Review of Regulations and Standards for Recycled Organics in Australia

Final Report for Department of Agriculture, Water and Environment

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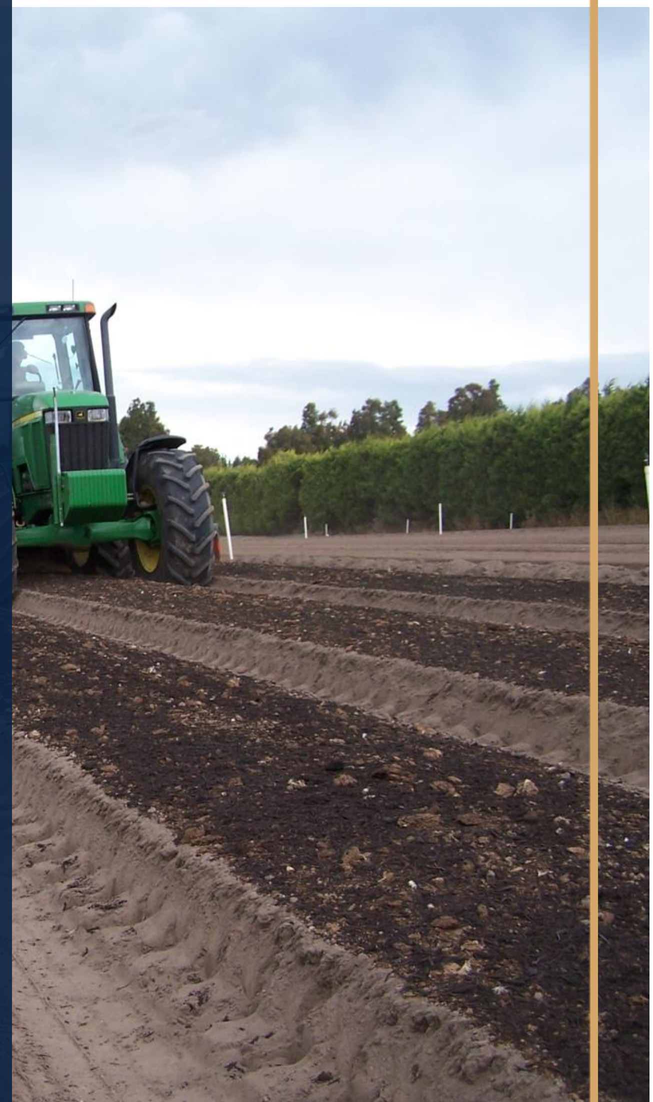

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EXECUTIVE SUMMARY

"Compost quality is of paramount importance to market development."

Background

Target 6 of the National Waste Policy Action Plan is to 'halve the amount of organic waste sent to landfill for disposal by 2030'. With increased adoption of food organics/green organics (FOGO) services across Australia, an additional 3.4 Mt of organic materials could be recycled within the decade, putting pressure on the organics recycling industry to provide additional processing capacity and find additional markets for end-products.

The Department of Agriculture, Water and Environment (DAWE) therefore appointed Frontier Ag & Environment and its partners to review the mix of policy settings in the Australian states, as well as national standards, to determine whether current arrangements for organics will meet future needs. Particular attention was given to factors affecting organics processing capacity (e.g., organics processing regulations) as well as those that could positively influence future market development and consumer confidence (e.g., end-product quality standards).

Key issues in organics recycling

The key issues identified in this project can be summarised as follows:

- Physical contamination with impurities in FOGO is a serious challenge to the sustainability of the RO industry. The success by which contamination issues have been dealt with for GO alone varies from one local government area to the next. Yet, the contamination challenge with FOGO is expected to be much greater than GO. Implementing FOGO collection and processing systems while contamination in GO continues to be a problem introduces a high level of additional risk.

- Some high-risk feedstocks are composted in the country. High-risk feedstock can be attractive to processors because they receive high gate fees for them. Furthermore, jurisdictions classify feedstock risks differently. The reasons for these differences are not clear but it raises the question as to whether the development of organics recycling guidelines has been founded on a solid evidence base.

"Contamination of feedstock is a serious challenge to the sustainability of the RO industry."

- Many local government authorities do not enforce source separation and minimisation of impurities in kerbside organics. There is often little incentive for Councils to engage in public education and to provide clean GO/FOGO to processors.

- Limits for chemical contaminants present in organics processing guidelines and the Australian compost standard (AS4454) do not reflect real-world risks. PFAS is a real concern to all stakeholders and some GO streams are at risk of herbicide contamination, but these chemicals are not tested for as part of AS4454 or as a requirement in the organics processing guidelines.

- When benchmarked against other standards worldwide, AS4454 stacks up reasonably well. However, many stakeholders believe that permissible levels of impurities are not low-enough.

- Opinions vary about whether AS4454 is essential for future market development. AS4454 is a voluntary Standard. Its effectiveness is undermined by a weak regulatory and quality assurance environment where producers at best seek compliance with pasteurisation requirements, and users do not understand the difference between pasteurised product, composted product or mature compost. It is questionable whether certification to the Standard in its current form confers a market advantage for those RO products that are supplied in bulk.

"AS4454 plays an adequate role as a baseline Standard but, for the future, the focus needs to be on development of specifications for fit-for-purpose products."

- Progress in accessing agricultural markets for RO products varies greatly between jurisdictions. Poor quality product is probably the main factor hindering market development in agriculture. States claiming good access to agricultural markets also claim that it is because their processors have a greater commitment to compost quality.

- The agricultural industries lack confidence in the benefits that can be derived from use of RO products. They are concerned about the risk of contamination and have the perception that RO products are low in value and therefore too costly. It is impossible to effectively market to the agricultural industries when compost quality is not given the highest priority.

- At the same time, end users in agriculture suffer from a massive information deficit. It is difficult to find reliable information on how to use RO products and the benefits associated with them.

- Infrastructure requirements for setting up a world class organics recycling system in Australia is complex, time consuming and expensive because of the need to obtain the buy-in from multiple stakeholders along the organics supply chain.

- Regulatory burden is seen as a major barrier to establishing organics recycling facilities**.** A solutions-oriented approach to organics regulation is sometimes lacking. Over-zealous application of organics processing guidelines by regulatory authorities can appear to put up roadblocks and risks costly delays in getting new facilities up and running.

"Regulatory burden is a major barrier to establishing organics recycling facilities."

- Due to the increased supply and risks associated with FO/FOGO, more regulatory pressure will be placed on organics processors. New composting sites will be increasingly harder to find close to the major cities and there will be a need to establish more sites around regional centres and in rural areas. Yet, organics processing guidelines were developed mainly with urban environments in mind. Blanket application of these guidelines outside urban environments could hinder establishment of lower-tech processing facilities that are appropriate in regional areas but not in urban centres.

- The key challenge for many existing and future organics recycling schemes are not of a technological nature, but to effect behavioural change so that people engage with and actively support organics recycling.

Conclusions and recommendations

Organics and the circular economy

From a circular economy perspective, RO products made from food should be returned to the land, ideally back to the soil used to grow it. Furthermore, all supply chain partners need to be able to derive tangible benefits, ensuring that the circular economy for organics is driven by economic motives. The agricultural industries already derive benefit from the return of farm-derived organic matter (e.g., manures and effluents) back to land.

Farm waste, such as manure, and urban-derived organic materials can be complementary. Yet there is little cross-over between the two systems. Previous attempts to conduct on-farm composting with kerbside collected GO have often failed due to high rates of physical contamination, reinforcing the view of farmers that they should not be a "dumping ground" for the city's waste. There are also examples of successful on-farm composting trials in Australia and on-farm composting of FOGO in regional areas is an integral part of Austria's strategy of managing organic waste.

There is also a clear need to increase future processing capacity for organics. One way to do this is to establish a distributed network of facilities across regional areas.

A distributed network of organics recycling facilities is an opportunity to:

- Reduce the regulatory pressure associated with the location of organics recycling facilities around urban areas.
- Increase processing capacity for composting. Processing capacity must keep pace with supply of feedstock.
- Process both farm-derived and urban-derived materials thereby providing an organics processing service to both agriculture and the city.
- Integrate organics processing more closely with agriculture to assist in the beneficial use of products back to farm that truly meet the needs of the market.
- Bring the supply of product closer to market thereby engaging rural communities to build trust in RO products

Policy integration

An integrated approach to policy development is also required if Australia is to remain committed to the application of circular economy principles.

"Explore ways in which an integrated and consistent approach to organics processing could be developed based on an end of waste code."

We suspect that policy development in organics recycling has not necessarily been based on a sound evidence base since individual States approach the regulation of organics recycling so differently. A case in point is the way in which different jurisdictions approach risks associated with feedstock. Yet, the quality of feedstock has a profound effect on compost quality. It follows that compost quality will have a profound effect on market development and the nation's ability to meet Target 6 of the National Waste Policy Action Plan.

A consistent approach to the evidence base on which individual regulations are based is urgently needed. The evidence base must also include risk factors associated with end-product use, not just environmental performance at the level of processing facility. A consistent approach to the evidence base would not necessarily hinder the capacity of individual jurisdictions to innovate in regulating organics processing.

There is a clear coordinating role for the federal government in setting the agenda at the national level. The role of individual jurisdictions should remain at the facility level (i.e., environmental performance of the site), whereas the federal government should lead in the development of the overarching policy framework. An ideal model for this is to follow the concept of an end of waste code for recycled organics. The end of waste concept is increasingly being recognized in many jurisdictions, but we have identified specific requirements that should apply for organics recycling.

A piecemeal approach to the roll-out of programs to promote organics recycling is inefficient. If systems are not currently working effectively to manage contaminants in GO, then there is every reason to be concerned that they will be overwhelmed as FOGO collections begin to be rolled out across the country. We see no real value in promoting the use of RO in agriculture unless the issue of contamination is dealt with. Controlling feedstock quality at source will go a long way to minimising contamination risks associated with the use of RO products.

End of Waste Code for compost

An effectively functioning organics recycling system requires federal leadership. For this reason, our first, and most important recommendation, is for the federal government to explore ways in which an integrated and consistent approach to organics processing and generating RO products with low contamination could be developed based on the model of an end of waste code (EoW) for compost as outlined in this report. This is an ambitious recommendation, but it is not completely without precedent such as in other areas of resource conservation (e.g., recycled water and biosolids).

"An effective EoW code involves the implementation of best practice across the whole organics recycling supply chain– not just end-product quality."

An EoW code for compost has the following basic elements:

- Source-separation is mandatory and maximum tolerable impurity levels are stipulated.
- Clear restrictions on what feedstocks can and cannot be composted.
- The application of an end-product standard (e.g., AS4454) with third-party accreditation.
- Products are manufactured for a designated market sector (as defined by the code).

- Products do not require further processing including maturation or re-screening for use in the designated market sector.

- Products meet any additional customer specifications, as agreed between the supplier and the customer.

An effective EoW code involves the implementation of best practice across the whole organics recycling supply chain – not just end-product quality. EoW compliant organics recyclers are therefore certified to a whole-of-business quality management system by an approved third-party auditor. Furthermore, it would place responsibility for feedstock quality on suppliers of raw materials used for composting.

"Establish a national committee to drive change and to ensure buy-in from all key stakeholders in the development and implementation of an EoW code for compost"

We recommend that the federal government establishes a national committee to drive change and to ensure buy-in from all key stakeholders in the development and implementation of an EoW code for compost.

"We need a National Anti-Contamination Campaign rather than a National Market Development Campaign." (a processor's viewpoint)

Supporting recommendations

The following recommendations are essential for the development of a sustainable organics recycling industry, whether or not an EoW code for compost is developed. They are:

- Develop a consistent approach to source separation for kerbside organics. Including standardization of what can and cannot go into FOGO bins, consistent labelling and signage and the roll out of an adequate education program (for the householder).

- Evidence-based information and guidance is urgently needed regarding the degradation of compostable caddy and bin liners and their use as a tool for increasing food waste capture rates and reducing plastic contamination in compost products.

- Initiate a federally funded research program to develop a consistent approach regarding feedstock and contaminant risk.
    - Develop a common understanding of what feedstocks can and cannot be recycled by identifying biological, chemical and physical contamination risks associated with them, and the most effective means of their control.

- To address the real or perceived risk associated with restricted animal material (RAM) in organics processing and use.
- Update contaminant limits in end-products to reflect actual risk factors in the feedstocks approved for recycling.

"Good quality compost cannot be made from poor quality feedstock ("rubbish in, rubbish out")".

- Investigate approaches to incentivize waste producers to take ownership of the contamination issue in kerbside and drop-off collected organics.
    - Funding incentives to promote RO buy-back policies by local government.
    - Develop legislative tools to give processors confidence that they will not be penalized for rejecting contaminated feedstock delivered under contract from local government.
    - Ensure council by-laws allow a flexible approach that can deliver desired outcomes.
    - Contaminant control systems combined with "carrot" and "stick" measures. For example, rebates for residents participating in kerbside source separation training programs. Stick measures could include barcode technology on bins and readers on trucks so non-compliant loads are not picked up and go to landfill at higher costs.

The following additional recommendations are contingent on improvements being made to feedstock and end-product quality. They are not necessarily less important, but their successful implementation would be undermined without having first addressed compost quality issues. They are as follows:

- Update and expand state-based organics processing guidelines.
    - To reduce barriers of entry for smaller regional organics processing facilities.
    - To develop and promote best practice guidelines for on-farm co-composting of agricultural and municipal organic residues.
    - To cover wet and dry anaerobic digestion and the beneficial use of digestate.
- Conduct a study to consider what a distributed network of organics recycling facilities might look like in each State.

- Considering combinations of municipal and agricultural organics, collection systems, processing technologies, secondary processing (i.e., value-adding) and end markets.

- Considering opportunities for integration with distributed energy systems (e.g., on-farm anaerobic digestion).

- Initiate a federally funded research and extension program on the use of recycled organics in agriculture to develop fit-for-purpose product specifications and end-product guidelines for specific applications and markets, including the use of lower grade RO products (B grade compost) for example in remediation projects.

  - Consider opportunities for delivery, e.g., through the CRC program.

  - Opportunities for integration of RO product use into the National Soil Research, Development and Extension Strategy.

- Establish a Compost Knowledge Hub that will collate, host and disseminate independent and un-biased information of a scientific and practical nature specifically for current and potential future users of RO products.

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Introduction

Background

Around 8.58 million tonnes (Mt) of organic material were recycled in Australia in 2018-19, with another 6.87 Mt landfilled (DAWE, 2020). Whilst the organics recycling industry makes a significant contribution to the Australian economy, the current recovery rate of about 60% suggests that there is still significant room for growth. Most commercially purchased compost in Australia is made from kerbside collected green organics (GO).

Target 6 of the National Waste Policy Action Plan (Action Plan) is to 'halve the amount of organic waste sent to landfill for disposal by 2030'. Currently, approx. 50% of Australian households have access to kerbside organics services, with around 28% of those being food organics/green organics (FOGO) services (DAWE, 2020). With more widespread adoption of FOGO services across Australia, an additional 3.4 Mt of organic materials could be recycled within the decade, putting pressure on the organics recycling industry to find additional markets for end-products[1].

As the majority of recycled organics (RO) products are currently supplied into the urban amenity market, which still has some capacity for expansion but is approaching market saturation with declining returns, additional RO products resulting from increased landfill diversion will have to be supplied into expanded and newly developed markets. Intensive (e.g., viticulture, vegetable production, fruit and orchards, turf production, nursery production) and extensive (broadacre cropping, pasture production and forestry) agricultural industries provide by far the largest potential markets for the beneficial use of significantly increased RO quantities in the future. However, agricultural users of RO products generally expect better quality products and have lower tolerance for chemical and physical contaminants than urban amenity markets. This is particularly the case for fruit and vegetable growers who must comply with stringent quality management regimes (e.g., Freshcare Standards).

The Department of Agriculture, Water and Environment (DAWE) therefore appointed Frontier Ag & Environment and its partners to review the mix of policy settings in each jurisdiction, as well as national standards, to determine whether current arrangements for organics will meet future needs. Particular attention was given to factors affecting organics processing capacity (e.g., organics

[1] The main end-products of organics recycling are composts, soil conditioners and mulches.

processing regulations) as well as those that could influence future market development and consumer confidence (e.g., end-product quality standards).

Scope

This report reviewed the current standards/regulations/guidelines/specifications nationally and in each Australian state and territory relevant to the recovery and reuse of organic residues. The scope of work included an investigation into:

- Regulations pertaining to the management of environmental, biosecurity and human health risks associated with organics processing and reuse.
- Maximum threshold levels of biological, physical and chemical contaminants in organic inputs (feedstock) and/or end products.
- Compostable plastics.
- The suitability of current arrangements for quality assurance of end-products (e.g., sampling, testing, reporting, certification and compliance processes).
- Organics processing standards, particularly with respect to composting, and how they affect end-product specifications and use.

Methods

Review of organics processing guidelines

To understand the current status of organic recycling from a regulatory and guidance perspective, a review of organics processing guidelines was undertaken, focusing on composting in the states that will have the potential of contributing most to achieving the nationwide goal for Target 6, *viz.* New South Wales, Victoria, South Australia, Queensland and Western Australia. Collectively, these states accounted for almost 95% of organic materials recycled in 2018-19 (Table 1). Tasmania, the Northern Territory, and the Australian Capital Territory, tend to have little or no detailed guidelines for organics recycling.

Table 1: Tonnes of organic material recycled in 2018-19 (Source: AEAS, 2020)

	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Food organics	290,885	39,361	70,975	8,223	95,633	34,220	-	158	539,455
Garden organics	1,134,617	566,846	608,092	300,428	216,161	46,075	-	252,606	3,124,825
Timber	292,954	291,152	106,262	254,308	62,061	-	-	21,547	1,028,283
Other organics	746,007	93,512	-	570,542	5,608	-	-	-	1,415,670
Biosolids	295,052	499,249	332,998	126,465	102,618	31,850	22,358	-	1,410,590
Total	**2,759,515**	**1,490,119**	**1,118,328**	**1,259,966**	**482,082**	**112,144**	**22,358**	**274,311**	**7,518,824**

Source: National Waste Report, AEAS

The main organics processing guidelines reviewed were as follows:

- Environmental Guidelines: Composting and Other Organics Recycling Facilities. 2004. Department of Environment and Conservation, New South Wales.
- Designing, Constructing and Operating Composting Facilities. Publication 1588.1. 2017. Environment Protection Authority, Victoria.
- Compost Guideline. 2019. Environment Protection Authority, South Australia.

- Guideline: Open Windrow Composting Under Environmentally Relevant Activity 53(a). Organic Material Processing by Composting. 2019. Department of Environment and Science, Queensland.

- Guideline: Better Practice Composting. 2020. Draft for External Consultation. Department of Water and Environmental Protection, Western Australia.

Rather than focusing on regulations that govern the siting, design and management of RO facilities, this review considered aspects that we believe may impact on market development for organics now and into the future. Since compost quality is largely determined by feedstock quality ("rubbish in, rubbish out") and processing controls (e.g., level of maturation), we have therefore considered critical control points in the RO supply chain that may affect feedstock and end-product quality, including:

- Requirements (if any) for source separation (i.e., prevention of physical contaminants such as plastic, glass and metals entering the feedstock at the source of waste generation).

- Allowable feedstocks (i.e., whether a guideline has a specific list of feedstocks that can be composted).

- Prohibited feedstocks (i.e., whether a guideline has a specific list of feedstocks that cannot be composted).

- How feedstocks are classified with respect to perceived risk and what controls (if any) are placed on different classes of feedstock.

- Relationship between the guideline and the Australian Standard for Composts, Soil Conditioners and Mulches (AS4454 – 2012).

- Contaminant and testing requirements.

- Any other aspect that may affect feedstock and end-product quality.

Review of contaminant and impurity limits, compostable plastics and quality assurance for RO products

Quality management and quality assurance will become an increasingly important aspect in the manufacturing of RO products destined for intensive agricultural markets, and to a lesser degree for other markets. A key consideration for this project was whether current quality standards for contaminants and impurities instill enough consumer confidence to facilitate increased demand for RO products into the future.

We therefore looked at the current status of quality management and quality assurance in the Australian organics recycling industry. In line with this, maximum allowable concentrations of chemical, physical and biological contaminants in RO products were reviewed and compared to those relevant for other organic amendments (e.g., biosolids) or used for RO products overseas. Due to recent high-profile cases of contaminated RO products (PFAS and herbicide residues), consideration was also given to new and emerging contaminants, for which no limits currently exist.

The use of certified compostable plastic products contributes to reduced production and wastage of oil-based plastic products, albeit small in scale. Yet, handling and degradation of these products in composting operations is not without its problems and critics. Since incomplete degradation of compostable plastic materials can result in visible particles in finished compost, i.e., increase physical contamination levels, we have investigated the current state of knowledge regarding the potential of residual compostable plastic having deleterious effects on compost quality through increased physical contaminant levels.

Stakeholder engagement

A stakeholder engagement plan was developed to capture different views on whether current policy settings and industry practices are strong enough to facilitate end-product confidence, market development and the nation's ability to achieve Target 6.

More than 30 interviews were conducted across a broad cross-section of stakeholders, including:

- state, territory and local government departments and agencies
- organics recycling companies

- past, present or future agricultural users of recycled organic products
- peak industry bodies representing organic waste collection and processing organisations, urban amenity groups (e.g., landscaping and garden use), and agricultural commodities (e.g., horticulture, viticulture, grains, grazing).

Stakeholder representation ensured a diversity of views from all levels and branches of the RO supply chain. The engagement framework we used was based on the ORID discussion method which sets out a structured process for interviewing stakeholders covering Objective, Reflective, Interpretive and Decisional type questions. The focus of the interviews was on the current regulatory/policy landscape and quality management and assurance through product standards as they affect market development of RO products, emerging issues, and future requirements from the stakeholder's perspective. Questions were modified to meet the specific needs of different stakeholders. A copy of the framework and questions is provided in Appendix 1.

The anonymity of stakeholders has been respected for this report. Their views are embedded throughout the report.

Organics processing guideline review

Rationale for review of processing guidelines

Processing of organic residues covers a wide range of different technologies, including:

- Composting (and derivations of it like mechanical-biological treatment, MBT)
- Anaerobic digestion
- Vermiculture
- Combustion for energy generation
- Non-biological processes such as pyrolysis, torrefaction, and gasification

Organics processing guidelines in Australia mainly focus on composting with limited coverage given to other processing technologies. Composting will continue to be the dominant technology employed across Australia for valorizing organic residues and will contribute most to the additional processing capacity required in meeting Target 6. As greater emphasis is given to food organics (FO) recovery, anaerobic digestion (AD) has the potential to play a greater role in processing such materials. Even with a growth in AD systems composting will remain the dominant technology for some time to come[2].

"Composting will continue to be the dominant technology employed across Australia for valorizing organic residues and will contribute most to the additional processing capacity required in meeting Target 6".

Mushroom composting has an established place in the economy but does not contribute significantly to diversion of organics from landfill[3]. Vermiculture occupies a small niche in the RO sector, whilst high capital and operating costs will continue to restrict the business case for technologies like

[2] AD systems can be either "wet" or "dry". Wet systems are most common, but their application is limited to liquid and high moisture feedstock (e.g., grease trap waste, whey, food processing residues, separately collected FO etc) and not suitable for FOGO. The proposed dry AD system for Byron Bay could be a good test case for the wider application of dry AD in FOGO processing.

[3] Feedstock for mushroom composting is typically wheat straw, poultry litter and gypsum.

pyrolysis and torrefaction to a significant degree. Co-combustion can also absorb significant quantities of woody materials (wood waste and the woody green waste fraction) in some cases, for example, where such facilities operate close to urban centres, such as sugar mills in QLD and Northern NSW.

