparison with traditional landfilling methods. It will review not only the environmental impact industrial scale composting has, but also the financial aspect, and whether composting is cost effective vis-à-vis with landfilling.

Keywords: composting, methane, landfills, Richmond Valley Council, recycling

Contents

1. Introduction

There is an increasing trend to find new ways to reduce anthropogenic emissions of carbon dioxide (CO_2) and other carbon compounds that are pollutants, commonly referred to as the "carbon footprint". Major amongst these is methane (CH_4) which is a naturally occurring alkane, and a gas at standard pressures and temperatures. Methane is produced biologically by anaerobic methanogenesis, in landfills, the stomachs of ruminant mammals and several other minor biological and chemical processes (Pardo, Moral, Aguilera & del Prado, 2015). Ruminant mammals such as cattle, pigs, goats and sheep account for 25% of biogenic methane production, and the remainder largely by landfills and other anoxic environments. This methanogenesis is the direct result of micro-organisms, specifically from the domain Archaea, breaking down acetic acid and carbon dioxide in an anoxic environment. One such organism was identified as *Methanobacterium thermoautotrophicum* in a study (Jäckel, Thummes & Kämpfer, 2005) and at concentrations of 2 x 10^8 methanogens per gram of matter.

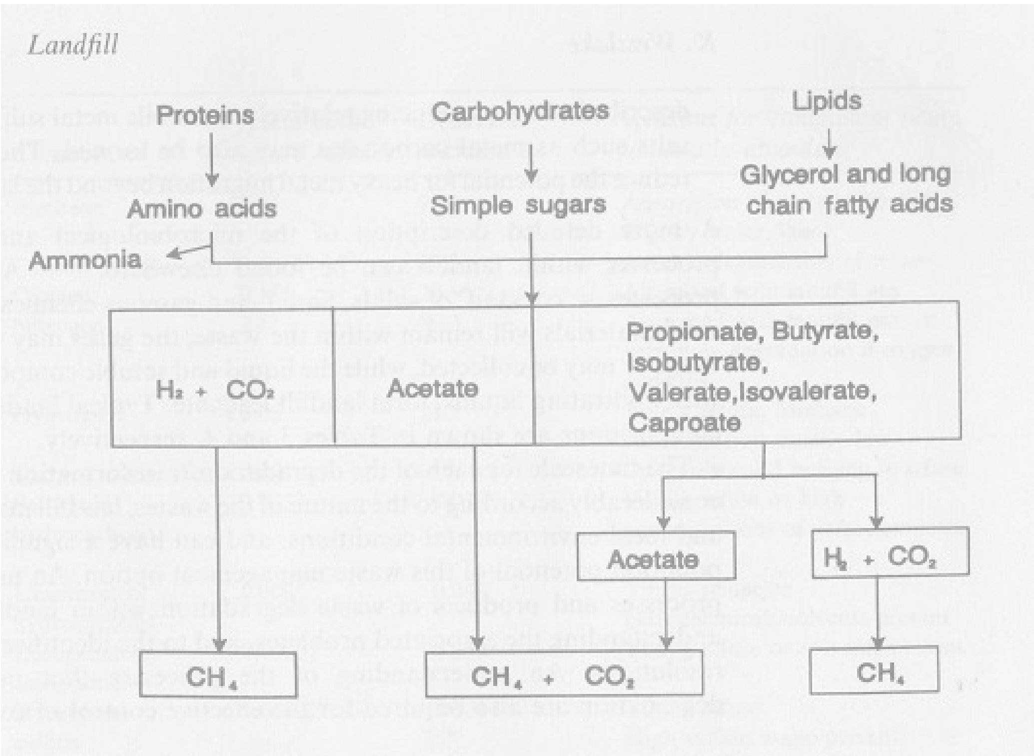

Figure. 1 Anaerobic methane and carbon dioxide production in landfills. Source: *Waste Treatment and Disposal*