Organics processing guidelines are the main tools used by the state regulatory bodies for guiding and setting licence conditions, determining environmental compliance and decision-making regarding organics recycling activities. These guidelines generally set out the design and operation of organics recycling facilities and may provide guidance or expectations on end-product requirements.

Although not a legislative compliance instrument, these guidelines and associated materials referenced in them, such as the Australian Standard for Composts, Soil Conditioners and Mulches (AS4454) as well as biosolids guidelines, are often used as a requirement in licensing conditions making them a proxy compliance requirement.

"Although not a legislative compliance instrument, organics processing guidelines are often used as a requirement in licensing conditions making them a proxy compliance requirement".

The National Waste Policy 2018 is the national framework for waste and resource recovery in Australia, covering roles and responsibilities for collective action by businesses, governments, communities and individuals. The National Waste Policy Action Plan 2019 created targets and actions to implement the National Waste Policy.

Organics processing guidelines in each state are typically developed with reference to national standards and state-based regulations. Additional guidelines, such as end-of-waste codes and resource recovery exemptions can also be found in some jurisdictions.

Examples of state level documents include:

- the Victorian Food Organics Recycling Guide,
- the Metropolitan Waste and Resource Recovery Plan for Victoria, 2016,
- the Waste Management and Resource Recovery Strategy for QLD and the forthcoming Organic Waste Action Plan,
- Transforming QLD's Recycling Industry directions paper,
- the WA Waste Avoidance and Resource Recovery Strategy 2030, and

- the NSW Waste Avoidance and Resource Recovery Strategy 2014-2021.

These documents generally set out a framework for waste management and reforms including infrastructure needs, actions for improving recycling, and supporting the development of markets for recycled materials. They outline high-level strategies and plans and are therefore not included further in this review (see Appendix 2 for further details).

Organics processing guidelines typically reference an extensive number of legislative requirements that need to be met along with other guidance documents, e.g., for odour, dust and noise (See Table in Appendix 2 for details). For example, the NSW guideline[4] references 35 different pieces of legislation, guidance documents, methodologies and standards. However, the majority of these are related to licensing, approvals and environmental impacts of processing rather than end-product requirements and specifications. Similarly, the *scheduled premises regulations* in Victoria[5] and similar instruments in Qld[6] regulate certain activities with the use of different types of approvals, i.e., licensing and works approvals. Regulations set out environmental requirements for organics processing facilities to ensure compliance with the overarching principals of their respective Acts. These types of regulatory and legislative tools have therefore not been further investigated as part of this review as they

Environmental compliance

NSW

"The focus of these guidelines is on the appropriate environmental management of organics processing facilities. The document discusses the need to minimise contamination of the organic materials themselves, but only briefly mentions the use of organics and contamination issues associated with use. These guidelines also provide information on how facilities can avoid contamination in the production of compost and related organics. They do not specify standards or other requirements relating to products from composting and related organics processing facilities."

Qld

"The department does not regulate product characteristics such as nutrient levels but general environmental duty requires that the end product does not contain pathogens or contaminant levels that when applied could cause harm to the environment and human health. Producers that sell or distribute a composting product should consider the level of product pathogen or contaminant levels that are appropriate for product end use. For example, certain products may be more appropriate for food production or residential use while other products are more suitable for development or rehabilitation of industrial sites. The sale or distribution of a product that could be found to have caused or contributed to environmental harm may result in enforcement action."

[4] Composting and Related Organics Processing Facilities, Department of Environment and Conservation NSW, July 2004
[5] Environment Protection (Scheduled Premises) Regulations 2017
[6] The 'Prescribed environmentally relevant activities' found in Schedule 2 of the Environmental Protection Regulation 2019

have limited direct impact on end-product quality and market development for organics.

Scope of guidelines

As mentioned, organics processing guidelines in Australia principally cover environmental management of processing sites. They focus heavily on the need for environmental controls across all aspects of facility operation and potential causes of environmental harm, with only minimal emphasis being given to end-product quality.

Although guidelines cover feedstock contamination, emphasis is typically given to ensuring that the facility itself has minimal environmental impact (e.g., from litter) rather than how it might affect end use. Some guidance on end-product quality is provided by reference to AS4454 requirements, but the guidelines often specify upfront that they are focused on facility operation rather than how it might affect product quality and end use (see call-out box "Environmental compliance").

This general approach to facility management rather than end-product quality is consistent across all jurisdictions. Nevertheless, South Australia explicitly incorporates tighter controls over feedstock inputs which will better influence end-product quality[7]. This is also the case for proposed new composting guidelines and model operating conditions in QLD, which will apply to new but not existing operations. New feedstock controls proposed in WA may also be implemented, but they will be applied across both new and existing sites[8].

[7] The SA guidelines are the newest published guidelines out of the suite of guidelines reviewed. Western Australian guidelines are still in draft. In Queensland, new feedstock controls are also being proposed.
[8] A transition period is proposed to allow existing sites to adjust to the new requirements.

Organics processing guidelines in Australia, as well as AS4454, are heavily influenced by the risk management approach employed in the US EPA Part 503 Rule for reduction of pathogens and contaminants in biosolids[9] and even more so by the precautionary principle European compost quality standards have employed. The Part 503 Rule was designed to protect the health and wellbeing of workers as well as the general public. The Rule was principally developed due to risks associated with biosolids but the risk management approach employed by the US EPA has since been applied more generally to thermophilic treatment of all organic wastes in Australia and elsewhere (see call-out box "Health and safety"). The precautionary principle employed in many other countries results in the monitoring of a broader suite of potential contaminants and considerably lower contaminant limits, than those imposed by US EPA Part 503 Rule (see section "Review of Contaminant and Impurity Limits").

Organics processing guidelines vary between jurisdictions with respect to what processes and processing technologies are specifically included or excluded.

For example, mushroom composting is captured in all guidelines except in QLD where it is a specific exclusion and therefore not regulated under the same strict regime as operations that process organic residues.

Anaerobic digestion (AD) is included in NSW and WA, but it is specifically excluded in Victoria. The South Australian and QLD guidelines are silent on whether AD is included or not[10].

Health and safety

WA

"Composters must demonstrate that compost products do not present an unacceptable risk to the environment and human health when used for their intended purpose. This can be achieved by Compliance with AS 4454-2012 and Biosolids Guidelines or Development and maintenance of a fit-for-purpose assessment report."

Vic

"Composts, soil conditioners and mulches produced from suitably composted materials that meet the general requirements of AS 4454: 2012 (outlined in this guideline under sections 7.2 Pasteurisation and 8.1 Product requirements) are regarded as a genuine product and not as a waste. Compost that does not meet these general requirements can sometimes be acceptable if made for a very specific use."

Vermiculture is included in SA and NSW, specifically excluded in Vic and silent in WA and QLD.

[9] See: A Plain English Guide to the EPA Part 503 Biosolids Rule.
[10] Apparently, QLD has ERA 53(b) Model operating guidelines for AD, but we have not been able to find it.

Shredding and mulching processes are included in NSW and QLD whereas in SA they are excluded.

Most jurisdictions have separate biosolids guidelines (or in the case of OLD, and end of waste code for biosolids). Composts containing biosolids must therefore also meet the contaminant and pathogen requirements of the given state's biosolids guidelines.

Treatment of Australian Standards in RO guidelines

Overview

The place of AS4454

Qld

"The Australian Standard AS4454 for composts, mulches and soil conditioners provides relevant information on requirements for pasteurization, internal composting temperatures, temperature profile monitoring and methodologies for sampling compost piles (amongst other things)."

NSW

"The processing conditions should be able to ensure a satisfactory reduction in the levels of human, animal and plant pathogens and the inactivation of noxious weeds, weed seeds and propagable shoots. The product should not contain harmful biodegradable contaminants. Products should meet the requirements of Australian Standard AS 4454–2003: Composts, Soil Conditioners and Mulches (Standards Australia 2003)."

How AS4454 deals with non-conformance

"Non-conformance with the standard does not indicate that the product may not otherwise be suitable for a range of specified applications that comply with other state or territory government regulations, guidelines, or specified end user requirements. Consequently, it is not appropriate for regulators to specify compliance with this standard as a mandatory requirement for facility operations, licensing or application of production outputs."

Organics processing guidelines in Australia have been developed considering AS4454 as a key component of the quality assurance expectations and outcomes of a facility. AS4454 is regularly referenced with respect to pasteurisation requirements and for end-product specifications.

Other Australian Standards relevant to end-product standards include:

- AS4419–2018 Soils for landscaping and garden use
- AS3743–2003 Potting mixes
- AS4736-2006 Biodegradable plastics (composting and microbial treatment)
- AS5810-2010 Biodegradable plastics (home composting)

- AS6000:2015 Organic and biodynamic products

Only the SA composting guidelines refer to a Standard other than AS4454[11].

AS4454 does not cover liquid organic wastes, liquid seaweed products, non-organic mulches, non-organic soils and non-organic soil conditioners (e.g., gypsum and sand), non-compostable organic materials (e.g., plastics) and materials variously described as compost starters and activators.

Product, not a waste

Vic

"Composts, soil conditioners and mulches produced from suitably composted materials that meet the general requirements of AS 4454: 2012… are regarded as a genuine product and not as a waste."

Shredded GO that are not pasteurised or composted are specifically excluded from AS4454 as they have a high probability of containing plant propagules or pathogens. The NSW guidelines cover shredding and/or mulching processes and state that products *"should meet the requirements"* of AS4454 for *"harmful biodegradable contaminants"*. Yet, such processes are excluded in AS4454 because *"they have a high probability of containing plant propagules and pathogens".*

Vermicast that has not been subject to pasteurisation or composting before or after being worked by worms may be covered by the standard if they pass specified provisions.

The objective of AS4454 is to provide the RO supply chain and government bodies with analytical and reporting requirements for physical, chemical and biological properties of RO products '*in order to facilitate the beneficial recycling and use of compostable organic materials with minimal adverse impact on environmental and public health*'. According to AS4454, it does this by '*requiring pasteurisation and compliance with associated regulations and guidelines for health and safety and by the correct characterisation of compost products to enable informed purchasing decisions and give users such as growers and consumers assurance of compliance with minimum requirements*'.

Legal status

As previously mentioned, organics processing guidelines are guidelines only; they do not describe mandatory legal requirements. However, they are used to provide advice, inform decision making

[11] SA composting guidelines also refer to AS4419, AS3743 as well as AS/NZS5024 2005 Potting mixes, composts and other matrices: examination for legionellae.

regarding licences, works/development approvals and are also used as a guide to resolve non-compliance.

Organics processing guidelines consider AS4454 as a key component of the quality assurance expectations of a facility with respect to chemical and physical contaminants. The guidelines also reference the pasteurisation requirements of AS4454 as if they represent industry "best practice". Whilst pasteurisation requirements for most organics processing technologies are based on thermal treatment, AS4454 does have provision for alternative processes that demonstrate the same level of pathogen reduction.

"The effectiveness of AS4454 as a standard is not helped by a weak regulatory and quality assurance environment where producers at best seek compliance with pasteurisation requirements, and users do not understand the difference between pasteurised product, composted product or mature compost."

AS4454 states that '*it is not appropriate for regulators to specify compliance with this standard as a mandatory requirement for facility operations, licensing or application of production outputs*' (see call-out box "Dealing with non-conformance").

The voluntary status of AS4454 should not limit its potential use in any compost quality assurance scheme. However, its effectiveness as a standard is not helped by a weak regulatory and quality assurance environment where producers at best seek compliance with pasteurisation requirements, and users do not understand the difference between pasteurised product, composted product or mature compost.

How each state references AS4454

South Australia

- For quality assurance the SA guidelines recommend that a number of standards including AS4454 be adopted when setting environmental goals and quality parameters.
- AS4454 is referred to for contaminant testing and product labelling requirements.
- Although not specifically referenced, pasteurisation requirements are consistent with AS4454 requirements.

New South Wales

- NSW organics processing guidelines specify that products should meet the requirements of AS4454.
- It references appendices N and O of AS4454-2003 as the recommended pasteurisation regimes for the various types of processes, but these appendices have since been removed from the updated Standard (AS4454-2012).
- Contaminant and testing parameters are not specified in the guideline rather it refers to the requirements of AS4454.

Victoria

- Victoria acknowledges that AS4454 is a voluntary standard and that their organics processing guidelines have been informed by elements of the 2012 edition of AS4454 that relate to environment protection.
- The guideline has adopted the pasteurisation and maturation processes and parameters verified (and published) by the United States Environmental Protection Agency (USEPA Part 503 Rule) and those required as process criteria in AS4454.
- The limits for chemical and physical contamination in the guideline are consistent with AS 4454.
- Composts, soil conditioners and mulches produced from suitably composted materials that meet the general requirements of AS4454 are regarded as a genuine product and not as a waste.
- Product classification is based on definitions as outlined in AS4454 for "pasteurised product", "composted product" and "mature compost".
- The guideline states that products should be tested in accordance with the guideline or AS4454 to demonstrate that the feedstocks and processes being employed are able to meet the "*required standard*".
- The guideline acknowledges alternative processes for pasteurisation, consistent with AS4454 and those outlined in the EPA Vic Guidelines for Biosolids Land Application (EPA Publication 943)

- The guideline maturation section refers to AS 4454 which outlines a variety of methods to demonstrate the level of maturity of the product, including reporting the details of the processing conditions and a variety of laboratory tests.

Western Australia

The guidelines acknowledge that compost products may be fit-for-purpose for a specific end use without meeting the specifications in AS4454.

The guidelines state that processors must demonstrate that RO products do not present an unacceptable risk to the environment and human health when used for their intended purpose. This can be achieved by:

1. Compliance with AS 4454 and Biosolids Guidelines. Licence holders producing products which comply with AS 4454 are required to classify their products according to the physical and chemical requirements set out in the standard. Most RO products produced from low- to moderate-risk feedstocks are expected to meet the physical, chemical and biological contaminant requirements set out in AS 4454, or

2. Development and maintenance of a fit-for-purpose assessment report is required where compost products do not comply with the physical, chemical and/or biological contaminant requirements in AS 4454.

3. The guideline refers to AS4454 for sampling and testing requirements.

Queensland

- Queensland guidelines only refers to AS4454 once and this is in relation to the composting process. There are no specifications listed in the guideline for the process rather it states that AS4454 provides relevant information on requirements for pasteurization, internal composting temperatures, temperature profile monitoring and methodologies for sampling compost piles (amongst other things).

- The document, "Model operating conditions ERA 53(a)—Organic material processing by composting" does not refer to AS4454.

Status of source separation

Source separation is defined as the physical sorting of waste at the point of generation into specific components suitable for resource recovery. South Australia is the only state that explicitly states in their guidelines that all feedstocks must be source separated. The NSW guidelines imply that source separation is an alternative technology rather than an essential requirement for organics recovery. It states, however, that source separation '*must be considered as part of any system to produce quality processed organics'.* There appears to be no specific requirement for source separation in Queensland. In Victoria, municipal waste needs to be source separated to be classified as a category 2 ("medium risk") waste type, whereas in WA, source separated municipal kerbside waste is classed as "moderate risk".

Feedstock controls

Overview

Classification of feedstock in organics processing guidelines is mainly based on their potential for negative environmental impacts at and around the processing facility.

Acknowledgement of potential impacts on the quality and use of end-products is sometimes given but interpretation is needed. For example, South Australia classifies feedstocks based on potential risk posed to the environment and/or human health which could be interpreted to be associated with the facility, end use or both. As the SA guideline has a strong focus on end-products it is assumed that this is based on both on-site and off-site use.

NSW based its feedstock categories on the potential to generate odour, attract vermin and vectors and to generate leachate which could contaminate surface water, groundwater and soil. It relates to selecting and using equipment and management techniques suitable for the particular incoming organics, in order to avoid the abovementioned negative impacts during handling and processing at the facility.

"Classification of feedstock in organics processing guidelines is mainly based on their potential for negative environmental impacts at and around the processing facility".

In its guideline, EPA Victoria states that appropriate management of feedstock is an important part of protecting the environment, human health and amenity. The categorisation approach adopted by EPA Victoria ranks feedstock into four categories from lowest to highest potential risk of harm to human health and the environment. It then specifies recommended technology types to manage feedstock such as open, enclosed/covered or enclosed with secondary odour control which is focused on reducing environmental and health risks on site.

The WA guidelines appear to have end use as a consideration for classifying feedstock as the stated objective of composting is to produce a fit-for-purpose product that can be used without presenting an unacceptable risk to environmental values, water resources and human health. However, risk categories are determined by the expected consequence and likelihood of emissions arising from each feedstock, with particular focus on odour and leachate. The potential for feedstocks to contaminate compost products with physical, chemical or biological contaminants is also considered. It acknowledges that different feedstocks pose different risks in terms of emissions (leachate and odour), environmental harm (disease and vectors) and compost product contamination.

> What's in compost?
> Tasmania
>
> "We need to know what is in compost by way of nutrients and contribution to biological activity. We need to manage biosecurity and we don't have enough confidence in what we are getting."

In QLD, greater autonomy is given to operators to select feedstocks that are beneficial to their specific operation without harming the environment or end use of the product. The guidelines state that, where the potential of environmental risk is greater than "low" for a given feedstock, it is the responsibility of the operator to assess the risk before it is accepted. This assessment should include the relevant material characteristics, contaminant levels and the potential for human or ecological toxicity. The guidelines note that inappropriate processing procedures and/or technologies for higher risk materials in open windrow composting have the potential to generate significant odour impacts, to attract vermin and other vectors (birds and insects), and to generate harmful leachate that could, unless contained, be released to contaminate surface water, groundwater and soil.

Categories of risk

Feedstock classification in each guideline is based on broad categories of risk, *viz*. "low", "medium" and "high" risk. The low-risk classification can also be called Category A or Category 1. There are inconsistencies across most of the states particularly in the medium to high-risk categories. What is deemed a high risk is a medium or even low risk for the same feedstock across different jurisdictions.

Category 1 and 2 feedstocks in NSW, Vic, WA and QLD are very similar in most cases. However, in WA, biosolids and fresh animal manures (including manure and animal bedding) is classified as high risk (Category 3), whereas they are Category 2 feedstocks in the other states.

Victoria's highest risk Category 4 includes liquid food waste and animal wastes which are Category 2 or 3 in the other states. Liquid food appears to be generally captured in Category 2 in the other states and liquid animal wastes in Category 3 in the other states. Victoria also captures meat, fish and fatty foods in Category 4 whereas in other states, these are generally captured in Category 3.

Western Australia has an "uncategorized" category which requires tighter controls and includes such feedstocks as crushed concrete, excavated natural materials such as sand, clay and calcium bentonite, some industrial by-products, some coal combustion products, biodegradable plastics and some drill wastes.

South Australia is the exception to the norm. SA has only two categories – Category A which is extremely broad and includes feedstocks classified as higher risk in other jurisdictions, and Category B (mineral-based industrial waste and grease trap waste) for which another guideline applies[12]. For example, Category A in SA includes biosolids and animal manures including liquid animal effluent and processing wastewater. These types of wastes are captured in the higher risk Category 2 in NSW or in the case of Victoria, Category 2 (medium risk) for biosolids and aged manures and Category 3 for animal manures and bedding (medium-high risk). Biosolids and animal manures are also classified in WA as Category 3 – high risk.

Waste acceptable as feedstock
Qld

"It is the responsibility of the operator to ensure that waste materials received onsite for feedstock are suitable for use in composting. It is not suitable to impose conditions on an environmental authority for an open windrow compost operation to indicate acceptable waste inputs."

Grease trap waste is another feedstock that varies in risk rating between jurisdictions. For South Australia, grease trap waste is a Category B feedstock; its risk rating in other states ranges from high to very-high depending on solids content.

Prohibited wastes as feedstocks for RO processing

Some types of waste streams are prohibited for use as feedstock for organics recycling. Prohibited wastes are classified by different jurisdictions with terminology such as: listed wastes, hazardous wastes, contaminated soils, prescribed industrial wastes, special type wastes. Identifying the specific waste streams that are prohibited is complicated and beyond the scope of this review.

[12] Standard for the production and use of waste derived soil enhancer (EPA 2010).

The common types of prohibited wastes across some of the jurisdictions are quarantine wastes, organics contaminated by pathogens that will not be rendered harmless by the process, hazardous wastes (defined differently in each state), PFAS contaminated wastes, and medical wastes.

Queensland is the only state that does not identify specific prohibited wastes since the onus is placed squarely on the operator to ensure that they select appropriate feedstock for composting. Furthermore, processing facilities in QLD can hold a "standard" ERA 53a license for composting (Environmental Relevant Activity, 53a) as well as ERA 58, which regulates treatment and de-contamination of hazardous materials. Though some such materials (e.g., contaminated soil, hydrocarbons etc) can be processed by means of composting, it is concerning when composting sites hold both kind of licenses (53a and 58) as hazardous materials and compost made from them, can easily 'disappear' by shandying ERA53a and ERA58 compost (Wilkinson et al., 2019).

Low risk feedstock

Vic

"Open environment – Low risk wastes can be processed in open air composting methods where the process can be kept aerated. This may not be appropriate in locations where there are insufficient separation distances for upset conditions."

NSW

"For processing Category 1 organics... the simpler open-air methods for composting have generally been found to be satisfactory, provided that the materials being processed (especially grass clippings, weeds and leaves) are not allowed to become anaerobic."

Specific requirements for different feedstock categories

As discussed, feedstock classification is mainly used to control risks associated with processing. For this reason, they are often used to determine specific processing requirements. However, none of the guidelines have a requirement to test incoming feedstock. Usually, suppliers of commercial / industrial residues are required to provide a contaminant analysis / declaration, but this is sometimes ignored, leaving the risk with the composting facility[13].

[13] If a composter asks for analytical test results, the supplier might take it to a competitor. This is a major problem with liquid waste where tankers deliver waste from various sources, and the composters do not have a relationship with waste generators, but only the waste transporters. The waste tracking system in parts of the country is not working as it should.

Some guidelines are "technology agnostic" since they require operators to demonstrate environmental compliance no matter what processing technology is used[14]. Victoria and NSW are exception to this since they recommend different technology types based on feedstock risk.

Category A, Category 1: Low risk feedstock

Open-air windrow composting is typically thought to be sufficient for low-risk feedstock, provided that the risk of odour is minimised (see call-out box "Low risk feedstock").

In South Australia, feedstock containing biosolids is also considered low-risk but a stabilisation and contamination grade is assigned in accordance with the draft guideline for the safe handling and reuse of biosolids (EPA 2017). Liquid wastes can fall into either Category A or B and must be blended with suitable binding agents and incorporated into the compost window within 24 hours of receipt.

Western Australia does not specify any particular requirement for low-risk feedstock.

Category B, Category 2: Medium risk feedstock

South Australia has only two categories of feedstock: Category A for lower risk materials, and Category B for mineral-based industrial residues including grease trap waste. Category B feedstock must be assessed in accordance with the "Standard for the Production and Use of Waste Derived Soil Enhancer" (EPA 2010) rather than the compost guideline. Category B feedstock must be '*beneficial to the compost product*' and they should be '*actively managed upon receipt at the site so as to prevent the generation of odour and other nuisances*'.

> **Category 3 Feedstock**
>
> **NSW**
>
> "It is most unlikely that the EPA would grant an environment protection licence for the open-air composting of Category 3 organics."
>
> **WA**
>
> "Premises which accept more than one type of liquid waste feedstock are required to implement appropriate procedures to segregate non-compatible wastes and avoid adverse chemical reactions. This will require technical oversight from a suitably qualified person."

In NSW, medium risk feedstock can be suitable for open air composting provided that strict feedstock preparation and operating controls are employed but enclosed facilities are preferred. If an open-air facility is proposed, the proponents would '*need to demonstrate that the location, design, operating methodology and resources of the facility will prevent odorous emissions and degradation of the local*

[14] Nevertheless, there is recognition that some types of systems are superior to others in certain circumstances. E.g., in-vessel reactors have improved capacity to control odour compared to open window systems.

amenity'. If the compost contains biosolids then conditions applying to processing and use are to be found in "Environmental Guidelines: Use and Disposal of Biosolids Products" (EPA 1997[15]).

In Victoria, the size of the facility and its location in relation to sensitive receptors are also considered in determining the recommended processing technology for a given feedstock category. For example, source separated kerbside GO is classified as Category 2 and can be processed by open turned-windrow technology but separation distances would have to be greater compared to Category 1 feedstock.

Category 3: High risk feedstock (med-high in Vic)

In NSW, open air composting of Category 3 feedstock has generally been found to be unsatisfactory due to the likelihood of odorous emissions being much greater than for Category 2 materials. The processing of Category 3 organics by vermiculture is an exception to the above, because there is no need to turn the biomass and, therefore, the degradation of organics can take place in containers covered with layers of material such as curing compost, generally without significant odour-emission problems.

Victoria also recommends enclosed or covered environments for composting medium-high risk materials, possibly even with secondary odour control. Categories 2, 3 and 4 feedstocks should be processed as soon as practicable and the most odorous wastes should not be stored for more than 48 hours.

Queensland and WA do not specify any particular requirement for these types of feedstock.

Category 4: Highest risk feedstock (Vic only)

This category is only relevant for Victoria and facilities with these feedstocks are recommended to use an enclosed system with secondary odour control. Liquid organic wastes are prescribed industrial wastes (PIW) and are required to be transported in line with the EP Act and IWR Regulations. PIW can only be processed at a facility authorised by EPA to accept the wastes. The categories 2, 3 and 4 feedstocks should be processed as soon as possible, and the most odorous wastes should not be stored for more than 48 hours.

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[15] Latest version is EPA (2000).

Other processing requirements for different feedstock categories

Pasteurisation requirements in all guidelines are generally consistent with the requirements of AS4454. That is:

- Open windrow composting of low-risk feedstock: the whole mass of compost is subjected to a minimum of three turns with the internal temperature reaching a minimum of 55°C for three consecutive days before each turn.
- Open windrow composting of higher risk feedstock: The core of the compost mass must be maintained at 55°C or higher for 15 days or longer, during which the windrow shall be turned a minimum of five times.
- Enclosed or in-vessel composting: The whole mass should be maintained at 55°C or higher for a minimum of three consecutive days, noting that the compost material will need to be in the enclosed vessel for longer to ensure it gets to and maintains temperature.

However, the application of these requirements may differ between jurisdictions depending on how feedstock risks are classified.

South Australia also has an expectation that manual and/or mechanical sorting will be necessary for the removal of physical contaminants/inclusions such as litter, plastic, glass and stones. The guideline recommends that feedstock, oversized materials, screened contaminants and finished compost products are stored in separate designated areas of the facility to avoid cross-contamination.

A pertinent comment on the role of the regulator

"EPAs are not responsible for determining or monitoring end-product quality. We regulate the facility and get involved if the application of products causes harm. We are not product specialists. The industry is continually wanting us or someone to tell them if their products are Ok or fit for purpose but we don't have the remit or resources to do that."

Contaminant and impurity limits and quality assurance for RO products

Background

The formulation of the first compost quality standard for kerbside collected food and garden organics in Germany in 1989 (Fricke and Vogtmann 1990) was informed by considerable research and development work over a five-year period and provided the blue-print for many successive compost quality standards, anecdotally including Australia's first version of the Australian Standard for Composts, Soil Conditioners and Mulches, AS 4454 - 1997.

While the the German standard contained maximum allowable contaminant levels to differentiate FOGO compost from municipal solid waste compost, the early versions of the Australian standard did not contain specific contaminant limits, but instead required that all materials comply with chemical and organic contaminant provisions of State or Federal guidelines for use of biosolids products that are for unrestricted use (Standards Australia 1999).

> The dumping ground – a regulator's view
>
> "Applying contaminated organics to land just transfers the problem from landfill to another land use; We don't want that."

AS4454-2012

Today, the Australian Standard AS4454 - 2012 is the benchmark standard for compost quality in Australia, and, apart from specifying minimum processing standards for the elimination of pathogens and weeds, also stipulates limits for chemical and physical contaminants. Contaminant levels in combination with a range of other analytical tests for both pasteurised and composted products in AS4454-2012 provide the key reference for industry when assessing and classifying compost quality.

> "Local government tenders and contracts often require contractors to make AS4454 compliant products, or at least provide a facility capable of manufacturing AS4454 conforming products".

AS4454 – 2012 is a voluntary quality standard, as are the associated standards, *Soils for Landscaping and Garden Use* (AS4419 – 2018) and *Potting Mixes* (AS3743 – 2003). The testing of compost products against some or all quality requirements stipulated in AS4454 - 2012 is entirely at the discretion of individual composting companies, as there is no legal requirement to do so. However, government agencies responsible for regulating composting operations may require compliance with the standard, although the legal status of doing so is not clear. Section 2 General Requirements – Containment of Disease, of the AS4454 – 2012 document states that *it is not appropriate for regulators to specify compliance with this Standard as a mandatory requirement for facility operations, licensing or application to land of production outputs*. Regardless of this statement regulatory authorities do reference the standard in license conditions for composting facilities. Local government tenders and contracts often require contractors to make AS4454 compliant products, or at least provide a facility capable of manufacturing AS4454 conforming products.

Do suppliers of product understand user needs?
Victoria
"They understand the problem with contamination, but their main interest is getting rid of the product."

AS4454 – 2012 presents minimum requirements for physical, chemical and biological product properties, which provide assurance for users that certified products are free of viable plant propagules and will not cause adverse effects if used appropriately. In addition, products certified to AS4454 – 2012 quality requirements must also comply with State or Federal chemical and organic contaminant guidelines for products suitable for unrestricted use in land application of products derived from organic wastes, compostable organic materials or biosolids, whichever is the more stringent.

"Unlike biosolids quality and end-use guidelines and codes, the AS4454 – 2012 compost standard does not differentiate between various contaminant classes and allowable uses, but stipulate only one class of allowed chemical, physical and biological contaminants for composted products and places no restriction on use."

AS4454 - 2012 contaminant limits and pathogen reduction requirements are shown in **Error! Reference source not found.**. They are aligned with the NSW Biosolids Guidelines for unrestricted use of Grade A biosolids products (NSW EPA 2000) but allow higher copper and zinc concentrations where this can be justified by agronomic considerations and where none of the other metal limits are exceeded. The new Queensland End of Waste Code Biosolids (QLD Department of Environment and Science, 2020) followed this lead and established also maximum copper and zinc concentrations of 150 mg/kg and 300 mg/kg for Grade A biosolids products that can be used without restrictions.

EPA is not interested in compost quality
Organics processor - SA
"Our license requires us to produce compost compliant with AS4454 requirements, but when we have site inspections, the EPA never asks to see test results."

AS4454 – 2012 differentiates products and minimum quality requirements according to product maturity (pasteurised product – composted product – mature compost) and particle size distribution (soil conditioner – fine mulch – coarse mulch), and in that way defines nine broad product types.

Unlike biosolids quality and end-use guidelines and codes, the AS4454 – 2012 compost standard does not differentiate between various contaminant classes and allowable uses, but stipulate only one class of allowed chemical, physical and biological contaminants for composted products (Table 2) and places no restriction on use. It could be argued that if the allowable land use criteria for biosolids are valid, then they should also be valid for other types of organic amendments.

Table 2: Impurity, pathogen, heavy metal and organic contaminant limits for compost products for unrestricted use according to AS 4454 – 2012

Product Characteristic	Unit	Compost Quality Criteria AS 4454
Impurities		
Glass, metal and rigid plastic	% dm	≤ 0.5
Plastic – light, flexible or film	% dm	≤ 0.05
Stones and lumps of clay	% dm	≤ 5
Pathogens#		
Faecal coliforms	MPN/g	< 1000
Salmonella spp		absent in 50 g dry weight equivalent
Heavy Metals#		
Arsenic	mg / kg dm	20
Boron*	mg / kg dm	100
Cadmium	mg / kg dm	3
Chromium (Total)	mg / kg dm	100
Copper	mg / kg dm	100 (150)**
Lead	mg / kg dm	150
Mercury	mg / kg dm	1
Nickel	mg / kg dm	60
Selenium	mg / kg dm	5
Zinc	mg / kg dm	200 (300)**
Organic Contaminants#		
DDT/DDE/DDD	mg / kg dm	0.5
Aldrin	mg / kg dm	0.02
Dieldrin	mg / kg dm	0.02
Chlordane	mg / kg dm	0.02
Heptachlor	mg / kg dm	0.02
HCB	mg / kg dm	0.02
Lindane	mg / kg dm	0.02
BHC	mg / kg dm	0.02
PCBs^	mg / kg dm	Not detected (=<0.2)

Pathogen, heavy metal and organic contaminant limits are largely aligned with NSW Biosolids Guideline values for Grade A product
* Testing for boron is generally only necessary for products that are based on seaweed, seagrass or unseparated solid waste that have a component of cardboard packaging.
** A product that contains levels of copper between 100 mg/kg and 150 mg/kg and/or zinc between 200 mg/kg and 300 mg/kg whilst not exceeding the limit values for all other contaminants, shall provide a warning label in accordance with labelling requirements.
^ The detection limit for PCBs shall be 0.2 mg/kg dm

This implies that, if compost regulations do not stipulate end-product contaminant criteria, then compost exceeding AS4454 – 2012 contaminant requirements, could be utilised in line with biosolids restricted use specifications, i.e., everywhere except for home lawns and gardens (depending on contaminant concentrations). Based on this reasoning, there is no need for many compost products to comply with AS4454 – 2012 contaminant requirements for unrestricted use.

As noted above, AS4454 is a voluntary standard and there are four methods which compost manufacturers can use to demonstrate compliance to the Australian Standard (Wilkinson *et al*. 2002), namely:

- *Product Certification (Third Party Assessment)*
  The manufacturer's capability to produce a product consistently to the Standard is assessed on an ongoing basis by an independent third-party certification body.

- *Quality System Certification (Third Party Assessment)*
  The manufacturer's quality management system is assessed against one of the international standards that describe models for quality assurance (AS/NZS ISO 9001 to 9003).

- *Customer - Supplier Assessment (Second Party Assessment)*
  A purchaser of a product may wish to assess a supplier to ensure that the product they buy meets their particular requirements. This would be a commercial arrangement between purchaser and supplier.

- *Self-Declaration (First Party Assessment)*
  The manufacturer declares that the products and/or production methods meet recognised standards. The manufacturer can state on labels and brochures that a product complies with the relevant standard, but since it is not a 'third party assessment', no recognisable symbol such as the Standards logo can be applied.

A regulator's view

"The lack of product testing and third-party accreditation is a major concern."

It is generally recognised that quality assurance schemes incorporating regular independent third-party assessment and product- or system certification provide the highest level of credibility. At present, most bulk compost producers in Australia only offer the weakest form of guarantee, 'Self

Declaration', or none at all, and certainly not third-party auditing and certification (Hazeldine 2019) although this might be changing slowly (Hazeldine 2021). Most manufacturers of bulk composts and soils will follow selected elements of AS4454 or AS4419 for all or some of their product range and claim compliance with the standards based on end-product analysis. However, achieving third party certification goes well beyond end-product compliance with AS4454 specifications, requiring implementation and maintenance of a quality management system, which is often seen as imposing additional costs and burden and not returning adequate benefits.

"It is generally recognised that quality assurance schemes incorporating regular independent third-party assessment and product- or system certification provide the highest level of credibility".

Let's learn to walk first - Organics processor SA

"Before we are in a position to think about a better compost standard, we first of all need to make sure that the majority of composters generate products that comply with the current standard. This has to be our first priority – and we still have a long way to go."

Most composters base their decision whether to certify or not certify their products against Australian Standard requirements on commercial considerations (i.e., whether the Standards Mark is recognised and valued in the marketplace), and whether or not a price premium can be achieved for certified products. In most cases, certification is not seen as providing a commercial return unless bagged products are supplied for retail or bulk products go into niche markets. There are not many third-party certified bulk compost, mulch and soil products in the market, and the supply (number of manufacturers / volume of product) of third-party certified bulk products that contain urban derived organics cannot be identified (Hazeldine 2021).

The acceptability to customers of compliance via product self-declaration depends on the reputation and past performance of the manufacturer, as well as the organics recycling industry as a whole.

As compost suppliers increasingly target commercial agricultural and horticultural markets where food safety and biosecurity requirements become ever tighter, it is expected that the pressure will grow for compost production systems and compost products to be independently audited and certified by a third party.

Recently published Freshcare guidelines for the use of recycled organics in horticulture (Freshcare undated) ranks third party certification highest when it comes to compliance, but self-declaration concerning pathogen elimination (evidence of treatment process [time-temperature curve]) and analysis for E. coli and Salmonella for supplied batch of product) is equally acceptable in avoiding withholding periods after product application (

Table 3).

AS4454 – 2012 is often criticised by a range of stakeholders, including composting businesses themselves. However, it must not be forgotten that it provides only minimum requirements for properties of composts, soil conditioners and mulches in order to facilitate the beneficial recycling and use of compostable materials with minimal adverse impact on environment and public health. Amid this criticism that AS4454 is inadequate, it is important to recognise that the Australian Standard AS4454 - 2012 does in no way prevent individual composters or the composting industry as a whole from producing superior products that far exceed AS4454 quality requirements, i.e., have low contaminant and impurity levels, are fit for purpose and deliver all the outcomes promised to users.

Several end-use specific product specifications for the use of recycled organics have been developed. These specifications exceed the generic minimum quality requirements stipulated in AS4454, and are relevant for the following end use areas:

- Sporting fields (NSW)
- Roadside rehabilitation (NSW and QLD)
- Storm water filtration (NSW)
- African lovegrass suppression (NSW)
- Freshcare code of practice for vegetable production (National)

Table 3: Evidence of compliance and requirements for use of RO products in horticulture under Freshcare program

Evidence of Compliance	Requirements
The supplier has an approved, certified treatment process	• Evidence of certification to AS4454 is kept
The supplier has a documented, verified treatment process	• Evidence of treatment process provided. • Certificate of analysis supplied for each batch of product, verifying the treatment achieves E.coli <100cfu/g and Salmonella not detected in 25g.
The supplier does not have a documented, verified treatment process	• Product is considered untreated for the purposes of Freshcare.
The materials have been treated on farm to a documented, verified process.	• Records kept detailing composition, treatment method, start and end dates, temperature readings, batch quantity and identification code and name of supervisor.

	• Certificate of analysis supplied for each batch of product, verifying the treatment achieves E. coli <100cfu/g and Salmonella not detected in 25g.

"It is important to recognise that the Australian Standard AS4454 - 2012 does in no way prevent individual composters or the composting industry as a whole from producing superior products that far exceed AS4454 quality requirements."

The main barrier to the wider adoption of third-party quality assessment and assurance, and potentially improved compost product quality in Australia is the high cost of producing certified compost relative to the low sale price achieved, or more accurately, the low margin between cost of production and achievable sales revenue. This, in turn, is due to four main factors:

- The wide availability and market acceptance of low cost, low quality products that claim to be composted, meeting AS4454 requirements and delivering all benefits generically attributed to all organic soil amendments.
- The cost associated with third-party product certification compared to self-declaration (which is free).
- The high cost (relative to product value) and complexity of evaluating and communicating compost attributes, particularly aspects such as stability and maturity, nutrient supply and fertiliser replacement, soil carbon dynamics and soil health specifics.
- Low levels of consumer/customer knowledge regarding how to judge compost quality and the additional value/lower risk it delivers for specific farming enterprises.

To date, many Australian composters operating under these constraints have chosen either to sell low quality, low-cost products, or invest in building their own trusted brand and customer base for higher value and higher quality products (or occasionally both). At the time of the last National survey of the organics recycling industry in 2012 indicated that only around 21% of generated recycled organic products were supplied into agricultural and horticultural markets, while the majority was supplied into the urban amenity sector (Recycled Organics Unit 2013). Since then, the supply of RO products has presumably moved somewhat towards agricultural and horticultural markets.

Contaminant limits

Biala and Wilkinson (2020) have compared AS4454 – 2012 contaminant limits with corresponding requirements in European and North American countries. Excerpts of their findings are presented below.

While AS4454 – 2012 has only one contaminant class for unrestricted use, compost quality standards in several overseas countries either differentiate product classes (e.g., A+, A, B) according to contaminant levels, or there are a range of different standards with sub-categories that are differentiated depending on feedstock processed, product type and end-uses.

The Compost Quality Assurance Association in Germany for example has established six different quality standards for RO products and administers associated quality assurance programs, as follows:

1. compost (product categories: pasteurised, mature, component in growing media),
2. digestate resulting from processing of organic residues (product categories: liquid, solid),
3. digestate resulting from processing of energy crops (product categories: liquid, solid),
4. products containing biosolids (product categories: fully composted, partially composted, blend containing raw biosolids),
5. biosolids for direct land application, and
6. ash from wood and plant fired boilers.

Physical, biological and chemical (heavy metals) contaminants

Table 4 provides a comparison of physical (impurities), biological (pathogens) and chemical (heavy metals) contaminant limits according to compost quality standards or regulatory requirements in Australia and selected overseas countries where organics recycling activities are widespread[16].

The comparison shows that maximum contaminant limits in AS 4454 are similar to overseas requirements, except for the very stringent requirements the Austrian regulation demands for grade A+ compost, which is for certified organic farms. However, it can be also seen that AS4454 heavy

16 A more detailed comparison of impurity and heavy metal limits in AS4454 and European countries can be found in Annexes C and D of Biala & Wilkinson 2020.

metal limits are significantly lower than those for Canadian B grade compost (restricted use) and those that are required in the USA. Biosolids quality requirements for land application were used both in the USA and Australia to establish contaminant limits for compost products. Probably the only difference is that the risks posed by contaminants in organic soil amendments are seen differently in the two countries. An extensive risk assessment that considered 25 potential pollutants in biosolids and 14 possible exposure pathways, which was the basis for developing EPA Rule 503 concluded that cumulative levels of pollutants added to land by 'Exceptional Quality (EQ)' or 'Pollutant Concentration (PC)' biosolids (see Table 4) do not have to be tracked because the risk assessment has shown that the life of a site would be at least 100 to 300 years under the conservative parameters assumed (US EPA 1994). The fact that maximum contaminant concentrations for unrestricted use of biosolids (Grade A) and compost (AS4454) are lower by factors between two and twenty (see Table 4) shows that Australian authorities are more cautious in their assessment of risks associated with the use of biosolids and compost.

It is worth noting that, for the first time, the 2012 version of the AS4454 stipulated contaminant limits that are closely aligned to limits stipulated in the NSW Biosolids Guidelines for unrestricted use. Previous versions of the Standard just referred to Federal or State regulations, which generally were biosolids guidelines or regulations.

Table 4: Impurity, pathogen and heavy metal limits for compost products in Australia and selected overseas countries.

Product Characteristics	Australia AS 4454	Europe Quality Assurance Scheme [a)]	Austria Compost Ordinance [b)]	Italy CIC [c)]	UK PAS 100 [d)]	USA EPA Part 503 Rule (EQ or PC biosolids) [e)]	Canada Guide Compost Quality [f)]
Impurities [g)]							
Glass, metal and rigid plastic [% dm]	≤ 0.5	≤ 0.5 (all impurities)	See Annex C (Biala & Wilkinson 2020)	≤ 0.5 (plastic, glass metals > 5mm)	≤ 0.25 with ≤ 0.12 plastic		≤ 1/2 pieces foreign matter > 25 mm in 500 ml
Plastic – light, flexible or film [% dm]	≤ 0.05						
Stones and lumps of clay [% dm]	≤ 5			≤ 5	≤ 8 [h)] (no mulch) ≤ 10 [h)] (mulch)		
Pathogens							
Faecal coliforms [MPN/g]	< 1000			< 1000 (*E. coli*)	< 1000 (*E. coli*)		< 1000
Salmonella spp	absent in 50 g dry weight equiv.	absent in 25 g dry mass		absent in 25 g	absent in 25 g fresh mass		absent in 4 g dry mass
Heavy Metals [mg/kg dm]							
Arsenic	20					41	75 (B) 13 (A)
Boron	100						
Cadmium	3	1.3	3.0 (B) 1.0 (A) 0.7 (A+)	1.5	1.5	39	20 (B) 3 (A)
Chromium (Total)	100	60	250 (B) 70 (A) 70 (A+)	0.5 (Cr VI)	100		1060 (B) 210 (A)
Copper	100 (150) [i)]	110 (300) [j)]	500 (B) 150 (A) 70 (A+)	230	200	1500	750 (B) 400 (A)

Lead	150	130	200 (B) 120 (A) 45 (A+)	140	200	300	500 (B) 150 (A)
Mercury	1	0.45	3.0 (B) 0.7 (A) 0.4 (A+)	1.5	1	17	5 (B) 0.8 (A)
Nickel	60	40	100 (B) 60 (A) 25 (A+)	100	50	420	180 (B) 62 (A)
Selenium	5					100	14 (B) 2 (A)
Zinc	200 (300) [i)]	400 (600) [j)]	1800 (B) 500 (A) 200 (A+)	500	400	2800	1850 (B) 700 (A)

a. European Compost Network, 2018
b. Austrian Ministry for Agriculture and Forestry, 2010
c. Italian Compost & Biogas Association, 2018
d. BIS, 2011
e. US EPA, 1994
f. Canadian Council of Ministers of the Environment, 2005
g. see Annex C for detailed description of impurity limits European countries
h. stones > 4mm
i. A product that contains levels of copper between 100 mg/kg and 150 mg/kg and/or zinc between 200 mg/kg and 300 mg/kg whilst not exceeding the limit values for all other contaminants, must provide a warning label in accordance with labelling requirements in AS4454.
j. Values exceeding 110 mg Cu kg^{-1} and 400 mg Zn kg^{-1} must be declared.

Organic contaminants

Few countries have set limits for organic contaminants in compost and related products. Table 5 shows that overseas compost standards and regulations (for regular compost) tend to stipulate limits for organic contaminants only very sparsely. The long-standing position of regulators in the UK, USA and Canada and many other countries is that there is no conclusive evidence that the levels of organic contaminants typically found in recycled organic materials are hazardous to soil quality, human health or the environment. The large number of potential contaminants, the relatively low levels of contaminants in recycled organic products, and the gap in knowledge about the chronic effects of contaminants on human health and the environment contribute to this position (Tremblay et al. 2014). For example, the Italian standards contain only a limit for polychlorinated biphenyl (PCB), and only for products that are co-composted with biosolids. The German standard for regular compost contains limits for perfluorooctanoic acid (PFOA) and perfluorooctanesulfonate (PFOS) and also for total dioxine and dl-PCB, while standards for biosolids based compost require testing for various other contaminants (German Compost Quality Assurance Association, undated).

"Since the presence or absence of organic contaminants in compost is primarily related to feedstock characteristics, most European countries identify and tightly control which feedstocks can and cannot be composted and therefore largely avoid having to deal with the issue of organic and emerging contaminants in compost products."

Since the presence or absence of organic contaminants in compost is primarily related to feedstock characteristics, most European countries identify and tightly control which feedstocks can and cannot be composted (Bernal et al. 2017) and therefore largely avoid having to deal with the issue of organic contaminants in compost products. Some countries like the Netherlands, Austria and Germany do not require the measurement of organic contaminants in compost and digestate when they are derived from source-separated materials (Saveyn and Eder, 2014). In the UK, the PAS 100 compost quality standard (BIS 2011) and the PAS 110 standard for digestate and related products (BIS 2014) do not require analysis of organic contaminants, but again, strict feedstock controls apply. The PAS Standards can only be applied to products derived from source-separated "biowaste (FOGO) and biodegradable" materials. However, composters must take care "to avoid any potentially polluting wastes, products or materials from becoming included with the input materials".