Figure 1 depicts the chemical processes by which methane and carbon dioxide are produced anaerobically. These gases displace nitrogen in the trapped air within a landfill, and an equilibrium of 60% methane and 40% carbon dioxide is eventually reached (Hester and Harrison, 1995). Methane produced in this manner is the direct result of the breakdown of biodegradable material (Williams, 1998, p.236), and is not produced by non-organic waste. Therefore, one mitigation strategy is to reduce or eliminate organic waste from landfills. Where organic waste material is simply dumped in a heap, it anaerobically produces methane unless some large-scale turning or aeration regime is implemented. The methane produced is often collected commercially as a biogas but the collection procedure and its viability as a biogas has been called into question (Bong et. al, 2016). However, landfilling is a major cause of soil poisoning and water eutrophication, and in certain situations, discarded sulphate containing materials such as plaster-board, like Gyprock, are reduced in anaerobic conditions and when the environment becomes acidic, the sulphates will be released as hydrogen sulphide (H_2S), which is a significant poison to life (Hester & Harrison, 1995). However, anaerobic digestion and breakdown has been demonstrated to have positive benefits in systems such as sewage treatment, abattoir waste and agricultural waste (Arvanitoyannis & Vazarkas, 2008) which further suggests that anaerobic waste treatment may be optimal for a closed system. Landfills, due to their open nature, cannot be adequately controlled in the same manner a sewage plant can be.

The landfill plant at Nammoona on the northern outskirts of Casino, Australia, is operated by the Richmond Valley Shire Council (Richmond Valley Council, 2017). Apart from being the fill for collected weekly waste, there are also depots for other household waste products such as electrical goods, car batteries, metal and wooden furniture and mattresses. Bulldozers and backhoes periodically turn the landfill. Some material is recycled, such as glass, aluminium and salvageable metal items, in addition to the lead from car batteries, itself a major soil pollutant and poison. To counter some of the build-up on non-biodegradable waste, the council has joined the DrumMUSTER program (Richmond Valley Council, 2017), which collects used agricultural and veterinary chemical containers that have been washed. This program is designed to prevent leaching of chemicals into the soil and waterways.

Due to concerns of methane production in landfills (Richmond Valley Council, 2017) the council implemented a household organic waste collection system, dubbed the Food and Organics collection scheme. All compostable material is gathered and collected separately from other household, commercial and industrial waste. This is done by the introduction of two separate bins: a larger 240 litre green-coloured bin which complements the yellow recyclables and red non-compostable waste bins ("wheelie" bins). The second is a five litre hinged lid caddy which is designed for internal use, to collect food and cardboard waste which is then transported outside to the larger green bin for periodic collection.

Figure 2. Five litre food organics caddy depicting liner bags. Source: Richmond Valley Council

As Figure 2 shows, biodegradable liner bags are available to line the caddy with, also allowing for a convenient way to carry the wastes to the larger bin. This initiative is part of a larger regional move to limit and/or thoroughly process household and organic wastes (North East Waste, 2017). This move comes under the North East Waste umbrella organisation in which regional councils in the Northern Rivers areas are moving to a unified collection and recycling/composting strategy.

Council Area	Organics (inc. food), collection	Garden waste collection	Self haul of green waste to facility
Ballina	Yes	Yes	Yes
Byron	Yes		Yes
Clarence Valley	Yes	Yes	Yes
Kyogle			Yes
Lismore	Yes	Yes	Yes
Richmond Valley	Yes	Yes	Yes
Tweed		Yes	Yes

Figure 3. Northern Rivers' council's collection readiness. Source: North East Waste

Figure 3 depicts an overall readiness among Northern Rivers' councils in organics collection. As shown, Richmond Valley is prepared across all three listed categories. The council operates a garbage collection service which picks up the three bins on one weekday per week depending on location within the Casino area. The green bin is collected weekly, whereas the red and yellow bins are collected fortnightly. The landfill at Nammoona is still open for disposal of larger or more hazardous material that cannot be discarded in the 240 litre bins. There is a fee for this, whereas council rates fund the kerbside collection service.

The next section will examine the various pollutant gases and their production methods in landfills, and a brief overview of how the emission of these gases can be mitigated. The three primary gases found in landfill emissions are carbon dioxide, methane and nitrous oxide. While there are traces of other gases, such as sulphur dioxide, this paper will not discuss them.