Nevertheless, organic contaminant limits for composts and related products do apply in some European countries (Table 5). In several EU member countries, legislation is specific to the feedstock being processed. For example, the German Sewage Sludge Regulation prescribes limits for biosolids products/composts, *viz*: 0.2 mg/kg dm for every of the PCB_6 congeners and 100 ng I-TEQ/kg dm for 17 priority PCDD/Fs. Austria also has a different set of limits for composts that are only approved for use in landfill capping and biofilter applications: 1 mg/kg dm for PCB_6, 50 ng I-TEQ/ kg dm for PCDD/F and 6 mg/ kg dm for PAH_6 (Saveyn and Eder, 2014)[17].

The US EPA Part 503 Rule for use of biosolids (US EPA 1994) does not contain limits for organic contaminants. Limits were considered when the regulation was developed (i.e., prior to 1993) but in the end no limits were included because the results of the sewage sludge survey in combination with the risk assessment to determine what limits would be required showed that none of the biosolids generated at the time would fall above those limits (Brown, 2019). A contributing factor to this decision was the fact that most of the compounds that were being considered had been banned by that time. A subsequent risk assessment of biosolids contamination with dioxins came to the same conclusion, i.e., not to establish limits and not to monitor for dioxin contamination.

There are no compost quality standards enforced by regulators in the US, though there has been a significant effort to harmonise testing standards through the development of the Testing Methods for the Evaluation of Composting and Compost (TMECC). Whilst the TMECC outlines standardised testing methods, including for some organic contaminants, it does not specify limits.

The Canadian Guidelines for Compost Quality (PN 130) recognises that "trace amounts" of persistent or bio-accumulating organic contaminants can be present in some compost feedstocks and recommends that special attention should be given to avoiding feedstocks with "high contents" of these contaminants (Canadian Council of Ministers for the Environment 2005). However, they consider that, given the low content of dioxin and furans in compost feedstock in Canada, routine analysis under the Guidelines for Compost Quality is not necessary. The same also applies to PCB and polycyclic aromatic hydrocarbons (PAHs), though composters are encouraged to seek specific advice from their provincial or territorial regulator.

Nevertheless, a degree of vigilance is always recommended to monitor and determine the significance and implications of 'emerging' organic contaminants that may be present in land-applied organic materials (e.g., see Clarke and Smith, 2011 with respect to biosolids).

[17] For example, compost derived from "alternative waste treatment" technologies.

Table 5: Organic contaminant concentration limits (mg/kg, except for PCDD/F) for compost and related products in Australia and selected EU countries [adapted from Saveyn and Eder 2014]

Chemical	Australia	Austria	Belgium/ Wallonia[a]	Germany	Denmark	France	Luxembourg[b]	Slovenia	Switzerland[b]
PAH		6[c]	5 (PAH_{16})		3[d]	Note[e]	10 (PAH_{16})	3	4 (PAH_{16})
PCBs	0.2 (PCB_s)	0.2 (PCB_6)	0.15 (PCB_7)	Note[f]	0.08 (PCB_7)	0.8 (PCB_7)[g]	0.1 (PCB_6)	0.4 (PCB_6)	
PCDD/F[h]		20	100	Note[f]			20		20
PFC (PFOS + PFAS)		0.1		0.1					
AOX		500	250						
LAS			1500[i]		1300				
NPE			25[i]		10				
DEHP			50[i]		50				
DDT/DDE/DDD	0.5								
Aldrin	0.02								
Dieldrin	0.02								
Chlordane	0.02								
Heptachlor	0.02								
HCB	0.02								
Lindane	0.02								
BHC	0.02								

[a] For digestate in the state of Wallonia; [b] Guide values for Luxembourg and Switzerland; [c] sum of benzo[a]pyrene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[ghi]perylene, fluoranthene and indeno[1,2,3-cd]pyrene; [d] sum of acenaphthene, phenanthrene, fluorene, fluoranthene, pyrene, benzo[b]fluoranthene, benzo[j]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, benzo[ghi]perylene and indeno[1,2,3-cd]pyrene; [e] individual limits for 3 cogeners; [f] Maximum sum of PCDD/F and dl-PCB: 30 ng WHO-TEQ/kg dm, in some cases additional restrictions for PCDD/F only of maximum 5 ng WHO-TEQ/kg dm; [g] Only for biosolids compost; [h] PCDD/F= sum of 17 polychlorinated dibenzo-p-dioxins/furans expressed in International Toxicity Equivalents; [i] Guide value; PAH_{16}= sum of US EPA 16 priority listed PAHs; PCB_6= sum of PCBs 28, 52, 101, 138, 153 and 180; PCB_7= sum of PCBs 28, 52, 101, 118, 138, 153 and 180;

Physical contaminants (impurities)

Contamination of feedstock with non-compostable materials, i.e., plastic, glass, metal, etc. has been identified by composting operations that process urban-derived organics as one of their biggest problems. The success of all source separation recycling schemes, expressed as diversion and contamination rates, relies primarily on the good will and active support of residents and businesses. This is even more the case for organics recycling than for dry recyclables since physical contamination cannot be easily segregated mechanically. Recent NSW data encompassing various kerbside FOGO collection systems reported physical contamination levels between 0.04% and 17.8% (w/w) of collected materials, with average impurity levels of around 2.6%. More recent bin audits in NSW revealed average contamination rates of 2.2% in NSW and 2.0% in South Australia. However, it is important to note that the majority of FOGO collection schemes in NSW have been established in regional NSW, not in the Greater Sydney region (Figure 1). Plastic, metal and containerised food were the most frequently encountered impurities. Average impurities in biowaste delivered to Italian composting and anaerobic digestion plants measured 4.8% (w/w), while source separated food organics from businesses in Hong Kong can easily contain up to 20% impurities (Biala et al. 2021).

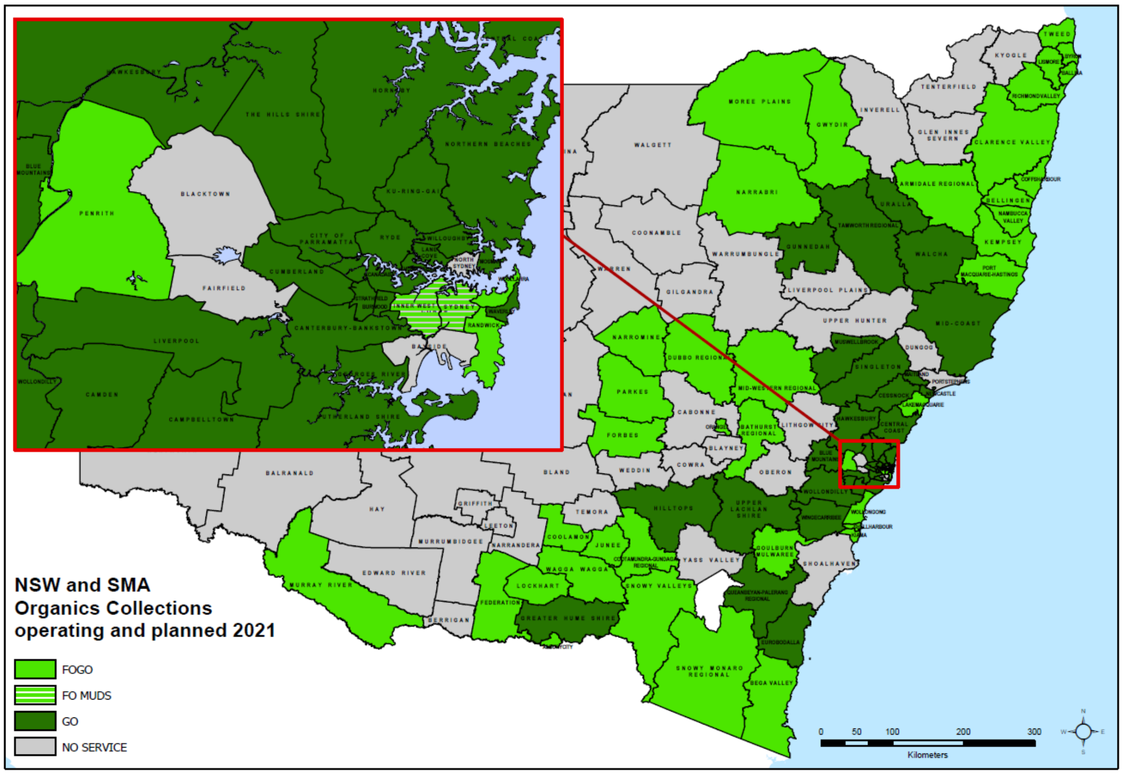


Figure 1: New South Wales organics collection services map (Source: EPA NSW, 2021)

As physical contamination of source separated residential FOGO is affected by a multitude of factors such as community education and engagement, housing structure, size of organics / residual waste bins, costs and charges, controls and bin identification linked to service fee, average contamination levels also vary widely between local government authorities (LGAs) (Figure 2).

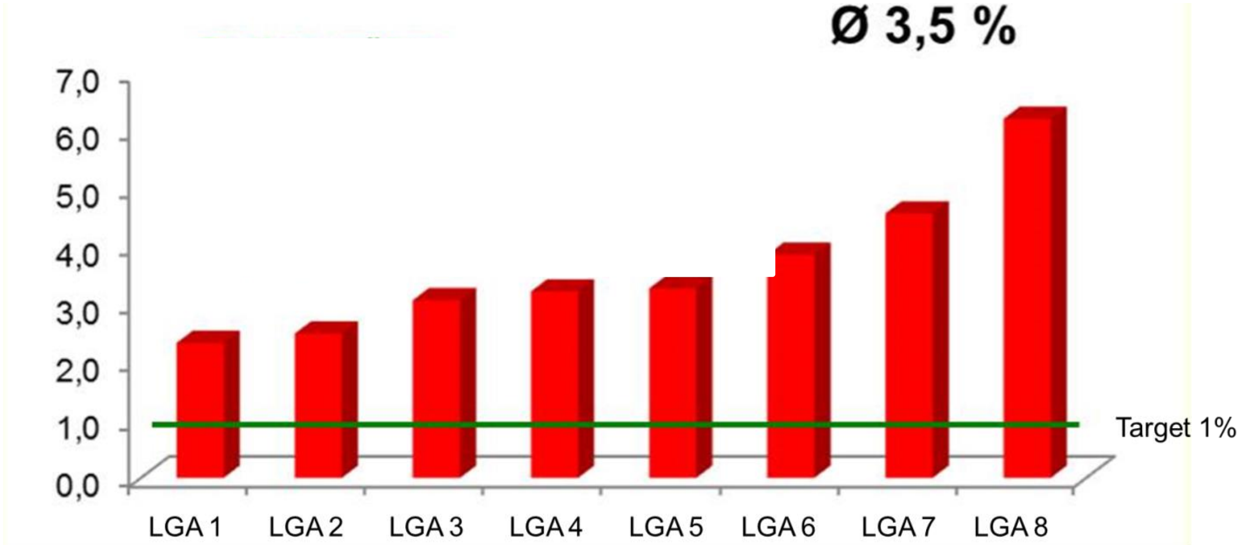


Figure 2: Average and target physical contamination levels (%, w/w) in FOGO collected in different local government areas in Germany (adapted from Kern 2017)

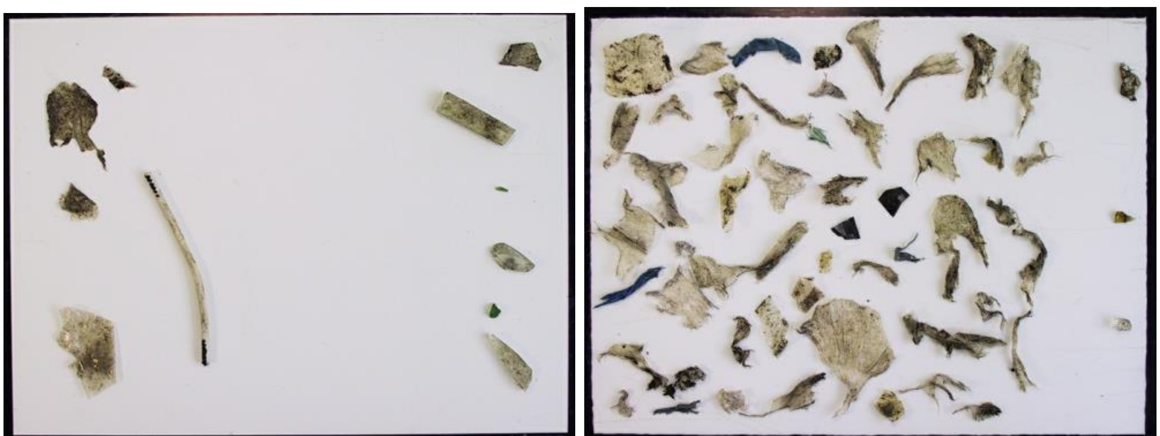
"Physical contamination of RO products can have amenity (visual), practical (compost spreading etc.) and health and safety (as in the case of sharp glass) implications which in turn can reduce the value and marketability of the end-product, impacting in turn on the viability of composting operations."

High levels of impurities in FOGO feedstock present a major challenge for organics recycling schemes since source segregation schemes are costly to establish and run, and excessive impurity levels in raw materials require additional processing steps and compromise end-product quality. Increased manual and mechanical removal of impurities can reduce physical contamination levels, but this requires costly additional processing steps and tends to result in a higher proportion of organic material being sent to landfill as contaminants and oversize material. In addition, processing steps aimed at removing impurities have their limits, reaching around 95% removal at best. This means that, in ideal conditions, raw materials containing 3% impurities can be transformed into screened compost that contains around 0.45% (w/w) impurities (Kehres, 2017). Although this concentration of physical contaminants complies with current limits stipulated in AS4454, emerging data and ongoing research concerning presence of plastics and microplastics are likely to force a future reduction of acceptable physical contamination levels in recycled organic products, and hence also in raw materials. For example, the introduction of revised fertilizer regulations in Germany demanding lower physical contaminant limits for organic soil amendments (0.1% flexible plastic and 0.4% other impurities (all >2mm, w/w, dm) resulted in the introduction of a 1% physical contaminant limit in FOGO feedstock by the German Compost Quality Assurance Association (2018). In line with this, Johnson (2021) called on the Australian compost industry to reduce physical contaminant levels to no more than 0.25% if they want to supply products to agricultural markets.

Physical contamination of RO products can have amenity (visual), practical (compost spreading etc.) and health and safety (as in the case of sharp glass) implications which in turn can reduce the value and marketability of the end-product, impacting in turn on the viability of composting operations.

Area based measurement

Virtually all compost quality requirements related to impurities, including AS4454, quantify physical contamination based on the mass of impurities in relation to total (dry) mass of product. One of the main limitations of mass-based methods is that products contaminated with large quantities of low-density plastic (e.g., pieces of plastic bags) will show very-low impurity levels if expressed as percentage of total mass, as is demonstrated in Figure 3. Impurities dominated by heavy particles have relatively low surface area, while impurities dominated by lightweight materials have a relatively high surface area.



Fraction	weight-% DM	surface area [cm²/l]
Impurities > 2 mm [total] in 1 L	0,47	8,60
light weight fraction [plastics] on the left	0,03	5,51
heavy fraction [glas, metal] on the rigth	0,44	3,09

Fraction	weight-% DM	surface area [cm²/l]
Impurities > 2 mm [total] in 1 L	0,17	68,91
light weight fraction [plastics] on the left	0,13	67,53
heavy fraction [glas, metal] on the right	0,04	1,38

Figure 3: Physical impurities (> 2 mm) in compost expressed on the basis of weight and surface area, dominated by heavy particles (left) or lightweight particles (right) [Source: Thelen-Jüngling 2008]

These circumstances prompted the German Compost Quality Assurance Association to establish an area-based limit for impurities in addition to the existing weight-based limit (0.5% dm). The new threshold was introduced in 2007 and set at a surface area of 25 cm² per litre of compost (Thelen-Jüngling 2008). The limit was tightened to 15 cm² per litre in July 2018 in a bid to further reduce plastic contamination in compost products (German Compost Quality Assurance Association 2018). To date, the German standard is the only one that has adopted area-based measurements of impurities.

Microplastics

Microplastics are very-small plastic fragments that measure less than 5mm in length and can enter ecosystems from a variety of sources. Primary microplastics are any plastic fragments purposely made to be that size (≤ 5.0 mm) before entering the environment and include for example microbeads used in cosmetic products and plastic pellets. Secondary microplastics are created from the degradation of larger plastic products once they enter the environment through natural weathering and degradation processes. A third group is emerging which comes from the human use of an object that gives off microplastics, for example from the road wear of synthetic tyres, washing synthetic clothes, or synthetic grass pitches and sports grounds. Plastics degrade very slowly, which increases the probability of microplastics being ingested and incorporated into, and accumulated in, the bodies and tissues of many organisms.

Nizzetto et al. (2016) have outlined why the presence of microplastics in soil can be problematic, stressing that these materials can potentially impact soil ecosystems, crops and livestock either directly or through the toxic and endocrine-disrupting substances added during plastics manufacturing. These substances include short/medium-chain chlorinated paraffins (candidates for inclusion in the Stockholm Convention) and plasticizers, which can represent up to 70% of the weight of plastics. Endocrinologically active alkylphenols, such as bisphenols, and flame retardants including several banned brominated compounds comprise up to 3% by weight of some plastics. The same authors also claim that, during use, plastic polymers efficiently accumulate other harmful pollutants from the surrounding environment, including a number of persistent, bioaccumulative and toxic substances, such as PCBs, dioxins, DDTs and PAHs.

Concerns about plastics and microplastics in the environment have undoubtedly focused on the marine environment in the past. However, as early as 2012, there were calls for a systematic examination of microplastics in soil as well as increased attention of policy makers and regulatory bodies to this matter (Rilllig 2018). In that regard, use of biosolids products on agricultural land came under scrutiny first, as over 90% of microplastics contained in sewerage are retained in the sludge (Nizzetto *et al.* 2016).

Based on high level estimates, Nizzetto et al. (2016) suggested that between 125 and 850 tonnes of microplastics per one million inhabitants are added annually to European agricultural soils through land application of sewage sludge or as processed biosolids. They estimated furthermore that these quantities equate to average and maximum area per-capita microplastic loading rates of 0.2 and 8 mg/ha/yr, respectively. However, He et al. (2018) pointed out that pollution of farmland with microplastic can also originate to a large degree from use of plastic mulch (and other plastic products) in agricultural practice. Yet, there is still a significant lack of data regarding concentrations, volumes, types and composition of microplastics in soil environments to allow analysis of the current pollution status of microplastics in the soil on a regional, national or global scale (He et al. 2018).

Work has been published recently that looked at the presence of microplastics in farmland soils. For example, the abundance of microplastics in twenty vegetable fields on the outskirts of Shanghai amounted to 78 ± 12.91 and 62.50 ± 12.97 pieces per kg in shallow and deep soils, respectively (He et al. 2018). The majority of microplastics found were made of polypropylene (50.5%) and polyethylene (43.4%), indicating that plastic mulch was the main contributor to microplastic contamination in soil. In another study that was conducted in China (Zhang et al. 2018), all fifty samples of arable soils contained plastic particles (10 - 0.05 mm), numbering between 7,100 and 42,960 particles per kg of soil, with 95% of plastic particles found being categorised as microplastics (1.00 - 0.05 mm).

Contamination levels found in Germany are significantly lower, yet still present. Piehl et al. (2018) found 206 pieces of macroplastic per hectare and 0.34 ± 0.36 particles of microplastic per kilogram dry weight in arable soil where microplastic-containing fertilizers and agricultural plastic applications were never used previously. They saw polyethylene as the most common polymer type, followed by polystyrene and polypropylene, and noted that microplastics were dominated by plastic films and fragments, whereas macroplastics were comprised predominantly of plastic film. The authors did point out that contamination levels are probably higher in fields where agricultural plastic is used (e.g., greenhouses, mulch, or silage films) or where organic soil amendments that contain plastic fragments such as biosolids or urban derived composts are applied.

In France, Watteau et al. (2018) developed and applied novel analytical methods to determine the level of microplastics in a long-term experimental field, where municipal solid waste (MSW) composts were applied every other year over 10 years. Their results showed that plastics and microplastics were present in the soil that was amended for 10 years with MSW compost, while not in the control soil. Microplastics were mostly observed as individual particles, present in the coarsest fractions as well as some of the fine soil fractions, but they had minimal association with the soil matrix. Most plastic particles did not show any signs of degradation (e.g., microbial lysis), which suggests that fragmentation is the main pathway of particle size reduction.

It should be understood that microplastics in soil is a new field of scientific investigation where much has yet to be learned. Bläsing and Amelung (2018) for example stated that "nearly nothing is known about plastic pollution of soil; presumably, because awareness is either not existent or because no standardised methods are available for plastic quantification in soil" and Scalenghe (2018) pointed out that plastic polymers found in the soil are not made of a homogeneous material but are different from each other and hence degrade differently in soil over different time spans.

Researchers in Germany investigated the content of microplastics > 1 mm in a range of products generated from various source separated organic residues that were processed either via composting or anaerobic digestion (Weithmann et al. 2018). Both the composting and the anaerobic digestion facilities processed FOGO material blended with vegetation residues, yet there were some important operational differences that affect impurity levels in the finished product.

All analysed product samples contained plastic particles, but quantities differed significantly depending on feedstock type and mix and efforts to remove impurities before processing. Composted FOGO contained markedly less plastic particles than digested FOGO, but this has nothing to do with the processing technology as such, but rather with differences in the feedstock mix (higher proportion of vegetation residues used in composting (Table 6) and the lack of pre-treatment (removal of packaging) in the anaerobic digestion facility. The level of degradation of the organic material, which affects particle size distribution and the mesh size chosen for screening also affects the content of plastic particles in the finished product.

Unfortunately, the authors did not report if the feedstock material (FOGO and vegetation residues) processed in the two facilities had similar impurity levels or not. Liquid digestate from an AD facility that processes primarily commercial residues from the food and beverage industry contained by far the highest number of plastic particles. No information was provided about measures to remove impurities in this operation. As a comparison, the authors also assessed digestates generated at facilities that process agricultural residues and energy crops and found very few plastic particles in those products.

Table 6: Comparison of microplastic particles >1mm in products generated from source segregated organics in Germany (Source: modified from Weithmann et al. 2018)

Parameter	Composting	Dry anaerobic digestion	Wet anaerobic digestion
Feedstock	FOGO + vegetation residues	FOGO + vegetation residues	Commercial organic residues (food and beverage industry)
Proportion vegetation residues	High (more than 50%)	Low (about 20%)	Unknown, probably none
Removal of impurities from feedstocks	Screening (80mm), material < 80mm => ferrous metal separation, material > 80mm => manual sorting, shredding	None	Unknown
Removal of impurities from finished product	Compost is screened to < 8mm and < 15mm	After digestion (28 days) the material is screened (20mm) and subsequently composted and matured	Unknown
Products assessed and microplastic particles (> 1mm) found per kg of product	Compost < 8mm: 20 Compost < 15mm: 24	Mature digestate A: 70 Mature digestate B: 122 Immature digestate C: 146 Percolate D: 14	Liquid digestate: 895

Certified compostable plastics

Background

The desire to replace petroleum-based plastics with plastics made from renewable raw materials, such as plants, that are designed to degrade, biodegrade, or compost drove the development of biobased plastics over the past 40 years. However, bioplastics also present challenges and create uncertainty for a wide array of stakeholders due to inconsistencies in product labeling and a lack of accepted definitions for industry terms (CORC 2011). A major source of confusion is the difference between the terms biodegradability, compostability and oxo-degradability.

Bioplastics refer to a large family of plastics which are sourced from biomass at the beginning of their life (bio-based). Biodegradable plastics are a relatively small subset of bioplastics which can be converted into water, carbon dioxide and biomass over time with the help of micro-organisms (Figure 4). And because the biodegradability of a plastic lies with the chemical properties of the polymer — and not the source of the feedstock— biodegradable plastics can be either bio- or petroleum-based.

Nearly every material will biodegrade, given enough time, but the length of the biodegradation process is highly dependent on environmental parameters such as humidity and temperature. Consequently, compostable plastic is a biodegradable bioplastic that undergoes degradation by biological processes during composting to yield carbon dioxide, water, inorganic compounds, and biomass at a rate consistent with other known compostable materials and that leaves no visible, distinguishable, or toxic residue (ASTM 2004).

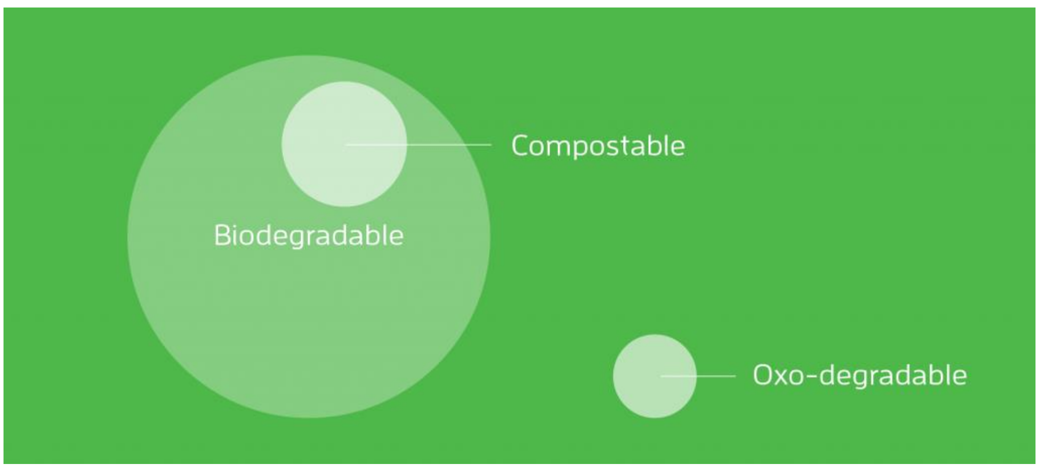


Figure 4: Biodegradable, compostable and oxo-degradable plastics within the large group of bioplastics [Source: Greendot Bio Plastics undated]

Compostable plastics are those plastics which have been tested and third party certified against international standards such as ASTM D6400 (U.S.), EN13432 (Europe) or AS 4736 – 2006 (Australia) for biodegradation in an industrial composting facility environment, certifying that materials will disintegrate within 12 weeks and biodegrade at least 90% within 180 days in a municipal or industrial composting facility at 58+/-5 °C (CORC 2011, Williams 2020). Approximately 10% of solid material will be left at the end of the six-month-long process. These standards also ensure that the generated compost will be free of toxins and not cause harm. In addition, Australia also has a standard for "Biodegradable Plastics Suitable for Home Composting" (AS5810 – 2010), which requires that materials will disintegrate within 180 days and biodegrade within 360 days in a home composting environment at 25+/-5 °C (Williams 2020).

The testing regime for the two Australian Standards include product characteristics, biodegradability, disintegration, plant and earthworm toxicity and some AS4454compost quality parameters (Williams 2020). However, it is worth noting that content of light, flexible or film plastic is not a testing requirement for AS 4736 or AS5810.

The problem

The development and subsequent introduction and use of biodegradable plastics has faced a lot of criticism over the years, which has markedly increased over the past 5 years, as marine and terrestrial plastic pollution has come into public focus. There are countless websites and blogs that attest to this. The above mentioned confusion of terminology and facts, combined with ill-informed and green-washed messages, resulted in a situation where certified compostable plastics have become 'collateral damage' in the broad assault on biodegradable (and non-degradable) plastics. "Compostable plastics aren't much better" as sub-heading in a recent article titled "A type of 'biodegradable' plastic will soon be phased out in Australia" (Downes et al. 2021) illustrates this point. The Australasian Bioplastics Association (ABA) responded with a 6-page statement, refuting many of the claims.

However, there are also the following common and legitimate questions regarding the use of certified compostable plastics:

- Testing for disintegration and degradation is done in ideal laboratory conditions, which may not necessarily represent conditions in a commercial composting facility.
- Certification assures that compostable plastics disintegrate within 84 days (12 weeks) and biodegrade within 180 days, but many commercial composting facilities do not compost for 12 weeks and sell compost well before 180 days is completed.
- As approximately 10% of compostable plastic is left after 180 days of composting, generated compost (in much less than 180 days) is likely to contain visible plastic particles indifferentiable from non-compostable plastic, which lower the value of compost.
- Compostable plastic materials that are discarded, based on the notion of biodegradability, and end up as litter in terrestrial or aquatic environments take a long time to break down and decompose because environmental conditions are markedly different to those encountered during composting.
- In addition, there are claims that (i) compostable plastic products contained in feedstock entering an organics processing facility cause operational problems when segregating impurities and during processing (composting, anaerobic digestion (AD)), particularly in AD facilities, and (ii) purist views that (compostable) plastics should be recycled back into (compostable) plastics, or that energy recovery through incineration from compostable

plastics is environmentally superior to composting them, which merely releases H_2O, CO_2 and minerals.

The speed of disintegration and biodegradation of compostable plastics depends not only on the conditions they are exposed to and for how long, but also on their thickness and the raw materials they are made from, as shown below in data published by Burgstaller et al. (2018).

Biodegradable under conditions of **industrial composting** (58 ± 2 °C, max. 6 month):

TPS, PHA, PCL:	ca. 4-6 weeks
PLA, PBAT, PBST:	ca. 6-9 weeks
PBS:	ca. 21 weeks

Biodegradable in **soil** (20-28 °C, max. 2 years):

TPS, PHA, PBSe, PBSeT, PBAT, PCL:	ca. 7-12 month
PLA:	no degradation after 1 year

Biodegradable in **fresh water** (20-25 °C, max. 56 days)

TPS, PCL, PHA:	<56 days
PBS, PBSA:	ca. 3 month
PLA, PBAT:	>1.5 years

Biodegradable in **seawater** (30 °C, max. 6 month)

PHA, PCL, TPS, PBSe:	<6 month
PLA, PBAT:	>1.5 years

Biodegradation under anaerobic conditions is not yet required for certification but can optionally be determined. TPS, PCL and PHA are degradable under anaerobic conditions, PLA only at temperatures >50 °C. Co-polyesters such as PBS, PBAT and PBST are not anaerobically degradable.

The above arguments and variability in degradation combined with the fact that compostable plastics do not add nutrient value and little else to compost (German Compost Quality Assurance Association 2014; Burgstaller et al. 2018) with weak evidence in favour of any particular agronomic benefit (Hann et al. 2020) has resulted in a situation where using compostable plastics and sending them to organics processing facilities is anything but uniform in Europe. Burgstaller et al. (2018), who looked at recycling options of biodegradable rather than just compostable plastics reported the following: *In Italy and France, regulations exist which favour the use of biodegradable plastics. France promotes the use of certain biodegradable plastic products by regulating that fruit and vegetable bags, as well as from 2020 disposable tableware and cotton sticks, must be home compostable and bio-based. In Italy, disposable plastic bags must be industrially compostable and bio-based. In addition, all products certified according to EN 13432 are approved for industrial composting and industrial composting of biodegradable plastic waste is already successfully integrated into the country's waste management strategy, with possible regional differences. Although the use of biodegradable plastics in the Netherlands is promoted by financial incentives, the Netherlands has not taken a clear position on biodegradable plastics. This also* *applies to Germany and Sweden, where financial incentives do not exist.* The situation in Australia is similarly diverse (APCO 2021).

The long-lasting discussions in Europe concerning the use and processing of compostable plastics have shown a differentiation between compostable liners for kitchen caddies and bins, and other products made from compostable plastics, such as catering products and packaging. A study for the European Commission concluded that material choices for products and packaging should prioritise recyclability over compostability, except for cases where the use of compostable plastic have proven 'added benefits' such as increasing the collection of organic waste and its diversion from residual waste or reduction in plastic contamination of compost (Hann et al. 2020). These findings are supported and exemplified by a joint statement of nine German industry associations representing the waste, recycling and organics management sectors, in which they categorically reject that compostable plastics should be collected with FOGO and processed in composting or AD facilities, except for compostable caddy / bin liners (German waste and bio-waste management associations 2019). This is in contrast to a joint statement by the Australian Organics Recycling Association (AORA) and the Australasian Bioplastics Association in which *AORA endorses the use of AS 4736 certified materials for the source separation of food waste in the home or commercial premises and also as a suitable alternative to otherwise non-recyclable packaging. Compostable coffee cups, capsules and compostable bags can all be successfully processed through normal organic recycling processes without concern of contamination* (AORA/ABA 2018).

However, despite the fact that the use of compostable catering products is slowly increasing in Australia, most of it goes to landfill after use and very little ends up in composting facilities. In some public events (e.g., WOMADELAIDE), compostable catering products are collected with food waste, but it has not been investigated whether / to what degree these materials contribute to visible contamination in finished compost products. On the other hand, replacing conventional plastics with certified compostable plastics for items that are often mixed with or attached to food waste, such as fruit stickers or tea bags, is welcome as it can help reduce contamination with conventional plastics (Hann et al. 2020).

It is generally accepted that compostable liners for kitchen caddies and bins have a role in supporting sustainable food waste management as their use increases the capture rate of food waste because consumers find them convenient (Burgstaller et al., 2018) and they help in reducing the use of conventional plastic bags, resulting in reduced contamination of RO products with visible plastic particles. Yet, there is also opposition to the use of compostable liners. Common arguments include (i) that the timeframe of organics processing (composting and/or AD) is inadequate for complete degradation, and therefore diminish compost quality, (ii) that the compostable bags, like plastic bags, obstruct the technical process, and therefore have to be extracted prior to processing, and (iii) that the 'plastic-like' appearance of compostable bags suggests that non-compostable bags can also be used[18] (Kern et al. 2017). Therefore, some municipalities and waste collectors recommend and support or require the use of certified compostable plastic bags for collecting bio-waste. Others however will not accept and ban the use of compostable plastic bags. A survey of more than 300 local councils in Germany that offer a FOGO service showed that only 16% recommend using compostable liners, while 44% reject their use and 40% have no preference either way (Kern et al. 2017). It is thought that a decision for or against the use of compostable liners would depend on the existing FOGO treatment infrastructure (e.g. composting or AD, typical processing time lines, treatment capacity, type of AD technology, way of removing impurities) (Burgstaller et al. 2018; Hann et al. 2020) but the survey by Kern et al. (2017) has shown that these aspects do not always govern the decision making process, which often appeared to be rather arbitrary.

A recent field study in Germany (Kern et al. 2020), which assessed plastic particles in compost from eight different organics processing facilities that employ combined AD and composting technologies dispelled the notion that time-lines for degradation of compostable plastics are too short, particularly in AD facilities. Four of the facilities processed FOGO from municipalities that allow and four that don't allow the use of compostable liners. A survey of 16 municipalities showed that, on average, each tonne of FOGO contained around 100 bags, 61% of which were made of conventional plastic, and 39% were made of compostable plastic. The number of film particles in the finished compost varied between 2.3 and 74.3 film particles per litre. The surface area index of the composts varied between 0.7 cm^2/L and 13 cm^2/L with a mean value of 5 cm^2/L for all 10 composts[19]. The number of compostable plastic film particles identified was eight in total or 0.3 pieces per average compost sample. That means that over 98 % of the film plastic particles were attributable to conventional plastics. Since approx. 39 % (range 19 % to 61 %) of bags in FOGO were made of compostable plastic, and only 1.8 % of plastic particles detected in composts were derived from compostable plastics, the authors concluded that the use of compostable plastic bags for food waste collection would lead to a significant reduction in plastic particles in the compost.

The solution

Evidence-based information and guidance is urgently needed regarding the degradation of compostable caddy and bin liners and their use as a tool for increasing food waste capture rates and reducing plastic contamination in compost products.

No clear recommendation can be given concerning the co-collection and composting of compostable catering products and packaging, since this issue is much more complex and requires more research and extensive consultation before viable separation, collection and processing schemes can be established. A good starting point for this is the recently released *National Compostable Packaging*

[18] It is likely that paper bags are recommended for use in these municipalities.
[19] The current allowable limit in Germany for certified compost is 15 cm^2/L

Strategy (APCO 2021), which was developed by the Australian Packaging Covenant Organisation (APCO) in cooperation with ABA and AORA.

The strategy advocates that compostable packaging should be managed according to the following principles:

- Compostable packaging should only be used when it generates the highest potential environmental value.
- Elimination, reduction, reuse and material recycling options should be considered first.
- A holistic systems approach is required to ensure compostable packaging is only favoured in scenarios where it is practical to collect and process through organics recycling facilities, with minimal cross contamination of other waste streams.
- To ensure high quality recycled products, it is necessary to avoid cross-contamination between organics recovery systems and plastics recovery systems.
- The use and recovery of compostable packaging must minimise impacts on the environment at every stage.
- Adding packaging to the feedstock for organics recycling should not reduce the quality and value or limit the application of composted end products.

Furthermore, the strategy acknowledges that the risks associated with use of compostable packaging need to be evaluated and managed. These include industry 'greenwashing', inadequate processing capacity, not being able to sort compostable packaging from non-compostable packaging at processing facilities, gaps between processing times within Australian standards and current commercial operating times, and potential for increased contamination of composting processes with non-compostable packaging.

Key Issues in Organics Recycling

The following section outlines the key issues facing organics recycling now and into the future. As discussed previously, emphasis is given to the issues that are likely to impact on Australia's ability to meet Target 6 of the National Waste Policy Action Plan.

The two main areas of focus were therefore:

- Factors that may *directly* affect the rate of diversion of organics from landfill (e.g., those impacting on processing capacity), and
- Factors that *indirectly* affect the rate of diversion of organics from landfill by impacting on future market development for organics (e.g., by affecting end-product quality).

Although there are always "exceptions to the rule", the issues identified in this review are common across Australia. These issues have been derived and tested by the project team through consideration of the evidence base (e.g., from the literature) and insight gained through stakeholder consultation[20].

Assumptions

The main assumptions we have used in identifying the key issues are well-supported by the evidence base. They are that:

1. New and expanded RO processing facilities will be required across the country if Target 6 is to be met.
    - Some additional capacity is currently available at existing facilities across the country (Olah 2021) but not enough to process the additional tonnage projected by 2030.
    - Emphasis will increasingly be given over time to FOGO so that landfill reduction targets can be met.
    - Composting will remain the dominant technology in Australia up until 2030.

There is some undeveloped market capacity for RO products in the urban and amenity market sectors, but not enough to find beneficial uses for the volume of product coming onto stream by 2030.

[20] As far as possible given budgetary and timeframe limitations.

- Increased emphasis therefore needs to be given to agricultural markets (e.g., see VORRS, 2015)

- GO in some parts of the country is collected and shredded but it is under-utilised (e.g., it can be used on landfill tracks or as capping) [21]. These activities are often undertaken by local government authorities.

2. Good quality compost cannot be made from poor quality feedstock ("rubbish in, rubbish out").

- Some waste streams currently being composted in the country are probably not suitable for composting (e.g., see Wilkinson et al., 2019).

- Feedstock controls, such as source separation, are much more effective at removing contaminants than "end of pipe" technological solutions (e.g., see Huerta-Pujol et al., 2011; Kehres 2017).[22]

"Good quality compost cannot be made from poor quality feedstock ("rubbish in, rubbish out")".

3. Compost of the highest quality must not only contain low contaminant levels[23] but also be "fit for purpose".

4. Poor quality compost undermines trust in RO products and hampers market development.

- The saying, "one bad apple spoils the whole barrel" aptly describes the effect poor-quality compost has on the entire RO industry.

- Discounting the price of contaminated compost is not a sustainable solution as it reinforces the perception that RO products are low value in the mind of the consumer.

- RO processors are less likely to invest in making quality compost when their competitors access the same markets with cheap, sub-standard product.

5. Quality assurance of compost is important to establish and maintain market confidence.

[21] Based on anecdotal evidence only; data on this practice is difficult to obtain.
[22] Put another way, end of pipe contaminant removal is more effective after source-separation. It is not meant to be the first line of defense. Experience with non-source separated MSW composting in WA and NSW shows that it is not a viable long-term option for organics processing.
[23] Contaminants can never be eliminated in urban derived RO, but they must be minimised.

- Third-party certification is the strongest form of quality assurance, but it will not be widely adopted unless it confers a market advantage or else if the market demands it.

Key issues directly affecting organics diversion

These key issues are as follows:

1. Infrastructure requirements for setting up a world class organics recycling system in Australia is complex, time consuming and expensive.

    - Government grants have been an effective means for attracting co-investment in organics recycling system infrastructure.
    - The design and implementation of effective organics recycling systems is complex and time-consuming because of the need to obtain the buy-in from multiple stakeholders along the organics supply chain. It is easier for government to promote investment in infrastructure than it is to influence behavioural change in the way that people engage with organics recycling.

> **Roll-out of FOGO**
>
> Commenting on a 3-month trial project: "Behavioural change is difficult but we have proved that it is possible. Our communities have embraced it; Particularly pleasing to see in regional areas. Participation rates have improved, and contamination rates are low but there is still room for improvement."

> **AORA's view**
>
> "Put simply, the major obstacles to growth – the biggest roadblocks to achieving the economic and environmental benefits available – are external to the industry and within the control of one or more tiers of government."

"Infrastructure requirements for setting up a world class organics recycling system in Australia is complex, time consuming and expensive."

2. Ongoing education and engagement of residential and commercial generators of organic waste materials.

3. The key challenge for many existing and future organics recycling schemes are not of a technological nature, but to effect behavioural change so that people engage with and actively support organics recycling, i.e., are "doing the right thing".

4. The success of all source separation recycling schemes, expressed as diversion and contamination rates, relies primarily on the good will and active support of residents and businesses.

- This is much more the case for organics than it is for dry recycling schemes. The good will and support of communities is not being activated due to the lack of public education and the absence of consequences for non-compliant behaviours.

5. Proper separation of materials that can and cannot be composted at the source is critically important for production of compost with minimal impurities, as mechanical separation of unwanted materials is costly and has its limits.

6. Regulatory burden is seen as a major barrier to establishing organics recycling facilities (*c.f.* Olah 2021).

    - It has been reported that regulatory authorities are tightening up in assessing proposals by new entrants in some states. This is not necessarily reflected in organics processing regulations but in how they are applied. Forthcoming new guidelines in QLD for example will apply only to new composting facilities.

    - A solutions-oriented, "can do" approach to organics regulation is sometimes lacking. Over-zealous application of organics processing guidelines by regulatory authorities can appear to put up roadblocks and risks costly delays in getting new facilities up and running.

    - Regulatory authorities have an essential role to play in protecting public health and the environment. Yet they have largely been "reactive" rather than "pro-active". The reactive mode of operation (e.g., to odour complaints) has contributed to disproportionate risk aversion since public complaints create unwanted media attention and political pressure.

"Regulatory burden is a major barrier to establishing organics recycling facilities."

- Once a new or modified (expanded / use of different processing technology) composting facility has obtained planning consent from State Government authorities, the local government authority can still prevent the proposed development from proceeding.

- Compost use is part of the solution to the problem of degraded Australian soil, but RO processing can be regarded by regulatory authorities as more of a threat to environmental well-being than as an important plank in climate change adaptation.

- Past behaviour of some in the RO industry is also partly to blame for the risk aversion of regulatory authorities – e.g., caused by multiple / ongoing breaches of licence conditions.

- The burden to demonstrate "no harm" to environment and public health is increasingly placed on RO processors. This is unreasonable given that i) criteria for 'no harm' are not or inadequately defined, ii) the processor has a vested commercial interest in accepting new feedstock materials, iii) the science is not always clear or available, and iv) RO processors are effectively offering a service to the community in support of government policy (diversion from landfill) and contributing to climate change adaptation.

7. A major reason why RO facilities fail is because of persistent odour complaints. Complaints by nearby residents/businesses place enormous pressure on the regulatory authorities to act in favour of the complainant. Planning schemes that allow urban encroachment around RO facilities have also increased conflicts.

   - Odour is commonly associated with stockpiles (as well as in other areas of RO processing); stockpiles are the result of lack of alignment between seasonal supply and demand[24], poor product quality or poor marketing.

   - Odour risk is also determined by feedstock. Sites processing FOGO have a higher risk of generating odour than GO sites.

"Physical contamination in FOGO is a serious challenge to the sustainability of the RO industry since it will hinder market development."

8. Due to the increased supply and risks associated with FO/FOGO, more regulatory pressure will be placed on organic processors.

   - Open windrow composting of FOGO will be fazed-out in urban areas, to be replaced by in-vessel/enclosed/covered aerated static pile/AD technologies, resulting in higher processing costs.

   - New composting sites will be increasingly harder to find close to the major cities and there will be a need to establish more sites around regional centres and in rural areas.

   - Increased feedstock supplies can quickly undermine processing standards as facilities seek the revenue from gate fees. Processors can be tempted to find ways to push through product before it has been adequately processed.

   - Organics processing guidelines were developed mainly with urban environments in mind. Blanket application of these guidelines outside urban environments could hinder establishment of lower-tech and lower-cost processing facilities that are appropriate in regional areas but not in urban centres.

[24] Supply of feedstock and demand for the end-product are both affected by season and supply can sometimes exceed demand.

No bargaining power - Organics processor QLD

"So far composters had no bargaining power since a fair proportion of GO was used for energy generation in the sugar mill, creating a supply shortage. This is only changing now with more supply becoming available and will change more as FOGO is not suitable for burning."

Factors that indirectly affect diversion from landfill

1. Physical contamination in FOGO is a serious challenge to the sustainability of the RO industry since it will hinder market development.

- These risks must be addressed with commitment across the entire RO supply chain.
- The success by which contamination issues have been dealt with for GO alone has been patchy at best[25]. The laissez-faire approach to preventing contamination in GO has resulted in complacency in the population towards this problem. The contamination problem in FOGO is much greater, and FOGO collection is ill-advised in areas that have not already got contamination in GO under control.
- Responsibility for the failure to deal with contaminants cannot be attributed to RO processors since contamination is best controlled at the source and is the responsibility of waste generators (see next point).

2. Physical and chemical contaminants in organic feedstock are best controlled at source, yet:

- Some high-risk feedstocks continue to be composted in the country[26]. Unfortunately, high-risk feedstock can be attractive to processors because they receive high gate fees for them[27].

[25] One could argue that the more complex problem of contamination in FOGO should not be tackled until the problem of contamination in GO is resolved.
[26] Controls on feedstock inputs vary across the country.
[27] For example, see this news report: https://www.abc.net.au/news/2021-05-01/swanbank-residents-hope-order-will-stop-smells-from-nugrow-plant/100105246

- Commitment to and successful implementation of source separation for kerbside organics has been very patchy across the country. Commitment varies from one local government area to the next.

"Unfortunately, high-risk feedstock can be attractive to processors because they receive high gate fees for them."

Impurities and AS4454

"You can have several litres worth of shredded plastic in a cubic metre of compost and still meet the standard. So, it's possible to meet the standard and still have grumpy customers."