2. Examination

2.1 Carbon dioxide

The 2013 Intergovernmental Panel on Climate Change (IPCC) stated that atmospheric carbon dioxide is 40% greater in 2013 than it was in 1750 (Hartmann et. al, 2013). The IPCC report further suggests that average global tropospheric air temperatures are very likely to have increased significantly over the same period (p. 162). Per these findings, the overwhelming majority of the CO_2 increases during this timeframe are anthropogenic in origin. Although this paper isn't focussed upon CO_2 emissions, this finding of the IPCC's illustrates that increases in atmospheric pollutants and global warming gases of anthropogenic origin are a concern.

In the Earth's atmosphere, the predominant greenhouse gas (GHG) is water vapour, with CO_2 following in order of abundance (Pardo, Moral, Aguilera & del Prado, 2015). Other GHGs of note are methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6) and various chlorofluorocarbons (CFCs). This latter category of GHG is wholly anthropogenic; a result of the refrigerant and spray can industries where these gases were used as propellants (Ramanathan, 1975). As well as their global warming potential (GWP), N_2O and the CFCs are notable ozone-depleting gases (Pardo, Moral, Aguilera & del Prado, 2015) that decompose through the action of sunlight in the stratosphere, and the resultant halogen ions combine with ozone (Newman, n.d) and are a direct contributor to ozone depletion.

CO_2 is a greenhouse gas (GHG) by which all other GHGs are compared to; a standard that is used throughout science to compare the warming potential of other gases. This standard is called the global warming potential (GWP), and the GWP of methane is 25 times that of CO_2 and 298 times for N_2O (Pardo, Moral, Aguilera & del Prado, 2015). Most anthropogenic CO_2 emissions are from industrial and commercial sources, such as the burning of fossil fuels for electricity generation, transportation and heating, among other uses (IPCC, 2007). Other man-made sources of CO_2 are the result of deforestation and agricultural production. By removing trees through deforestation, anthropogenic CO_2 is increased due to a lack of transpiration and gas exchange between O_2 and CO_2 that the forests provided. Some of this loss is being mitigated by the implementation of carbon sink plantations and reforestation

(Commonwealth Dept. of the Environment, 2011) though there are concerns that these will be insufficient to reverse anthropogenic CO_2 emissions.

2.2 Methane

Methane (CH_4) emissions can be both natural and anthropogenic (Bong et. al, 2016). The primary route of CH_4 entry into the atmosphere is by methanogenesis via anaerobic breakdown of organic matter. Figure 1 earlier in this paper illustrated the complexity of the process though it can be simplified to Equation 1:

$$C_6H_{12}O_6 \rightarrow 3CO_2 + 3CH_4$$

This shows that glucose is broken down to its resultant gaseous products. Figure 4 depicts the entirety of methane generation, both natural and anthropogenic. Attention is drawn to the figure for landfills, as this percentage is increasing, and it was on this basis that Richmond Valley Council have initiated the Food and Garden Organics Collection scheme.

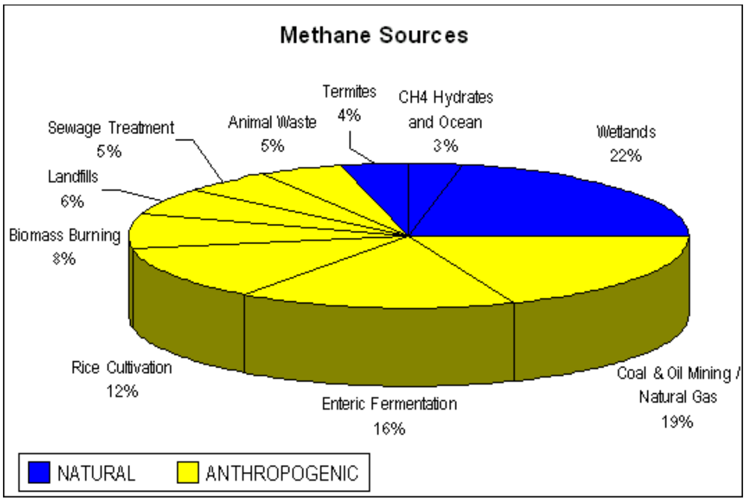

Figure 4. Global sources of methane. Source: NASA

Some of the sources for methane listed in Figure 4 can be directly addressed by humanity with changes in waste disposal and agricultural practices, namely biomass burning and sewage treatment. The effects of rice cultivation and domesticated animal exudations are beyond the scope of this paper, though it is notable the graph lists enteric fermentation as anthropogenic. This is due to the raising of ruminant animals for their products (e.g., meat, milk and hides), and suggests that the methane production would not be so high if these animals were not bred domestically. Interestingly, the Commonwealth Government of Australia includes the storing of livestock manure in special ponds as part of its Carbon