A processor's point of view

"Government has to mandate maximum physical contamination in feedstock – processors do not have the leverage to force this issue with our clients. (i.e., Councils)"

- Many local government authorities that have introduced kerbside organics collection schemes do not enforce source separation and minimisation of impurities very well and they do not take responsibility for the quality of feedstock they supply to processing facilities. There are some good examples in Australia of public education with respect to GO/FOGO collection and source separation (e.g., see the Halve Waste initiative operating in NSW and Vic[28]), however there is little incentive for Councils to engage in public education and to provide clean GO/FOGO to processors. Councils must pay for public education and contaminant minimisation at the source, while processors have to cover the costs for removing impurities in feedstocks.

- Even if contracts between Councils and processors include clauses that impose penalties for contaminated feedstock, they may not be enforced for fear of not being able to get the next contract with Council. Even worse, there are also many cases where organics processors do not have a commercial relationship, let alone a contract, with local authorities that supply GO, since shredding contractors own the ground GO, and then on-sell and distribute ground GO.

[28] Halve Waste is an initiative of Albury City Council, City of Wodonga, Federation Council and the Shires of Towong, Greater Hume, Indigo and Alpine Shire Councils.

- Information on what can and cannot go into kerbside bins also varies greatly and causes confusion.

3. Chemical contamination is a real threat to compost quality and market development.

    - PFAS is a real concern to all stakeholders, particularly for RO suppliers of the urban amenity market, since strict limits apply to PFAS concentrations in urban soils (PFAS NEMP 2020), while that is not the case for agricultural soils at this point in time.

    - Even some GO streams are at risk of herbicide contamination, but these chemicals are not tested for as part of AS4454 or as a requirement in the organics processing guidelines[29].

    - Limits for chemical contaminants present in organics processing guidelines and AS4454 do not necessarily reflect real-world risks.

    - Data is lacking on chemical contamination risks associated with particular feedstocks in Australia.

4. Composts derived from FOGO are classified as "restricted animal material" (RAM) due to risks associated with transmissible spongiform encephalopathies (TSEs). Although TSEs are not known to occur in Australia, authorities across the country have banned the feeding to ruminants of all meals, including meat and bone meal, derived from all vertebrates, including fish and birds (AHA, 2019). This means that, for example, ruminants must not have access to heaped piles of products containing RAM. In addition, if a product containing RAM is applied to pasture, a 3-week withholding period is required before animals can return for grazing.

5. When benchmarked against other standards worldwide, the Australian Standard (AS4454) stacks up reasonably well (see Biala and Wilkinson 2020), but

    - Limits on organic contaminants need to be updated to better reflect actual risks associated with GO/FOGO.

> **Reforming AS4454**
>
> "When it was proposed by the AS4454 Committee to update chemical contaminant limits, experts from the various states couldn't come to an agreement. Revisions were proposed, but the question was always, 'what is the scientific evidence for the new number?' The process was therefore stalled."

[29] See here for example: Recycler Suez says herbicides in contaminated compost came from Melbourne council waste - ABC News

- Limits on heavy metals in AS4454 are for unrestricted use. Different limits for some micronutrients such as copper and zinc should be considered for agricultural applications[30].

"AS4454 plays an adequate role as a baseline Standard but, for the future, the focus needs to be on development of specifications for fit-for-purpose products."

- Permissible levels of impurities (i.e., glass and plastic) are not low-enough. A product meeting the requirements of AS4454 can still have physical contaminants visible in it.

- No information is available that benchmarks generated RO products against AS4454 quality requirements, indicating levels of compliance, and areas where product quality needs to be improved.

- The effectiveness of AS4454 is undermined by a weak regulatory and quality assurance environment where producers at best seek compliance with pasteurisation requirements, and users do not understand the difference between pasteurised product, composted product or mature compost.

6. Opinions vary about whether AS4454 adequately benchmarks compost quality and whether it is essential for future market development.

   - AS4454 is a voluntary Standard. Processors can claim that their product "meets AS4454" without having third party verification and certification.

   - A product that "meets AS4454" can still look unsightly (e.g., due to contamination) undermining the credibility of the Standard in the eyes of the consumer.

   - It is questionable whether certification to the Standard in its current form confers a market advantage for those RO products that are supplied in bulk[31].

   - Some argue that AS4454 plays an adequate role as a baseline Standard but, for the future, the focus needs to be on development of specifications for fit-for-purpose products. Several such specifications have already been developed.

7. Progress in accessing agricultural markets for RO products varies greatly between jurisdictions. The reasons for this are not entirely clear, but we can make the following observations:

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[30] In the light of the use of copper sprays (as a fungicide) and the fact that agricultural soils are frequently deficient in zinc.

[31] The situation is different for the bagged market where consumers are accustomed to look for the Australian Standards logo and large retail chains require third party accreditation, i.e., the five-ticks logo.

- States claiming good access to agricultural markets (e.g., SA and NSW) also claim that it is because their processors have a greater commitment to compost quality. However, consistent state policies and the level of state government investment in various support programs may also be important in promoting product improvement and market access.

> **End user views**
>
> "Farmers don't want to be the dumping ground for the city's crap."

"States claiming good access to agricultural markets (e.g., SA and NSW) also claim that it is because their processors have a greater commitment to compost quality."

- Very-high prices for products are possible for clean "fortified" compost. This can involve secondary processors[32] or smaller sized "boutique" composters processing clean feedstock (often derived from agriculture) to sell specifically for the agricultural market.

- Organics recycling is part of our waste management and resource recovery system. It therefore carries with it a certain paradigm that has traditionally been about waste treatment and disposal. For this reason, some argue that composting companies outside the waste industry sector are more likely to make products that meet a market need. The need for a paradigm shift from "waste management" to "compost production" was identified many years ago in Australia's first best practice composting guideline (EcoRecycle Victoria 1998), but progress in this area has been uneven[33].

> **Opposing views about AS4454**
>
> "Without it we'd be stuffed. It helped us focus on producing quality product."
>
> "AS4454 is not strict enough to meet future needs. Niche markets will increasingly be developed requiring tighter specifications."

8. Poor quality product is probably the main factor hindering market development in agriculture. However, better education of the agricultural industries on the potential contribution of RO products to soil health and productivity is also very important as this could help drive change in the RO sector.

- Market-driven quality criteria and product specifications are likely to be a much more effective motivator for renewed focus on fit-for-purpose specifications than regulations primarily focussed on environmental and public health "protection".

9. In general, the agricultural industries:

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[32] A company that takes compost from another supplier and value adds to it before marketing to agriculture.

[33] It is not surprising given the historical link between local government (the main customer) and waste management companies (as the service providers). After all, one of the main services provided by local government to residents is waste disposal. In this scenario, compost quality risks playing second fiddle to the waste disposal service

- Lack confidence in the benefits that can be derived from use of RO products compared to purchase, transport and application costs (benefit cost ratio).
- Do not always have access to product because of unviable transport distances.
- Have the perception that RO products are low in value and therefore too costly[34].
- Are concerned about the risk of contamination.
- Prefer manure derived products since they are derived from known sources.

"Compost quality is of paramount importance to market development."

10. The RO industry is not always well equipped to engage effectively with agricultural markets.

    - It is impossible to effectively market to the agricultural industries when compost quality is not given the highest priority. The best salespeople with knowledge of agronomy and soils soon become disillusioned and will realise that their talents are best served elsewhere.
    - This is not always a problem provided that the RO supplier acts as a wholesaler by supplying a base product to a secondary processor who has the expertise and networks to market to the agricultural sector.
    - There is a general lack of reliable data on quantifiable agronomic and economic benefits. The RO industry therefore relies often on anecdotal information or questionable science.
    - The RO industry does not generally provide detail on product quality, recommended uses, or benefits associated with their use.

Conclusions

The main issues that have emerged from this analysis are as follows:

1. Compost quality is of paramount importance to market development.
2. A justifiable price that reflects agronomic and economic benefits from using RO products is key to farmers making purchase decisions.

[34] On the other hand, some farmers are willing to pay high prices for good quality product from a trusted supplier.

3. Organics processing guidelines are primarily focussed on environmental impacts of the facility and have little direct impact on compost quality.

4. Over-zealous regulation of organics processing facilities risks restricting Australia's processing capacity, especially as FOGO is rolled out.

5. Over-zealous regulation of organics processing facilities fails to recognise that organic amendment of soils is critical to the future of Australian agriculture and climate change adaptation.

6. Physical and chemical contamination is by far the biggest hindrance to market development. Roll-out of FOGO collections are ill-advised in situations where GO contamination is not already under control[35].

7. Composts derived from FOGO are also classified as restricted animal material (RAM) and must comply with the ruminant feed ban when used in agriculture.

8. A major determinant of compost quality is the quality of the feedstock ("rubbish in, rubbish out"). Yet, commitment to contaminant control in feedstock varies across the country.

9. Physical and chemical contaminant limits in AS4454 and the organics processing guidelines do not reflect real-world perceptions and risk factors.

10. As it stands, AS4454 will continue to be of limited value in supporting market confidence in RO product quality but can continue to serve as a minimum quality requirement for RO products ('the first hurdle to be taken').

11. An industry paradigm shift from "waste management" to "compost production" is required to give greater emphasis to compost quality and the development of fit-for-purpose products.

[35] Fix contamination in GO first since the challenges associated with FOGO will be greater.

A Future Vision for Organics Recycling

The Australian states and territories have vastly different approaches to feedstock control, and support for genuine source separation has been inconsistent and patchy across the country. A national approach to compost quality could help address one of the major issues identified in this study, *viz.*, uncertainty around how best to manage emerging chemical contaminants. Having a uniform approach to feedstock classification and risk, and identifying which inputs are allowed (or prohibited) could simplify requirements for end-product testing since both physical and chemical contaminants are best controlled at source[36].

"Having a uniform approach to feedstock classification and risk, and identifying which inputs are allowed (or prohibited) could simplify requirements for end-product testing since both physical and chemical contaminants are best controlled at source."

. From waste…

We have discussed previously how the RO industry, and indeed the whole organics recycling supply chain, needs to rebrand itself by switching from the "waste management paradigm" to one of "compost production". We believe this is fundamental to placing compost quality as the number 1 goal for any RO processing system.

The waste management paradigm's main emphasis is on waste treatment and disposal. The main factors indicating that this is the dominant paradigm for a given RO recycling system are when:

1. There is insufficient investment in education and promotional programs by local government in source separation.
2. In establishing an organics recycling system, local governments seek the lowest possible price.
3. RO processing guidelines permit potentially hazardous industrial waste streams to be processed.

[36] A contaminant only needs to be tested for if it is likely to be present in the feedstock.

4. A facility is willing to process high risk feedstocks even though they may negatively impact end-product quality.
5. The end-product contains physical impurities (and possibly chemical contaminants) and therefore attracts a low-price in the market.
6. Processors do not have in place systems for quality control of feedstock (e.g., to reject non-compliant batches of feedstock).
7. Processors have no or minimal quality control and management systems in place for RO products with only occasional product testing.
8. With few exceptions, processors have no or minimal knowledge of what constitutes quality compost.
9. With few exceptions, processors have no or minimal knowledge of diverse market requirements.
10. There is insufficient investment in contaminant removal technologies at the processing facility.
11. Supply chain relationships for the end-product are weak. Short-term disposal of product is emphasized rather than building long-term markets through trust.
12. There is little consideration for farmer's needs and the problem they aim to overcome (e.g., soil constraints) by using compost.
13. There is little product development and differentiation between grades of compost based on maturity.
14. There are stockpiles of end-product for which a market cannot be found.[37]

…to product

In contrast, the compost production paradigm contains the following elements:

1. Tight controls on feedstock quality, encompassing:

[37] It should be noted that stockpiles are a major source of odour and put processing facilities at risk of being shut down.

a) Clear regulations by government on which waste materials are acceptable feedstocks for composting and which are not.

b) Clear emphasis on removing contaminants at the source with on-going investment in programs to educate waste producers (e.g., urban residents, food outlets) and enforce compliance.

c) RO processors have feedstock quality control systems in place at the gate to the facility. Non-compliant feedstock batches are rejected and become the responsibility of the waste generator or transporter.

2. A real circular economy approach in which all supply chain partners, including farmers, can derive tangible benefits from organics recycling. Farmers pay a fair price that reflects the agronomic and economic benefits they can derive from using RO products. All other costs are borne by waste generators.

3. An unwavering commitment by RO processors to produce the highest possible quality product[38] backed up by a recognized quality assurance system encompassing third party certification.

4. Markets developed on the back of strong relationships of trust between supplier and end user in which:

   a) The supplier seeks to understand the needs and production system constraints of the end user.

   b) Fit-for-purpose products are produced meeting a specific need in the market.

   c) The supplier provides the end-user with information on feedstock materials used, current laboratory analysis, and best practice handling, storage and use of the product for target applications.

All stakeholders in the organics supply chain have a role to play in moving to the new paradigm; it is not just the responsibility of industry. Governments have a particular role to play by developing policy settings that incentivize the move for a more sustainable footing for the RO sector. Local government authorities hold pivotal roles on both the supply and demand side of the organics recycling supply chain, that will decide about success or failure of organics recycling schemes, and also have a major impact on whether Target 6 will be met or not.

[38] In this context this means that the product is both clean, safe and fit-for-purpose.

End of waste code for compost

What is it?

An end of waste (EoW) code for compost could be developed at the national level to support the roll-out of the new paradigm in each state/territory. An EoW code clearly defines the criteria by which a waste product is no longer considered a waste and is not subject to further waste management controls (WRAP 2012).

A national EoW code could provide the over-arching framework for this whilst still providing individual jurisdictions with flexibility in how it is delivered. The intent of such an approach is to provide greater regulatory certainty for processors and increased confidence in the marketplace. Processors may be encouraged to seek certification to an EoW code if doing so resulted in reduced regulatory burden (e.g., with respect to product testing requirements, controls around application to land or for establishment of new facilities), whereas controls over the operation of non-compliant processors could be increased[39].

An EoW code for compost would encompass all aspects of sourcing and processing organic waste materials, as well as the supply of RO products, hence facilitate and provide the framework for an overarching quality assurance scheme (Figure 5). For example, local government could be incentivized to provide clean feedstock through various means such as:

- Financial support for the maintenance of educational programs on source separation.
- A requirement that feedstock supply contracts contain penalties for delivery of non-compliant batches to processors.
- Uniform end-product buy-back policies rolled out across local government areas[40].

Components of an EoW code for compost

EoW codes for compost have been developed for the United Kingdom and other parts of Europe (WRAP, 2012; Biala and Wilkinson, 2020). The European Compost Network has also been a driving force in developing EoW criteria for the whole of the European Union (Saveyn and Eder, 2014).

[39] We recognize that increased regulation is inevitable in some areas, but not necessarily across the board.
[40] The RO sector has long campaigned for local government buy-back policies to be adopted. We support this because local government is principally responsible for ensuring that clean feedstock is collected from kerbside. If Councils are committed to buying back some of the end-product for use in their parks and gardens, they are more likely to be motivated to improve the quality of feedstock.

For a compost to meet an EoW code it must:

- Be manufactured from source-separated biodegradable waste only.
- Be made from feedstocks taken from an approved list of allowable inputs (in the case of the UK; WRAP, 2012 and in the case of Germany see Biala and Wilkinson, 2020), *or else* they must not be made from any feedstock found on a list of prohibited materials (as per the European Compost Network proposal; Saveyn and Eder, 2014).
- Meet the requirements of an approved standard for use in the market it is destined for and have third-party accreditation for meeting standard requirements.
- Be destined for appropriate use in a designated market sector (as defined by the code[41])
- Not require further processing including maturation or re-screening for use in a designated market sector.
- Meet any additional customer specifications, as agreed between the supplier and the customer.

In the UK, EoW compliant producers must demonstrate that these criteria have been met. They must do this by:

- *"Obtaining certification from an approved certification body; and*
- *Producing and keeping copies of customer supply documentation that includes a declaration that the quality compost meets the approved standard, the Quality Protocol[42] and any additional customer specifications (as agreed between the supplier and the customer)."*

"We recommend that a national approach be taken to develop an end of waste code for compost."

[41] Designated markets include, land restoration, "soft" landscaping, horticulture (including domestic), agriculture and forestry.
[42] A Quality Protocol in the UK defines the requirements for their EoW codes.

Figure 5: Integration of End-of-Waste criteria into European Compost Network quality assurance scheme [Source: Siebert 2019]

Progress towards EoW code for compost in Australia

We recommend that a national approach be taken to develop an end of waste code for compost.

As it stands, Australian states have some, but not all, of the desired elements of an EoW code for compost. For example:

- The Victorian RO processing guideline considers that "*composts, soil conditioners and mulches produced from suitably composted materials that meet the general requirements of AS 4454*" … "*are regarded as a genuine product and not as a waste*".
- The SA guideline covers only a list of approved feedstocks. Mineral-based industrial waste and grease trap waste must follow a different guideline (Standard for the production and use of waste derived soil enhancer, EPA 2010).
- Queensland currently has an EoW classification system, but it is applied to individual waste materials, some of which may be feedstocks for composting, but there is no EoW code for compost products as a whole.[43]
- The "Orders and Exemptions" system in NSW places reduced regulatory controls over land application of approved products originally derived from waste materials. For example, an Order and Exemption exists for compost as well as for pasteurised garden organics.[44]
- Proposed new WA guidelines are expected to set feedstock and end of waste requirements.

[43] The new draft Qld guidelines now has a list of prohibited waste streams that cannot be composted.
[44] See here Current orders and exemptions (nsw.gov.au)

A national approach to an EoW code for compost could help address many of the major issues identified in this study, including variable feedstock classification and risk, source separation and emerging contaminants.

"A national approach to an EoW code for compost could help address many of the major issues identified in this study, including variable feedstock classification and risk, source separation and emerging contaminants."

Other key elements of an EoW code that are currently missing in Australia include:

- A consistent approach to third-party certification since AS4454 is only a voluntary standard.
- Providing an unambiguous legal status to RO product quality specifications, either through AS4454 or other means (if through other means, limit values have to reflect AS4454 limits).
- Declaration of feedstock material categories that were used for producing compost products.
- Lack of consistent information on end-product specifications and guidelines for use in the major market sectors[45].

Making a quality, fit-for-purpose product is not just about compliance to an end-product standard like AS4454. Rather, it involves the whole operation from the control of feedstock quality through to provision of appropriate documentation and advice to end users. An EoW code for compost should therefore involve third-party certification for the whole operation[46].

"Making a quality, fit-for-purpose product involves the whole operation from the control of feedstock quality through to provision of appropriate documentation and advice to end users. An EoW code for compost should therefore involve third-party certification for the whole operation."

Next level third-party certification

"I think a third-party certification system should encompass the whole operation as part of a best management practice program. There are good examples of this in the agriculture sector, for example the Smartcane BMP (for sugarcane) and the myBMP program for cotton."

[45] The UK Quality Protocol also includes various codes of practice and other guidance materials for handling, storage and application of RO products to land.
[46] This is essentially what the UK Quality Protocol does as well.

At the present time in Australia, only bagged products or a few good, low volume products are certified, while the large bulk of lower-quality product is supplied into the market without certification. Whole facility certification under a national EoW code would, among other things, also require that processed feedstocks be disclosed, helping to enforce regulatory limitations of allowable feedstock.

A distributed network of RO processing facilities servicing farm and city

From a circular economy perspective, RO products made from food should be returned to the land, ideally back to the soil used to grow it. All supply chain partners need to be able to derive tangible benefits, ensuring that the circular economy for organics is driven by economic motives. The agricultural industries already derive benefit from the return of farm-derived organic matter (e.g., manures and effluents) back to land.

Farm waste, such as manure, and urban-derived organic materials can be complementary.[47] Yet there is little cross-over between the two systems. Previous attempts to conduct on-farm composting with kerbside collected GO[48] have often failed due to high rates of physical contamination, reinforcing the view of farmers that they should not be a "dumping ground" for the city's waste. The success of city to farm composting projects has also been undermined in some cases by poor process control. Yet, there are also examples of successful on-farm composting trials in Australia (e.g., Biala 2003), and on-farm composting of FOGO in regional areas is an integral part of Austria's strategy of successfully managing organic waste (Amlinger et al., 2009).

There is also a clear need to increase future processing capacity for organics. One way to do this is to establish a distributed network of facilities across regional areas.

"An effective EoW code is a necessary condition for making a success of any distributed network of organics recycling facilities."

A distributed network of organics recycling facilities is an opportunity to:

- Reduce the regulatory pressure associated with the location of organics recycling facilities around urban areas.

[47] RO products derived from FOGO can be low in nutrients, whereas manures typically have a relatively high nutrient content.
[48] Pasteurised GO ("hot mix") has often been delivered to farm for the completion of composting.

- Increase processing capacity for composting. Processing capacity must keep pace with supply of feedstock.
- Process both farm-derived and urban-derived materials thereby providing an organics processing service to both agriculture and the city.
- Integrate organics processing more closely with agriculture to assist in the beneficial use of products back to farm that truly meet the needs of the market.
- Bring the supply of product closer to market.

The EoW code has all the elements needed in support of quality compost production and marketing. An effective EoW code is therefore a necessary condition for making a success of any distributed network of organics recycling facilities.

Conclusions and Recommendations

An integrated approach to organics recycling

Realising the full potential of organics recycling requires an integrated approach to policy development across all levels of government in Australia. Such an approach is essential if we are to remain committed to the application of circular economy principles, which entail fundamental systemic change in business and industry operations. One could argue that an integrated approach is sadly lacking at present since the main driver for organics recycling in much of the country continues to be the provision of waste management services to the community by local government.

We are cognizant of the challenges involved since a truly integrated approach to organics recycling would cover a wide range of policy areas, including:

- Waste management.
- Funding of sustainable organics recycling supply chains.
- Environmental protection.
- Resource conservation.
- Food packaging.
- Climate change.
- Agricultural policy.
- Public health and safety.
- Consumer protection.

> **Support for a consolidated approach from regulators**
>
> "We need a national framework around feedstock and end of waste. We have consistent requirements nationally for other products- why not compost?”
>
> “Jurisdictions are all different with different requirements and different levels of action. We need a consolidated approach.”

“The role of individual jurisdictions should remain at the facility level (i.e., environmental performance of the site), whereas the federal government should lead in the development of the overarching policy framework.”

We suspect that policy development in this space has not necessarily been based on a sound evidence base since individual States approach the regulation of organics recycling so differently. A case in point is the way in which different jurisdictions approach risks associated with feedstock. No justification is given in organics processing guidelines as to how feedstock is classified, and as a result, the differences between jurisdictions are stark. Yet, the quality of feedstock has a profound effect on compost quality. It follows that compost quality will have a profound effect on market development and the nation's ability to meet Target 6 of the National Waste Policy Action Plan.

A consistent approach to the evidence base on which individual regulations are based is urgently needed. The evidence base must also include risk factors associated with end-product use, not just environmental performance at the level of processing facility. A consistent approach to the evidence base would not necessarily hinder the capacity of individual jurisdictions to innovate in regulating organics processing.

National coordination

There is a clear coordinating role for the federal government in setting the agenda at the national level. The role of individual jurisdictions should remain at the facility level (i.e., environmental performance of the site), whereas the federal government should lead in the development of the overarching policy framework. An ideal model for this is to follow the concept of an end of waste code for recycled organics. The end of waste concept is increasingly being recognized in many jurisdictions, but we have identified specific requirements that should apply for organics recycling.

A piecemeal approach to the roll-out of programs to promote organics recycling is inefficient. Of particular concern is the significant investment being made in some areas without having addressed 'the elephant in the room', *viz.* physical and chemical contamination. If systems are not currently working effectively to manage contaminants in GO, then there is every reason to be concerned that they will be overwhelmed as FOGO collections begin to be rolled out across the country. Similarly, we see no real value in promoting the use of RO in agriculture unless the issue of contamination is dealt with. It is unrealistic to expect there to never be issues associated with contamination, but every effort must be made to minimise the problem. Controlling feedstock quality at source will go a long way to minimising contamination risks associated with the use of RO products. Experience from Europe suggests that contamination risks are less of a concern where appropriate feedstock controls are in place.

A regulator's opinion on the importance of national legislation

"We need a nationally driven legislative approach like Europe with the EU landfill target set in legislation. Having a strategy is great but it is not a requirement. Most are aware but there is not the drive to action. More effort to diversion will happen if its targeted and legislated nationally. We need a consolidated approach."

"Our first, and most important recommendation, is for the federal government to explore ways in which an integrated and consistent approach to organics processing could be developed based on the model of an end of waste code."

An effectively functioning organics recycling system requires federal leadership. For this reason, our first, and most important recommendation, is for the federal government to explore ways in which an integrated and consistent approach to organics processing and generating RO products with low contamination could be developed based on the model of an end of waste code (EoW) for compost as outlined in this report. This is an ambitious recommendation, but it is not completely without precedent considering the initiative made by the federal government in areas such as setting national guidelines for recycled water and biosolids.

As discussed, for a product to meet an EoW code it must:

- Be manufactured from source-separated biodegradable waste only.
- Be made from feedstocks taken from an approved list of allowable inputs, *or else* they must not be made from any feedstock found on a list of prohibited materials.
- Meet the requirements of an approved standard (e.g., AS4454) for use in the market it is destined for and have third-party accreditation for meeting standard requirements.

"An effective EoW code involves the implementation of best practice across the whole organics recycling supply chain – not just end-product quality."

- Be destined for appropriate use in a designated market sector (as defined by the code).
- Not require further processing including maturation or re-screening for use in a designated market sector.
- Meet any additional customer specifications, as agreed between the supplier and the customer.

An effective EoW code involves the implementation of best practice across the whole organics recycling supply chain – not just end-product quality. EoW compliant organics recyclers are therefore certified to a whole-of-business quality management system by an approved third-party auditor. Furthermore, it would place responsibility for feedstock quality on suppliers of raw materials used for composting.

We recommend that the federal government establishes a national committee to drive change and to ensure buy-in from all key stakeholders in the development and implementation of an EoW code for compost.

"Establish a national committee to drive change and to ensure buy-in from all key stakeholders in the development and implementation of an EoW code for compost."

Tier 1 supporting recommendations

The following recommendations are essential for the development of a sustainable organics recycling industry, whether or not an EoW code for compost is developed. They are:

- Develop a consistent approach to source separation for kerbside organics.
  - Standardisation of what can and cannot go into FOGO bins,consistent labelling and signage and the roll out of an adequate education program (for the householder and commercial food outlets).
  - Review and revise (as necessary) the national FOGO Best Practice Collection Manual in consultation with the States.[49]
- Initiate a federally funded research program to develop a consistent approach regarding feedstock and contaminant risk.
  - To develop a common understanding of what feedstocks can and cannot be recycled.
  - Identify biological, chemical and physical contamination risks associated with common feedstock types, and the most effective means of controlling them.
  - To address the real or perceived risk associated with restricted animal material (RAM) in organics processing and use.[50]
  - Update contaminant limits to reflect actual risk factors in the feedstocks approved for recycling[51]. Any new limits must be supported by scientific evidence which requires

A processor's view

"We need a National Anti-Contamination Campaign rather than a National Market Development Campaign."

[49] FOGO Best Practice Collection Manual. First written by Hyder in 2012 for the federal government.
[50] A quantitative risk assessment could be conducted like the one conducted by Gale (2004) in the UK.
[51] This task is made more manageable by having a clear position on what can and cannot be recycled in the first place.

new research to be conducted. Reliance on the consensus of experts alone (i.e., with the supporting research) is unlikely to succeed.

- Investigate approaches to incentivize waste generators to take ownership of the contamination issue in kerbside and drop-off collected organics.
  - Funding incentives to promote RO buy-back policies by local government.
  - Develop legislative tools to give processors confidence that they will not be penalized for rejecting contaminated feedstock delivered under contract from local government.
  - Ensure council by-laws allow flexible approach that can deliver desired outcomes.
  - Contaminant control systems combined with "carrot" and "stick" measures to incentivize residents and businesses to take ownership of the contamination issue in kerbside collection. For example, rebates for residents participating in kerbside source separation training programs. Stick measures could include barcode technology on bins and readers on trucks so non-compliant loads are not picked up and go to landfill at higher costs.
  - Truthful information from all levels of government to waste generators (residents and food outlets) that improved recovery and recycling of organics will not be cheaper than landfilling but cost more because it delivers improved outcomes.

Tier 2 supporting recommendations

Tier 2 recommendations follow the implementation of Tier 1 recommendations. They are not necessarily less important, but Tier 2 recommendations will be undermined without Tier 1 recommendations also being implemented.

- Update and expand state-based organics processing guidelines:
  - To reduce barriers of entry for smaller regional organics processing facilities.
  - To develop and promote best practice in on-farm co-composting of agricultural and municipal organic residues.
  - To cover anaerobic digestion and the beneficial use of digestate.
- Conduct a study to consider what a distributed network of OR facilities might look like in each State.

    - Considering combinations of municipal and agricultural organics, collection systems, processing technologies, secondary processing (i.e., value-adding) and end markets.
    - Considering opportunities for integration with distributed energy systems (e.g., on-farm anaerobic digestion).
- Initiate a federally funded research and extension program on the use of RO in agriculture to develop fit-for-purpose product specifications and end-product guidelines for specific applications and markets, including the use of lower grade RO products (B grade compost) for example in remediation projects.
    - Consider opportunities for delivery, e.g., through the CRC program.
    - Opportunities for integration of RO product use into the National Soil Research, Development and Extension Strategy.
- Establish a Compost Knowledge Hub that will collate, host and disseminate independent and un-biased information of a scientific and practical nature specifically for current and potential future users of RO products.

References

AEAS [Australian Economic Advocacy Solutions] (2020). The economic contribution of the Australian organics recycling industry. Report published by the Australian Organics Recycling Association, Hove, SA

AHA [Animal Health Australia] (2019). Australian Ruminant Feed Ban National Uniform Guidelines 2019-20.

Amlinger F., Peyr S., Musken J., Cuhls C., Clemens J. (2009). The State of the Art of Composting. A guide to good practice. Austrian Ministry for Agriculture and Forestry, Environment and Water Management.

AORA/ABA [Australian Organics Recycling Association / Australasian Bioplastics Association] (2018). Joint Position Paper Certified Compostable Bioplastics. https://www.aora.org.au/sites/default/files/uploaded-content/website-content/180503-certified-compostable-plastics-position-joint-policy-statement.pdf Accessed 22 May 2021

APCO [Australian Packaging Council Organisation] (2021). National Compostable Packaging Strategy. https://documents.packagingcovenant.org.au/public-documents/National%20Compostable%20Packaging%20Strategy Accessed 20 June 2021

ASTM Standard D6400 (2004). "Standard Specification for Compostable Plastics." ASTM International. West Conshohocken, PA, USA. DOI: 10.1520/D6400-04. www.astm.org.

Bernal M.P., Sommer S.G., Chadwick D., Qing C., Guoxue L., Michel F.C. Jr. (2017). Current approaches and future trends in compost quality criteria for agronomic, environmental, and human health benefits, Advances in Agronomy, 144: 143 – 233

Biala J. (2003). On-farm composting of municipal and commercial organics as an environmentally and socially sustainable resource recovery scheme for rural communities. Report for Environment Australia, Natural Heritage Trust, Canberra, Australia

Biala and Wilkinson (2020). International comparison of the Australian Standard for Composts, Soil Conditioners and Mulches (AS4454 – 2012). Report for the Australian Organics Recycling Association.

Biala J., Pandey A., Wong J. (2021). Options for improving the quality of source separated food and garden organics. Presentation given at the International Conference on Sustainable Biowaste Management, Hong Kong, 12-15 April

BIS (2011). PAS 100:2011 Specification for composted materials, British Standards Institution, London, UK

BIS (2014). PAS 110:2014 Specification for whole digestate, separated liquor and separated fibre derived from the anaerobic digestion of source-segregated biodegradable materials, British Standards Institution, London, UK

Bläsing M., Amelung W. (2018). Plastics in soil: analytical methods and possible sources. Science of the Total Environment 612: 422 – 435

Brown, S, 2019. Personal communication, Research Professor, University of Washington, Seattle, USA

Burgstaller M., Potrykus A., Weißenbacher J., Kabasci S., Merrettig-Bruns U., Sayder B. (2018). Gutachten zur Behandlung biologisch abbaubarer Kunststoffe (Assessment of the treatment of biodegradable plastics). Published as Texte 57/2018 by Umweltbunddesamt (German Federal Agency for the Environment), Dessau-Roßlau, Germany.

Canadian Council of Ministers of the Environment, 2005. Guidelines for Compost Quality PN 1340, Winnipeg, Manitoba, Canada

Clarke B.R.; Smith S.R. (2011). Review of 'emerging' organic contaminants in biosolids and assessment of international research priorities for the agricultural use of biosolids. Environment International 37: 226–247

CORC [California Organics Recycling Council] (2011). Compostable plastics 101. https://cdn.ymaws.com/uscc.site-ym.com/resource/resmgr/images/Compostable_Plastics_101_Pap.pdf. Accessed 20 May 2021

DAWE [Department of Agriculture, Water and Environment] (2020). National Waste Report 2020. Prepared by Blue Environment Pty Ltd.

Downes J., Borg K., Florin N. (2021). A type of 'biodegradable' plastic will soon be phased out in Australia. That's a big win for the environment. The Conversation: 9 March 2021. https://theconversation.com/a-type-of-biodegradable-plastic-will-soon-be-phased-out-in-australia-thats-a-big-win-for-the-environment-156566. Accessed 20 May 2021

EcoRecycle Victoria (1998). Guide to best practice – Composting green organics. EcoRecycle Victoria, Melbourne.

EPA [Environment Protection Authority] (2000). Environmental guidelines: Use and disposal of biosolids products.

EPA [Environment Protection Authority] (2017). Guidelines for the safe handling and reuse of biosolids in South Australia. EPA South Australia, Adelaide.

EPA [Environment Protection Authority] (2010). Standard for the production and use of waste derived soil enhancer. NSW EPA, Sydney.

Freshcare (undated). Using compost safely – a guide for the use of recycled organics in horticulture. https://www.freshcare.com.au/wp-content/uploads/Compost-Factsheet-Growers.pdf Accessed 13 May 2021

Fricke K. and Vogtmann H. (1990). Qualität von Bioabfallkompost [Quality of compost from source segregated garden and kitchen organics]. 109 – 154 in: K. Fricke, T. Turk and H Vogtmann (eds): Grundlagen der Kompostierung, EF-Verlag für Energie und Umwelttechnik, Berlin, Germany.

Gale P. (2002). Risk Assessment: Use of Composting and Biogas Treatment to Dispose of Catering Waste Containing Meat. Contract Report no. 12842-0. Marlow, Bucks, UK: Wrc-NSF Ltd.

German Compost Quality Assurance Association (2014). Kompostierung von 'Biokunststoffen' ist ein Irrweg [Composting of bioplastics is misguided] https://www.kompost.de/fileadmin/user_upload/Dateien/Themen_Positionen/5.4.1_Position-BAW_2014_final.pdf Accessed 21 May 2021

German Compost Quality Assurance Association (2018). Kunststoffe in Kompost und Gaerproduckten [Plastic in compost and digestate] https://www.kompost.de/fileadmin/user_upload/Dateien/HUK-Dateien/2018/Q4_2018/Kunststoffe_in_Kompost_und_Gaerprodukten_HUK_Q4_2018.pdf Accessed 14 May 2021

German Compost Quality Assurance Association (undated). Schwellenwerte und Grenzwerte (Gütesicherung Kompost) [Threshold values and limits (Compost Quality Assurance)] https://www.kompost.de/fileadmin/user_upload/Dateien/Guetesicherung/Dokumente_Kompost/Dok._251-006-4_Schwellen_Grenzwerte.pdf Accessed 22 April 2021

German waste and bio-waste management associations (2019). Position Statement on the disposal of biodegradable plastics through bio-waste treatment (composting and anaerobic digestion). https://www.kompost.de/fileadmin/user_upload/Dateien/HUK-Dateien/2019/Q2_2019/Position_Verbaende_BAK_englisch-final_2019_07_09.pdf Accessed 21 May 2021

Greendot bioplastics (undated). A straightforward explanation of biodegradable vs. compostable vs. oxodegradable plastics. https://www.greendotbioplastics.com/biodegradable-vs-compostable-vs-oxo-degradable-plastics-a-straightforward-explanation/. Accessed 20 May 2021

Hann S., Scholes R., Molteno S., Hilton M., Favoino E., Geest Jakobsen L. (2020). Relevance of biodegradable and compostable consumer plastic products and packaging in a circular economy. Report for the European Commission, DG Environment, Publications Office of the European Union, Luxembourg

Hazeldine, M. (2019 & 2021). Personal communication, Client Manager, Product Certification, SAI Global, Port Melbourne, Victoria

He D., Luo Y., Lu S., Liu M., Song Y., Lei L. (2018). Microplastics in soils: Analytical methods, pollution characteristics and ecological risks. Trends in Analytical Chemistry 109: 163 -172

Huerta-Pujol O., Gallart M., Soliva M., Martínez-Farré F., López M. (2011). Effect of collection system on mineral content of biowaste. *Resources, Conservation and Recycling*, 55: 1095-1099.

Johnson A. (2021). 0.25% by 2025. Presentation given at the 2021 Annual AORA Conference, Lovedale, NSW, 15-17 June 2021.

Kehres B. (2017). Anforderungen and die Sortenreinheit von Bioabfällen [Requirements concerning the purity of FOGO feedstock]. 5-9 in: Bayrisches Landesamt fuer Umwelt (Hrsg): Strategien zur Fremdstoffreduktion im Biogut – Praxiserfahrungen und Empfehlungen, Augsburg, Germany

Kern M. (2017). Biogutqualitaet in Deutschalnd – Ergebnisse aus Biogutanalysen [FOGO audits reveal FOGO quality in Germany]. 10-28 in: Bayrisches Landesamt fuer Umwelt (Hrsg): Strategien zur Fremdstoffreduktion im Biogut – Praxiserfahrungen und Empfehlungen, Augsburg, Germany

Kern M., Koj U., Turk T. (2017). Vergleichende Betrachtung und Bewertung der öffentlich-rechtlichen Entsorgungsträger mit erlaubtem bzw. untersagtem BAW-Biobeuteleinsatz [Comparison and assessment of German public waste management authorities allowing or banning compostable plastic bags for organic waste collection] Müll und Abfall 9-17: 451-455

Kern M., Neumann F., Siepenkothen H-J., Turk T., Löder M. (2020). Kunststoffe im Kompost – Praxisversuche zur Bestimmung der Polymerzugehörigkeit [Plastics in compost - Practical tests to determine polymer affiliations] Müll und Abfall 5-20: 245-251

Nizzetto L., Futter M. Langaas, S. (2016). Are agricultural soils dumps for microplastics of urban origin? Environ. Sci. Technol. 50: 10777 - 10779

NSW EPA (2021). NSW organics collection services map. https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/wasteregulation/fogo/map-organics-collections-2021.pdf?la=en&hash=690BF0E111556A2F1C15EB7CCF1F041CCCBA2A3E Accessed 19 June 2021.

Olah P. (2021). Organics recyclers are ready and able: AORA. Waste Management Review.

PFAS NEMP [National Environmental Management Plan] Version 2.0 (2020). Heads of EPA Australia and New Zealand.

Piehl S., Leibner A., Löder M.G.J., Dris R., Bogner C., Laforsch C. (2018). Identification and quantification of macro- and microplastics on an agricultural farmland. Scientific Reports 8:17950

Queensland Department of Environment and Science 2020. End of Waste Code Biosolids. https://environment.des.qld.gov.au/__data/assets/pdf_file/0029/88724/wr-eowc-approved-biosolids.pdf Accessed 14 April 2021

Recycled Organics Unit 2013. Organics recycling in Australia: Industry statistics 2012

Rillig M.C. (2018). Microplastic disguising as soil carbon storage. Environ. Sci. Technol. 52: 6079 – 6080

Saveyn H. and Eder P. (2014). Technical proposals for end-of-waste criteria for biodegradable waste subjected to biological treatment (compost & digestate), JRC Scientific and Policy Reports, European Commission, EU Report 26425 EN

Scalenghe R. (2018). Resource or Waste? A perspective of plastics degradation in soil with a focus on end-of-life options. Heliyon 4, e00941

Siebert, S., 2019. European biowaste management and the new EU Fertilising Product Regulation, presentation given 4 June 2019

Thelen-Jüngling, M. (2008). A new method for evaluation of impurities in compost, 195 - 196 in: Fuchs J. G., T. Kupper, L. Tamm and K. Schenk (eds.): Compost and digestate: sustainability, benefits, impacts for the environment and for plant production. Proceedings of the International Congress CODIS 2008, February 27-29, Solothurn, Switzerland

Tremblay L.A., Gielen G., Northcott G.L. (2014). Organic materials guidelines – Organic contaminants review, Centre for Integrated Biowaste Research (CIBR), Nelson, Rotorua and Hamilton, New Zealand

US EPA, 1994. A plain English Guide to the EPA Part 503 Biosolids Rule. https://www.epa.gov/sites/production/files/2018-12/documents/plain-english-guide-part503-biosolids-rule.pdf Accessed 22 April 2021

VORRS [Victorian Organics Resource Recovery Strategy] (2015). Sustainability Victoria, Melbourne.

Watteau F., Dignac M.-F., Bouchard A., Revallier A., Houot, S. (2018). Microplastic detection in soil amended with municipal solid waste composts as revealed by transmission electronic microscopy and pyrolysis/GC/MS. Frontiers in Sustainable Food Systems 2:81

Weithmann N., Möller J. N., Löder M. G. J.,Piehl S., Laforsch C. Freitag, R. (2018). Organic fertilizer as a vehicle for the entry of microplastic into the environment. Science Advances 4 (4) eaap8060

Williams R. (2020). Bioplastics? Presentation given at AORA Members Webinar, August 27th. https://bioplastics.org.au/wp-content/uploads/2020/09/ABA_AORA-Webinar-20200827_RWilliams.pdf Accessed 20 May 2021

Wilkinson K., Biala J., Schliebs D. and Hazell L. (2019). Critical evaluation of composting operations and feedstock suitability, Phase 2 report – Contamination issues. Report by Arcadis for Department of Environment and Science, Queensland.

Wilkinson K., Paulin R., Tee E., O'Malley P. (2002). Grappling with compost quality down-under, 527 – 539 in: S.C. Michel Jr, R.F. Rynk, H.A.J. Hoitink (eds): Proceedings of the 2002 International Symposium on Composting and Compost Utilization. 6–8 May 2002, Ohio State University, Columbus, USA

WRAP [Waste and Resources Action Programme] (2012). Quality Protocol Compost – End of waste criteria for the production and use of quality compost from source-segregated biodegradable waste. Environment Agency, Branbury, UK.

Zhang G., Liu Y. (2018). The distribution of microplastics in soil aggregate fractions in southwestern China. Science of the Total Environment 642: 12 - 20

Appendix 1: Stakeholder Engagement

Principal Aim of Stakeholder Engagement: In the view of stakeholders, do current policy settings and quality standards for organics facilitate end-product confidence, market development and governments' ability to achieve Target 6.

Sub-Aims: To seek stakeholder views on:

- The status of organic recycling in the State - what works well, and challenges.
- Whether the current arrangements for QA of recycled end products are sufficient for future needs.
- What an ideal organic recycling system looks like.
- Barriers and opportunities to achieve a sustainable OR industry.
- The needs of different stakeholders across the recycled organics supply chain.

Questions for government agencies

Objective questions:

- What is the role of your agency in achieving Target 6 of the National Waste Policy Action Plan?
- What policy/programs/regulatory tools are used by the agency to help facilitate or regulate organic recycling?

Reflective:

- What is currently working well in your State?
- What do you see as some of the challenges associated with organic recycling?
- How is Target 6 affecting the way you operate now and how do you see it affecting you into the future?
- What is the relationship like between your agency and the RO industry?
- What do you feel about AS4454 as a quality standard?
- How comfortable are you with the current arrangements for QA of recycled end products?

Interpretive:

- What are the main constraints to diverting more organics from landfill?
- What do you see currently as the main constraints to making a success of organic recycling?
- Can you identify what are the main risks associated with RO product reuse?
- When is a recycled organic product no longer classified as a waste?
- What are the main challenges associated with end product use?
- Are current product quality standards sufficient to support future market development?

Decisional:

- What does a sustainable organic recycling system look like to you (from waste to end use)?
- What is stopping the development/implementation of such a system in your State?
- What needs to be done differently to achieve your ideal RO system?
- What are the priority steps for improving organic recycling in your State?
- Who should be responsible for facilitating and implementing these changes? What can government do? What can industry do?
- Do you do you think any of the following options could be used to improve RO processing and reuse?
    1. Better source separation
    2. Greater regulatory control over what feedstocks can be processed
    3. More research on identification and management of risk
    4. Third party certification of end products
    5. More rural and regional facilities (closer to end market)
    6. Development of improved product specifications and standards for fit for purpose products i.e., customised compost for agricultural use
    7. Research on end use cost:benefits
    8. Cost sharing arrangements for organic recycling considering a more equitable balance between public and private benefits
    9. Development of more targeted guidelines (e.g., covering technologies other than composting, or for on-farm composting)

Questions for processors

Objective questions:

- What is the current regulatory regime (guideline / license) under which you operate, and how does it affect the feedstock you process and the way in which you monitor / manage product quality?
- Which markets do you predominantly supply? (give percentage if possible)
- How do you monitor / manage end product quality?
- Are any of your RO products third-party certified against AS4454 or other recognised quality standards?

Reflective:

- How do you regard the current regulatory regime concerning its impact on end-product quality?
- What do you think of regulations that prevent certain feedstocks from being composted? (end of waste code for compost)
- Do you think that current regulations have any concern for, or impact end-product quality?
- Do you think AS4454 has helped or hindered the composting industry?
- Why do you think very little bulk compost is third-party certified and accredited?

Interpretive:

- What are the main hurdles to increase organics diversion, processing and use?
- What is the best way of preventing the need for permanent vigilance concerning existing, as well as new and emerging contaminants?
- What do you think of an end of waste code for compost?
- What would the financial implications be for your facility if you could no longer accept certain high contamination risks materials? (if applicable)
- What are the main challenges associated with end product use and expanding into existing / new markets?
- Are current product quality standards sufficient to support future market development?

Decisional:

As above for government agencies.

Questions for end-users (individuals and groups)

Objective:

- Do you use (or have you used?) composted soil conditioners (e.g., animal manures, composts, digestate etc.)
- What type of composted soil conditioners have you used?
- Do you know what is in composted soil conditioners?

If they do not use compost:

- Have you used or considered using composted products previously? If so, what type of products were they?

Reflective:

- What do you like about using composted soil conditioners?
- What benefits have you observed?
- Do you feel that the products you use meet your needs?
- Do you feel that the supplier of the product understands your needs?
- Do you have any concerns about product quality?
- Are you aware of certification schemes governing the quality of recycled organics?
- Are you aware if your products were quality assured?
- Would you use organics such as compost made from municipal Food Organics and Garden Organics?
- What concerns would you have when / if using FOGO compost?

If they do not use compost:

- What are the reasons why you don't use compost?
- What are your concerns with using recycled organic products?
- Why do you think recycled organics are not suitable products for you?
- Are you aware of certification schemes governing the quality of recycled organics?

- If you were to use compost, where would you use it on your farm and why?
- Would compliance with Aust Stds change your feeling about compost?