Farming Initiative (Dept. of the Environment, n.d), so that trapped methane within the manure cannot readily escape into the atmosphere. This is part of the overarching Carbon Farming Initiative to meet Australia's quotas under the Kyoto Protocol.

A scheme in the United States introduced in 2003 offered "carbon credits" to primary producers and others who diverted carbon emissions from landfilling to other methods, such as anaerobic digestion and methane capturing (McComb, 2009). This was a financial initiative aimed at compensating primary producers for utilising alternative methods of organic waste disposal. McComb suggests that a trial scheme undertaken in Massachusetts at Cape Cod, implemented a credit scheme that returned USD$1.25/ton (2009). It was noted that GHG emissions decreased in the time the trial scheme operated.

In the atmosphere, CH_4 has a mean lifetime of ten years, due to its reactions with hydroxyl radicals (OH) to eventually form CO_2 and water. However, this process relies on free hydroxyl radicals, and with increasing anthropogenic amounts of atmospheric methane, it has been suggested that methane's lifetime in the atmosphere may increase (Holmes, Prather, Søvde & Myhre, 2013). There are potential sources of methane release into the atmosphere that are outside the scope of this paper, such as the melting of methane clathrates in the deep ocean and polar regions of the world (MacDonald, 1990). Clathrates are compounds that are physically trapped in the crystal structure of another (Oxford University Press, 2015). The clathrates, however, do present challenges for climate science in addition to other sources of methane emission.

2.3 Nitrous oxide

Nitrous oxide (N_2O) is a naturally occurring colourless and odourless gas that currently occurs in the atmosphere at concentrations of ~ 320 parts per billion (US EPA, 2017). Its global warming potential is 300 times that of carbon dioxide (Kramer, Reganold, Glover, Bohannan & Mooney, 2006) and most anthropogenic emissions are via agricultural fertiliser use. Through nitrification, the nitrogen within fertilisers such as urea and ammonium nitrate is reduced to N_2. However, a small fraction remains in compound form, including nitrous oxide (Kramer, Reganold, Glover, Bohannan & Mooney, 2006). This process also occurs in landfills and composting heaps unless steps are taken to minimise the emissions. Within these, nitrification occurs via anaerobic and aerobic processes (Nag, Simaoka, Nakayama, Komiya & Xiaoli, 2015). In landfills, heterotrophic organisms produce it anaerobically, whereas autotrophs produce it aerobically. It has been found through study that forced aeration of landfills and composts can impel N_2O production (Nag, Simaoka, Nakayama, Komiya & Xiaoli, 2015), which is problematic for aerated composting heaps, such as those found at the Lismore Recycling and Recovery Centre.

The paper of Nag et. al suggested that this nitrification process is dependent upon temperature of the landfill or composting heap (2015). N_2O emission was found to be at its greatest between 25-30°C, and as explained in the composting section below, the temperature maintained at the Centre in Lismore is ~ 60°C, where N_2O nitrification is minimal.

3. Methods of methane, leachate and pollution reduction - a comparison of landfill and composting approaches

While the overarching rationale for the introduction of the Food and Garden Organics Collection scheme is to reduce landfill-created methane, there are other ways to minimise its anthropogenic introduction to the atmosphere. These alternative methods of methane minimisation and their associated issues are discussed below.

3.1 Remediation

It has been suggested that landfills are problematical for society in many ways. One is that people do not ordinarily want to live near them, as they carry connotations of odours and decay. They also can occupy valuable arable land (Adhikari, Barrington, Martinez and King, 2007), and once the landfill had reached its useable end, remediation of the site can take many years. These aspects have been taken into consideration by councils and authorities worldwide, including the City of Montreal and the City of Toronto, and in 1998, the Government of Nova Scotia banned organic and food wastes from landfills (Adhikari, Barrington, Martinez and King, 2007). Thus, it could be argued that similar findings have given Richmond Valley Council impetus to implement the Food Garden and Organics Waste Collection Scheme.

Another issue facing landfills is the redirection of fauna from their traditional feeding and breeding grounds to the landfills. In the case of the Lismore Recycling and Recovery Centre, large flocks of Australian white ibises (*Threskiornis molucca)* have taken to feeding and nesting on the landfill piles, as shown in Figure. 5.

Figure 5. Feeding Australian white ibises on a landfill pile. Photograph: Peter Booth

These birds have migrated to urban centres such as landfills as their traditional wetland habitats have been subject to degradation (Martin, French, Ross & Major, 2011). The core population of the birds have shifted to urban areas where they have been viewed as a significant problem due to their odour and aggressive foraging habits (Smith & Munro, 2010). The ibis' wild populations were once considered at threat, but with increasing urbanisation, their numbers have paradoxically increased (Martin, French, Ross & Major, 2011). Transitioning green and organic matter from landfills to specialised composting systems will not abate the ibis' urban feeding habits as Figure 5 shows, they also feed off the compost heaps. (The compost heap is to the left of the landfill pile in that photograph.). Smith and Munro have suggested that landfills and other urban refuse centres are shifting the ecological requirements for these birds and that trying to remove them back to the original wetlands may be pointless, and in fact deleterious to the birds' ecology (2010).

3.2 Sewage and eutrophication

Sewage treatment is conducted by anaerobic digestion (Westlake, 1995), and it is suggested that the handling be undertaken in this manner as the method requires less energy than aerobic (p. 24). The sewage is often mechanically dried to produce a stable solid (Hester and Harrison, 1995, p. 24) which can then be used agriculturally as fertiliser, soil covering or mulch. The waste water is filtered to prevent eutrophication and pollution of waterways, and in some cases, is recycled for general household or domestic use. Several methods are employed to filter waste water, including membrane separation, reverse osmosis and membrane bioreactors (p. 37-38). The methane produced by the anaerobic methods can be siphoned or captured and several novel ways of capturing the gas have been proposed

(Martin-González, Colturato, Font & Vicent, 2010) to increase biogas yields. The upshot of these new and improved methods is to keep anthropogenic methane from entering the atmosphere.

Poisoning and eutrophication of watercourses is a concern with landfills and industrial waste in general. Per one definition, when the leachate is hazardous to the environment it is considered pollution (Westlake, 1995, p. 87). Compounds and chemicals that are leached into the water table include (but are not limited to) nitrates (NO_3^-) and fluorides, as well as toxic elements and their compounds such as mercury, lead, cadmium and arsenic (p. 88). While most of the NO_3^- entry into watercourses is from fertiliser use (Kramer, Reganold, Glover, Bohannan & Mooney, 2006), it is a key component of landfill leachates. These fertilisers comprise of urea, ammonium sulphate, ammonium nitrate and manures from various sources (Pastén-Zapata, Ledesma-Ruiz, Harter, Ramírez & Mahlknecht, 2014) and these are often bound up in agricultural and domestic green waste, where it decays releasing the nitrates into the ground and water table.

3.3 Sound landfill construction

Mitigating leachate runoff can be achieved by various methods. The foremost is grounding the landfill on an impervious and non-permeable base, usually of a phyllosilicate clay such as bentonite. The base needs to be compressible as to absorb the weight of the landfill without rupturing or breaking. A liner, usually made from polyethylene, is added on top of the base to provide further protection from leachates entering the water table. Also, the liner needs to be resistant against corrosion and reactivity from volatile wastes, and possess some protection against the tenacity of plant root systems. Despite these precautions, there have been concerns expressed that the liner and base will eventually fail (US EPA cited in Lee, 2009), though this failure can range from decades to thousands of years after the landfill's operations have ceased, troublingly though, one study suggested that the more likely figure is about twenty years (Lechner, Heiss-Ziegler & Humer, 2002).

Well-designed landfills have a system of leachate pipes to redirect leachate away from the water table. These are built using either a gravity-assisted system where the runoff goes down a slope, or by using pumps, or a combination of both. The leachate then enters the filtration system where toxic and eutrophic chemicals are removed. Eutrophic chemicals are those which cause eutrophication in water courses. The leachate pipes are subject to an array of problems including corrosion from the leachate, infestations by microorganisms, clogging from residues and precipitated solids, silt and mud in the leachate. These problems need to be factored in when the pipe system is designed and built.

The leachate is often delivered to a purpose-built pond for storage and further treatment if needed. Nammoona landfill near Casino contains a leachate pond as part of its operations. This pond, like others in New South Wales, has been constructed to meet Environmental Protection Agency rules. The pond must be robust enough to handle water from a 1 in 25 year rainfall and/or flooding event. Additionally, the pond is not constructed over a previously existing landfill. Doing so would cause residual pollutants to enter the pond, and for similar reasons, the pond needs to be constructed on ground that is geologically stable. Water from this pond is treated to remove pollutants such as heavy metals before it is released to the water table (EPA NSW, 2015).

While the introduction of the Food and Garden Organics Collection scheme will not directly address agricultural runoffs, it is expected to ameliorate entry of eutrophic compounds, such as nitrates, into the water table of the Northern Rivers area by collecting domestic and industrial green waste that would ordinarily decay in a landfill. Additionally, the BIOCycle system implemented in Lismore also includes a newer landfill. This landfill has been constructed with a bentonite base to limit leachate runoff into the water table (Lismore City Council, n.d).

4. Composting

4.1 Definition

Composting is defined under the New South Wales Protection of the Environment Operations (Waste) Regulation 2014 as a managed biological transformation, to achieve pasteurisation for a period of not less than six weeks with content at greater than 40% moisture level, and the resultant product satisfies the components of three different environmental tests as defined in the regulation (Environmental Protection Authority, 2016). Composting is performed at every level of society, from households for gardening purposes right through to industrial scales such as what is found at the Lismore Recycling and Recovery Centre. There are suggestions that composting is ideal for home use, especially where population densities are lower (Bong, et. al, 2016) such as Australia. This implies that Australians could adopt home composting to dispose of green and organic waste on a larger scale than what currently exists, due to Australia's small overall population density. Composting is a process that has existed since antiquity and has long been recognised for its potential to return value and nutrition to the soil (Bong, et. al, 2016). It has been suggested that composting not be considered a source of anthropogenic carbon dioxide as the CO^2 was previously removed from the atmosphere by the process of photosynthesis (Hellmann, Zelles, Palojärvi and Bai, 1997), and it has been praised for its ability to act as a carbon sequestration sink (Bong, et. al, 2016). Consequently, it can be considered a clean form of waste dispersal, however, as the following paragraphs demonstrate, the process is not 100% effective in all situations.

4.2 Operations, benefits and problems

It has been recognised that organic material decaying in a landfill contributes to land, water and air pollution (Lechner, Heiss-Ziegler & Humer, 2002). This paper suggests that organic and "green" wastes not be discarded in traditional landfills, and instead they be treated via composting. Some rationales prescribe this for the environmental benefits – reduced methane emissions – and others for the long-term viability of soil used in agriculture (Bong, et. al, 2016). This latter characteristic can occur, like when the composting product is offered for sale to the public, as it is at the Lismore Recycling and Recovery Centre. One study suggested that returning composted material to the soil has the effect of reducing fertiliser and pesticide requirements (Zeman & Rich, 2001) in agriculture. This would also have the run-on effect of reducing eutrophic chemical dispersal into waterways, which is a current consequence of fertiliser and pesticide use in agriculture.

Aerated composting, where the material has air introduced into it by various methods, allows for methane to be reduced to carbon dioxide, which has a far smaller GWP. However, some have suggested that not all methane production is circumvented in aerated compost piles (Jäckel, Thummes & Kämpfer, 2005) and that there exist spots within the pile that do not receive adequate aeration. Additionally, a minimum temperature is required for methane to oxidise into carbon dioxide, as Figure 6 depicts.

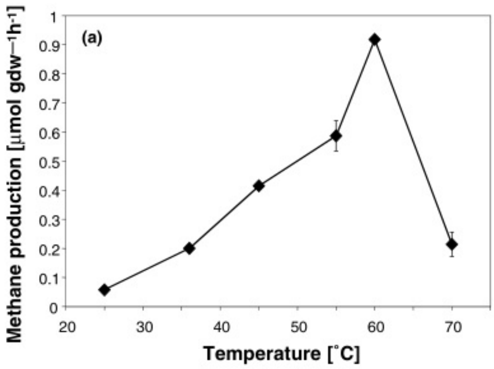

Figure 6. Required temperatures for methane oxidisation. Source U. Jäckel et. al.

This shows that a temperature of ~ 60°C is required for optimum methane oxidisation, and if temperatures in the pile vary, then overall efficiency may not be achieved. The BIOCycle program at the Lismore Recycling and Recovery Centre maintain their compost pile at 60°C and higher, though the stated purpose for this is weed seed eradication (Lismore City Council, n.d) and not for uniform methane oxidisation or limiting nitrous oxide production.

The Lismore Recycling and Recovery centre operate two kinds of aeration regimes for their composting. There is a belt-driven tumbler, and this is fed compostable material in two ways. One is via a conveyor belt and the other is by manual introduction using a bulldozer or a backhoe. Figure 7 illustrates the tumbler in operation, with one of the Centre’s bulldozers feeding it material. The tumbler then rotates it in a large drum to mix the material, aerating it and aiding it to reach a uniform size and density composition.

Figure 7. Composting tumbler in operation at Lismore. Photograph: Peter Booth

The second method is by under-bed aeration where air in injected into the composting pile through a series of jets. The method used by the Centre is piping installed under concrete, with air being pumped through holes in the pipes. Figure 8 depicts a portion of the under-bed aerator at the Centre.

Figure 8. Under-bed compost aeration system at Lismore. Photograph: Peter Booth

As can be seen, a raised concrete structure demarcates the compost pile. The piping is installed underneath the concrete with holes spaced along the pipes to evenly pump air into the composting material. The material is also manually turned in the tumbler as a back-up procedure. Sifting of the material is performed before any composting regime begins though the Centre admits there is scope for pollutants and toxic bioaerosols in the material (North East Waste, 2017) in their literature.

Infestation of the compost pile by organisms can be an issue. Green waste can be infested with organisms ranging from the Asian citrus psyllid, fungi of the *Fusarium* genus to the tobacco mosaic virus (Coker, 2016). Some of these organisms are significant dangers to food crops, particularly the tobacco mosaic virus, and *Fusarium* wilt can pose problems to lawns and other expanses of cultivated grass. There is nothing in Lismore City Council's literature that speaks of disease and pest control within their BIOCycle composting at the Lismore Recycling and Recovery Centre, however it has been mentioned that the composting process takes place at 60°C and findings in the United States suggest that is sufficient to neutralise all pathogen and unwanted seeds except for tobacco mosaic virus (Coker, 2016). Formerly, De Ceuster & Hotnick, (1999) stated that composting is ideal for suppressing pathogens since the general banning of methyl bromide as an agricultural fumigant has left primary producers with few other alternatives to process green wastes in an environmentally sound manner, although a more up to date study is required to confirm.

As well as the threat of pathogens, composting can spread weeds due to insufficient heating of the compost, and this is an issue ranging from domestic operations found in suburban backyards to large industrial processes, such as the BIOCycle program in Lismore. Literature from Lismore City Council states that although there is a 12-week pasteurisation procedure to reduce pathogen levels (Lismore City Council, n.d), some weed seeds may not be eradicated from the product during the BIOCycle process. Experiments conducted have demonstrated that seed viability for ten different and common weed species is terminated at ~ 75°C (Thompson, Jones & Blair, 1997) as Figure 9 shows.

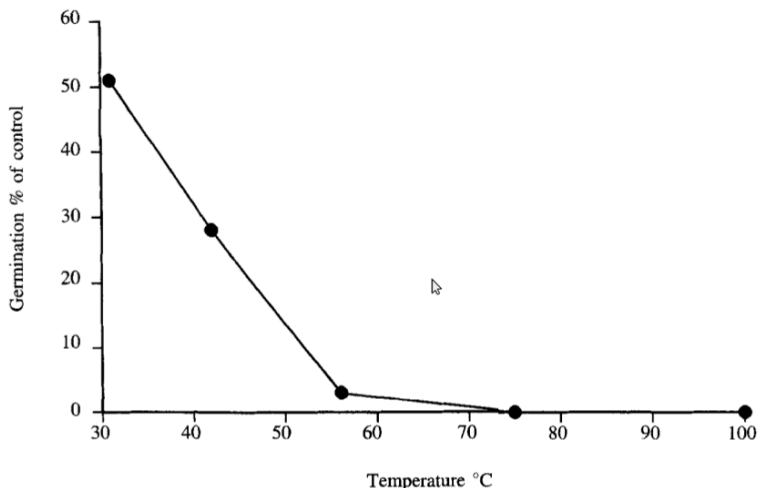

Figure 9. Viability rate of ten selected weed seed species at differing temperatures. Source: Thompson, Jones and Blair (1997).

As mentioned, the temperature of the BIOCycle composting program does not reach this figure, however the experiments conducted by Thompson, Jones and Blair (1997) demonstrate that there is a 90% non-viability rate for seeds in the temperature ranges of 56°C to 75°C. It could be argued then that the temperatures maintained by the BIOCycle process would be statistically insignificant (< 10%) as to not disperse weeds to the consumer.

Once processed, the composting is made available to the public in set amounts, which at the time of writing this paper, is \$35 per m^3 (Northern Rivers Waste, n.d). This product has been certified 100% organic. Figure 10 depicts the 10mm compost awaiting sale, where it can be collected in trailers or other suitable conveyances.

Figure 10. Processed compost pile at Lismore. Photograph: Peter Booth

The cost of establishing a large-scale composting regime, and maintaining it, is defrayed by the sale of the compost. Although Lismore City Council has not published any specific data on the balance of costs of the Lismore Recycling and Recovery Centre, estimations from the Commonwealth Government put the gross cost of composting between \$25 - \$130 per tonne (Dept. of the Environment, 2012). It is pertinent to note that Lismore City Council operated at a profit for the financial year 2015/16 (Lismore City Council, 2016) so it can be assumed that any associated costs in operating the composting piles were absorbed from general revenues. The Council also admits in their 2015/16 report that closure of the Lismore Recycling and Recovery Centre will involve “considerable costs” (2016), in land reclamation and remediation of their exhausted landfill sites.

Lismore City Council was one of the first councils in Australia to introduce kerbside collection of green and food organics (Dept. of the Environment, 2012) and its progress has been used as a case study by the Commonwealth Department of the Environment. Per the department's fact sheet, the collection has been a "cost-effective solution to resource recovery in the Lismore region" (2012) and notes that there has been a 91% compliance rating in placing the green "wheelie" bins out each week for collection. Further, it states that there is a 92% capture rate for domestic food and organics. Richmond Valley Council has not published any figures along these lines but since it contributes to the North East Waste consortium, and that the collection of green and domestic waste is ongoing, it suggests that it too has been successful.

5. Conclusion

From an environmental and ecological viewpoint, the Food and Garden Organics Collection scheme is a success. It was implemented in a straightforward and deliberate manner that households in the Council area had no difficulty in understanding and complying with. There seems to be a near-universal compliance in using the caddies and green “wheelie” bins. Richmond Valley Council has stated they are committed to the diminution of methane emissions by limiting anaerobic methanogenesis in landfills, and an emphasis on responsible waste disposal and/or recycling. The processes still require careful and constant monitoring throughout the lifetime of the scheme.

From empirical evidence and literature, the composting collection and processing scheme Richmond Valley Council has is an efficient process, particularly in conjunction with the larger North East Waste consortium. The overall cost of operations has been defrayed by the resale of the compost, and additional revenues from other council sources. Other jurisdictions throughout the world that have been covered by this paper also show similar results. Therefore, the conclusions drawn are that the Food and Garden Organics Collection service is a meritorious operation from both an environmental and an economic viewpoint, and fits well into the larger paradigms of recycling and reuse.

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