Interpretive:

- What would give you greater confidence with respect to product quality?
- Would certification provide you with more confidence to use such products?
- What additional information, if any, would you like to see supplied with recycled organics products?
- How important are product specifications to you?
- What information do you currently receive from suppliers of the product?
- Have you heard of AS4454?
- What does the Australian standards mean to you?
- Is compliance with the Australian standards important?

If they do not use compost:

- What would you need to know to overcome your concerns before using compost?
- Have you heard of AS4454?
- If so, what does the Australian standards mean to you?
- Is compliance with the Australian standards important?
- Would a customised product targeted to your needs overcome your concerns?

Decisional:

- What is holding farmers back from using more composted soil conditioners?
- Would a product guarantee or certification encourage greater use of composted soil conditioners?
- What can farmers do to encourage change?
- What would you want to see specified to make recycled organics more attractive?
- What would you want to see in an Aust Std or quality assurance program?

Do you do you think any of the following options (strategies) could help to increase reuse (or start using) of recycled organics?

As above for government and processors.

If they do not use compost:

- What would need to change for you to use compost?
- Would a product guarantee or certification encourage greater use of composted soil conditioners?
- What can farmers do to encourage change?
- What would you want to see specified to make recycled organics more attractive?
- What would you want to see in an Aust Std or quality assurance program?

Do you do you think any of the following options (strategies) could help to increase reuse (or start using) of recycled organics?

As above for government and processors.

Appendix 2: State-based organics processing guidelines

	South Australia	New South Wales	Victoria	Western Australia	Queensland
Guidelines	Compost guideline, EPA SA, Updated June 2019	Composting and Related Organics Processing Facilities, Department of Environment and Conservation NSW, July 2004	Designing, constructing and operating composting facilities Publication 1588.1* June 2017	Guideline Better Practice Composting, Government of Western Australia, Department of Water and Environmental Regulation, May 2020- External consultation	Guideline Open windrow composting Open windrow composting under environmentally relevant activity 53(a) Organic material processing by composting, Queensland Government Version 2.01 Effective: 23 NOV 2018
Scope	Includes: • open windrow • forced aeration • mushroom substrate • vermiculture. Excludes: • Bioremediation: see Soil bioremediation (EPA 2005). • Biosolids: see draft South Australian biosolids guideline for the safe handling and reuse of biosolids (EPA 2017).Where biosolids are used as a feedstock in composting the requirements specified	Includes: • aerobic processes (including windrow composting, static piles) • anaerobic processes (including facilities that employ digestion and fermentation technologies) • vermiculture • shredding and/or mulching processes • facilities involved in the preparation of mushroom growing substrate • organics processing facilities that	Includes: restricted to thermophilic, aerobic composting processes only. Excludes: It does not cover the entire range of organic waste processing activities that are scheduled under A07 in the Environment Protection (Scheduled Premises) Regulations 2017. • vermiculture • vermicomposting • anaerobic digestion, dehydration • or the composting of contaminated wastes for the purpose of bioremediation.	Includes: Compost manufacturing and soil blending: premises on which organic material (excluding silage) or waste is stored pending process, mixing,drying or composting to produce commercial quantities of compost or blended soils. Includes: • aerobic and anaerobic composting activities of organic material or waste and • includes anaerobic digestion. • It also relates to composting activities	Includes: Organic material processing by composting: Organic material means— a) animal matter, including, for example, dead animals, animal remains and animal excreta; or b) plant matter, including, for example, bark, lawn clippings, leaves, mulch, pruning waste, sawdust, shavings, woodchip and other waste from forest products; or includes: • a substance used for manufacturing fertiliser for agricultural, horticultural or garden use;

	in the biosolid guideline will be applicable. • Mulching, spread and shred applications of green waste, and the direct application of manure to land	incorporate a biological processing stage (e.g. mechanical–biological treatment (MBT) of municipal solid waste). Excludes: facilities that produce fuels from organics by nonbiological processes such as pyrolysis, hydrogenation or gasification.		that may take place at other types of prescribed premises either under Category 67A or as a directly related activity (see Glossary). Activities typically associated with Category 67A composting facilities include: Alcoholic beverage manufacturing, Liquid waste facility, Solid waste facility, Solid waste depot, Putrescible landfill site, Cattle feedlot, Intensive piggery. Excludes: • soil blending premises where composting is not undertaken, • solid waste depots/waste transfer stations, • solid waste facilities receiving and storing composting feedstock"	• animal manure; • bio-solids; • cardboard and paper waste; • fish processing waste; • food and food processing waste; • grease trap waste; • green waste; • poultry processing waste; • waste generated from an abattoir; Excludes: manufacturing mushroom growing substrate; or the composting of organic material from agriculture or livestock production if: • the organic material is either— • composted at the site where it was produced; or • transported to another site, where agriculture or livestock production is carried out, and composted at that site; and • the composted organic material is supplied, free of charge, for use at a site where agriculture or livestock

					production is carried out Does not include: • clinical or related waste; • contaminated soil; • quarantine waste; or • synthetic substances, other than synthetic substances used for manufacturing fertiliser for agricultural, horticultural or garden use.
Relationship with AS4454: 2012 Composts, Soil Conditioners and Mulches.	Guideline developed considering a number of legislative and guidance documents including Australian Standard 4454. For Quality assurance EPA recommend that the following Australian Standards be adopted in setting environmental goals and quality parameters for compost products including: AS 4454 Product labelling refers to AS 4454–2012 section 5.3(h) 12 See AS 4454–2012 section 5.3(h) for copper and zinc	Destruction or inactivation of other harmful organisms: Products should meet the requirements of Australian Standard AS 4454–2003 The Best Practice Guidelines for Composting Systems in Appendixes N and O of AS4454–2003 (Standards Australia 2003) recommend pasteurisation regimes for the various types of processes that are currently being used. These regimes can be used as guides to achieving a successful outcome. If organics used for transport to and are used in viticulture area must meet protocols to minimise risk of phylloxera survival which	Acknowledges AS4454 is voluntary standard. Guideline informed by elements of the 2012 edition of the standard that relate to environment protection. EPA has adopted the pasteurisation and maturation processes and parameters verified (and published) by the United States Environmental Protection Agency and required as a process criteria in Australian Standard (AS) 4454: The limits for chemical and physical contamination are consistent with AS 4454.	Existing standards and guidance for the product specifications of compost produced in Western Australia include: Standard AS 4454-2012 The department acknowledges that compost products may be fit-for-purpose for a specific end use without meeting the specifications in AS 4454-2012 Product specification: Compliance with AS 4454-2012 and Biosolids Guidelines-Licence holders producing compost products which comply with AS 4454-2012 are required to classify their products according to the	Composting process: The Australian Standard AS4454 for composts, mulches and soil conditioners provides relevant information on requirements for pasteurization, internal composting temperatures, temperature profile monitoring and methodologies for sampling compost piles (amongst other things).

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	require composting to AS4454	Composts, soil conditioners and mulches produced from suitably composted materials that meet the general requirements of AS 4454: 2012 (outlined in the guideline under sections 7.2 Pasteurisation and 8.1 Product requirements) are regarded as a genuine product and not as a waste. EPA Product classification based AS4454 definitions in for Pasteurised product, Compost and mature compost. Products should be tested in accordance with the guideline or AS 4454: 2012 to demonstrate that the feedstocks and processes being employed are able to meet the required standard. EPA recommends alternative processes demonstrate they can meet the standards listed above in Table 8; these are based on AS 4454: 2012 and EPA Guidelines for Biosolids Land Application (EPA Publication 943)	physical and chemical requirements set out in the standard. The department expects that most compost products produced from low- to moderate-risk feedstocks will meet the physical, chemical and biological contaminant requirements set out in AS 4454-2012. Development and maintenance of a fit-for-purpose assessment report required where compost products do not comply with the physical, chemical and/or biological contaminant requirements in AS 4454-2012 The department requires the following minimum standards for sampling and testing: Each batch of compost product is sampled and prepared in accordance with the sampling protocol in Appendix D of this guideline. Further guidance on sample size, preservation, transport and preparation for analysis at the laboratory is provided in AS 4454-2012

			Maturation section: AS 4454: 2012 outlines a variety of methods to demonstrate the level of maturity of the product. These include reporting the details of the processing conditions and a variety of laboratory tests that can be undertaken by NATA-accredited laboratories.	Each sample of compost product is tested by a NATA-accredited laboratory to assess compliance with: Table, 10,11 and 12 which are derived from AS4454. Product sampling protocol- licence holders should refer to refer to AS4454 and NATA lab for guidance	
Source separation	All feedstocks must be source separated	Alternative technologies have the potential to recover significant value from mixed residual waste (McMillen 2001). Such technologies should be regarded as a complement to, rather than a substitute for, the segregated collection of waste. A variety of management practices, including source segregation, must be considered as part of any system to produce quality processed organics (e.g. Rynk 2001).	Municipal waste needs to be source separated to be classified as a category 2 medium risk waste type	Municipal kerbside garden waste needs to be source separated to be classified as a moderate risk	Not specified
Feedstock category determination	Classified on the level of potential risk they pose to the environment and/or human health. **Consideration of end products**	Based on : • potential to generate offensive odours • potential to attract vermin and vectors • potential to generate harmful leachate, which could contaminate	The categorisation approach adopted by EPA ranks feedstock into four categories from lowest to highest potential risk of harm to human health and the environment.	Composting is undertaken using feedstocks that will produce a fit-for-purpose compost product that can be used without presenting an unacceptable risk to environmental values,	Not specifically specified Inappropriate processing procedures and/or technologies for higher risk materials in open windrow composting have the potential to generate

	surface water, groundwater • and soil. **Based mainly on Facility**	Management of feedstocks based on potential to • generate offensive odours • attract vermin and vectors • generate harmful leachate, which could contaminate surface water, land and groundwater • contain harmful pathogens • contain plant pests and propagules. These risks can lead to non-compliance with the SEPPs. **Facility based**	water resources and human health. Different feedstocks pose different risks in terms of emissions (leachate and odour), environmental harm (disease and vectors) and compost product contamination. The risk category is determined based on the expected consequence and likelihood of emissions arising from each feedstock, with particular focus on odour and leachate emissions. The potential for feedstocks to contaminate compost products with physical, chemical or biological contaminants is also considered. The department will apply regulatory controls in proportion to the level of risk posed by the type of compost feedstock. Stricter regulatory controls will be applied to premises accepting higher-risk feedstocks.	significant odour impacts, to attract vermin and other vectors (birds and insects), and to generate harmful leachate that could, unless contained, be released to contaminate surface water, groundwater and soil. Determining waste acceptance criteria is the responsibility of the operator. Where there is a greater than low potential of environmental risk from adding the waste streams received onsite to the compost, the operator should assess the risk and characteristics of the waste materials and source before inclusion. This assessment should include the relevant material characteristics, contaminant levels and the potential for human or ecotoxicity (noting that contaminants can combine to form a substance(s) of greater environmental risk than the original waste stream). Feedstocks are selected that are beneficial to the composting process of an individual facility and will not have adverse environmental impacts

				Mainly facility and end product	such as odour nuisance, contamination of surface and ground water, and environmental harm in the end use of the product. The operator can effectively assess the potential environmental risk of different feedstock and is familiar with industry standards and best practices for processing feedstock and can determine a maturation period of sufficient length to produce stable and mature products that are safe and beneficial for use without risk of adverse impact on environment or health. **Mainly Facility based**
Feedstock categories	**Category A** Includes green wastes, kerbside collected green waste (may include food waste), untreated timber, sawdust, pallets, branches, straw, peat, pulp, paper, cardboard, virgin soil, manures and sludges from primary production waste water management systems, sludges from food and agricultural processing wastewater management systems, wastes from preparation of meat and	**Category 1: Lowest potential environmental impact** Garden and landscaping organics: Grass; leaves; plants; loppings; branches; tree trunks and stumps. Untreated timber: Sawdust; shavings; timber offcuts; crates; pallets; wood packaging. Natural organic fibrous organics: Peat; seed hulls/husks; straw; bagasse	**Category 1: Lowest Risk** Garden and landscaping organics:Grass, leaves, plants, branches, tree trunks and tree stumps Untreated timber: Sawdust, shavings, timber offcuts, crates, pallets, wood packaging Natural organic fibrous organics: Peat, seed hulls/husks, straw, bagasse and other natural organic fibrous organics	**Low:** Green waste derived from controlled collections and landscaping sources: Grass, leaves, plants, branches, tree trunks and stumps. This category is applicable to green waste streams with very low levels of contamination. Untreated timber: Sawdust, shavings, timber offcuts, crates, pallets and wood packaging.	Organic materials associated with a **low potential environmental impact**: plant material (including vegetation from garden and landscape management) untreated timber products and shavings. Natural organic fibrous organics such as peat, seed, hulls/husks, and straw, processed fibrous organic materials such as cardboard and paper waste, paper-

	fish and other foods of animal origin, animal faeces, urine and manure, farmyard bedding, biosolids and unclassified sludges from sewage treatment works.	and other natural organic fibrous organics. Processed fibrous organics: Paper; cardboard; paper-processing sludge; non-synthetic textiles.		Natural fibrous organics: Peat, seed hulls/husks, straw, bagasse and other natural organic fibrous organics. Processed fibrous organics: Paper, cardboard, paper-processing sludge and non-synthetic textiles. Neutralised acid sulfate soils: This waste type is only considered low risk if it is sourced from a non-contaminated site.	processing sludge and non-synthetic textiles.
	Category B Mineral based industrial residues. Including but not limited to mineral-based industrial waste; grease trap waste	**Category 2:** Other natural or processed vegetable organics: Vegetables; fruit and seeds and processing sludges and wastes; winery, brewery and distillery wastes; food organics excluding organics in Category 3. Biosolids and manures: Sewage biosolids, animal manure and mixtures of manure and biodegradable animal bedding organics.	**Category 2: Medium Risk** Municipal source separated kerbside garden waste: Grass, leaves, plants, branches, tree trunks and tree stumps. Biosolids and aged manure: Biosolids that meet treatment grades T1 to T35. Aged manure that has a dry matter greater than 35%	**Moderate** Municipal source separated kerbside garden waste: Grass, leaves, plants, branches, tree trunks and stumps. This category is applicable to green waste streams which are uncontrolled and expected to contain contamination, such as garden organics only green-top bins. Aged manure: Aged manure that has a dry matter greater than 35 per cent. Other natural or processed vegetable organics: Vegetables, fruits and seeds and processing wastes, solid winery, brewery and distillery wastes.	Organic materials associated with **a low to medium** potential environmental impact risk: other natural processed vegetable organics such as fruit and seeds, pomace and grape marc, processing sludges and wastes, winery, brewery and distillery wastes, biosolids and manures such as sewage biosolids, septic wastes (unprocessed), animal manures, mixtures of manure and biodegradable animal bedding organics.

	Liquid Waste As defined in liquid waste classification test (EPA 2003)"	**Category 3: Greatest potential environmental impact** Meat, fish and fatty foods: Carcasses and parts of carcasses; blood; bone; fish; fatty processing or food. Fatty and oily sludges and organics of animal and vegetable origin: Dewatered grease trap; fatty and oily sludges of animal and vegetable origin. Mixed residual waste containing putrescible organics: Wastes containing putrescible organics, including household domestic waste that is set aside for kerbside collection or delivered by the householder directly to a processing facility, and waste from commerce and industry.	**Category 3: Medium to High** Dewatered sewage sludge and fresh manures: Dewatered sewage sludge (does not meet the T1 to T3 standards), animal manure and mixtures of animal manure and animal bedding organics Other natural or processed vegetable organics: Vegetables, fruits and seeds and processing wastes, winery, brewery and distillery wastes, food organics excluding organics in category 4 Mixed source separated kerbside (Garden waste/food waste – FOGO): Grass, leaves, plants, branches, tree trunks and stumps, vegetables, fruit and meat Grease interceptor trap wastes: Grease trap waste with less than 10% solids"	**High** Grease interceptor trap wastes: Grease trap waste. Treated septage: Waste from septic tanks which has undergone treatment to a level to significantly reduce pathogens and microorganisms. Biosolids (see Glossary): Sewage sludge from a wastewater treatment plant which has undergone further treatment to significantly reduce disease-causing pathogens and volatile organic matter, e.g. by liming or anaerobic digestion and then dewatering. Dewatered sewage sludge: Dewatered untreated sewage sludge from a wastewater treatment plant. Fresh manures: Fresh animal manure and mixtures of animal manure and animal bedding organics. Mixed-source separated kerbside food organics and	Organic materials associated with the **greatest potential environmental impact** risk: meat, fish and fatty food wastes and animal by products such as carcasses and parts of carcasses, including blood, bone, fish, and fatty animal processing wastes, fatty and oily sludges and organics of animal and vegetable origin including dewatered grease trap waste, mixed residual waste containing putrescible organics (such as food and animal by-products) from household domestic waste sources or wastes from commercial and industrial waste sources.

		garden organics (FOGO): Food, kitchen and garden putrescible wastes disposed from domestic and commercial sources. Grass, leaves, plants, branches, tree trunks and stumps, vegetables, fruit and other food scraps. Meat, fish and fatty foods: Animal mortalities, parts of carcasses, bone, fish and fatty processing or food and abattoir waste. Contaminated Solid Waste (see Glossary): Contaminated soil. Liquid wastes: Putrescible and organic wastes including animal effluent and residues (e.g. blood and paunch), liquid grease trap waste, food and beverage processing wastes. Oils including waste mixtures/emulsions of oils and water or hydrocarbons and water, oil interceptor wastes and oil sludges.	
	Category 4: Highest risk Liquid organic wastes (excluding grease interceptor trap waste with less than 10% solids): Liquid food waste and liquid food	**Uncategorised- must be tightly managed** crushed concrete excavated natural materials such as sand, clay and calcium bentonite, some industrial	

			processing wastes (including sludges), liquid animal wastes (blood) and paunch (sludge), grease trap with greater than 10% solids. Meat, fish and fatty foods: Animal mortalities, parts of carcasses, bone, fish and fatty processing or food	by-products such as foundry sand, some coal combustion products such as fly ash, biodegradable plastics some drill wastes in the form of liquids and earthen materials from activities such as water boring, infrastructure drilling and coal seam gas drilling.	
Feedstock exclusions	Prohibited wastes Listed wastes (including products containing listed wastes), hazardous wastes, contaminated soil,non-biodegradable/ non-compostable plastic and medical waste."	Must not receive organics other than those permitted in licences (see Section 3 Table 3) organics seized or subject to controls issued by the Australian Quarantine Inspection Service (AQIS) or NSW Agriculture or another agricultural agency, unless the facility receives and complies with any additional requirements that AQIS or the agricultural agency may impose to ensure destruction or inactivation of the contaminants or pathogens of concern. Organics that are contaminated by chemicals and/or pathogens that will not be rendered harmless by the process or that may	PIWs that are not listed in the feedstock categories are not considered as appropriate for aerobic composting due to the increased risk to the environment and risks of dilution and impact on the final product. In some cases, the composting process can be used for bioremediation of some PIW provided tight controls are in place; this is out of the scope of the guideline.	Liquid feedstocks which are not suitable for composting and must not be accepted at composting facilities are: Waste streams which present a higher risk of PFAS contamination, quarantine waste (see Glossary), clinical and related waste (see Glossary), liquid waste derived from diseased animals containing pathogens which may constitute a health or environmental risk and will not be rendered harmless by the composting process. Any other waste stream which does not add beneficial ingredients to the compost thereby increasing the quality of the final compost product; and is not effectively bioremediated	Not specified

	constitute a health or environmental risk, including clinical waste and other related wastes of clinical origin, and diseased carcasses. Organics containing contaminants classified as hazardous wastes or industrial wastes in any statutory instruments (see: Protection of the Environment Operations Act 1997 and Environmental Guidelines: Assessment, Classification and Management of Liquid and Non-Liquid Wastes (EPA 1999a))."	or treated during the composting process. Solid Feedstocks which are not suitable for composting and must not be accepted at composting facilities are: wood and wood-derived wastes impregnated with preservatives, pesticides, painted, or with any non-biodegradable layer, quarantine waste (see Glossary), waste which includes asbestos and asbestos cement products – Special Waste Type 1 (see Glossary) -clinical and related waste including those classified as Special Waste Type 2 or Hazardous Waste (see Glossary), soils and other solid wastes impacted by PFAS – Special Waste Type 3 (see Glossary), other waste streams which present a higher risk of PFAS contamination, solid waste derived from diseased animals containing pathogens which may constitute a health or environmental risk and will not be rendered harmless by the composting process

Additional Feedstock Category Specific QA requirements	**Category A:** No requirement to test incoming feedstocks. Finished compost product should be tested in accordance with Table 2. Compost containing biosolids should be assigned a stabilisation and contamination grade in accordance with the draft Biosolids guideline for the safe handling and reuse of biosolids (EPA 2017). Records should be maintained and made available to the EPA when requested. **Category A** feedstocks to be incorporated into the windrow upon receipt or within 48hr. Biosolids and/or unclassified sludges from sewage treatment works should be managed in accordance with the draft Biosolids guideline for the safe handling and reuse of biosolids (2017).	Occupiers of facilities are responsible for selecting and applying the best mix of techniques suitable to the category of incoming organics in order to meet environmental performance requirements. Particular care should be taken when grass clippings are present in the feedstock. For processing **Category 1 organics**) the simpler open-air methods for composting have generally been found to be satisfactory, provided that the materials being processed (especially grass clippings, weeds and leaves) are not allowed to become anaerobic.	**Category 1:** Lowest potential risk of harm to human health and the environment: open environment, enclosed or covered environment and enclosed with secondary odour control	The operator can effectively assess the potential environmental risk of different feedstock and is familiar with industry standards and best practices for processing feedstock and can determine a maturation period of sufficient length to produce stable and mature products that are safe and beneficial for use without risk of adverse impact on environment or health. For any individual waste streams that typically pose a greater than low environmental risk (see waste section categories) in open window composting, it has been demonstrated that waste(s) can be effectively composted by the facility whilst managing risk of adverse environmental impacts.	Not specified
	Category B: The feedstock must be homogenous and beneficial to the finished compost product. The feedstock need to be assessed in accordance with	For processing **Category 2** organics, open-air methods for composting have been found to be satisfactory with strict feedstock preparation and operating	**Category 2**: Medium potential risk of harm to human health and the environment: open environment, enclosed or covered environment and	See composting process below	Not specified

	Type B WDSE as specified in section 5.3 of the Standard for the production and use of waste derived soil enhancer (EPA 2010). Feedstocks should be actively managed upon receipt at the site so as to prevent the generation of odour and other nuisances.	controls. Category 2 organics are best processed in enclosed facilities. For this reason, if the applicant intends to use an open-air facility to compost Category 2 organics, they will need to demonstrate clearly at the planning and community consultation stage that the location, design, operating methodology and resources of the facility will prevent odorous emissions and degradation of the local amenity. Conditions applying to processing and use can be found in Environmental Guidelines: Use and Disposal of Biosolids Products (EPA 1997).	enclosed with secondary odour control The categories 2, 3 and 4 feedstocks should be processed as soon as practicable and the most odourous wastes should not be stored for more than 48 hours.		
	Liquid waste: Liquid wastes will fall into either Category A or B as and the applicable QA processes will apply. Feedstock should be received in a concrete bund, blended with suitable binding agents and incorporated into the compost windrow within 24 hours of receipt.	For processing **Category 3** organics open-air methods for composting have generally, but not invariably, been found to be unsatisfactory. It is most unlikely that the EPA would grant an environment protection licence for the open-air composting of Category 3 organics. As with Category 2 organics, the applicant would need to demonstrate clearly at the	**Category 3:** Medium to high potential risk of harm to human health and environment: enclosed or covered environment and enclosed with secondary odour control The categories 2, 3 and 4 feedstocks should be processed as soon as practicable and the most odourous wastes should not	See composting process below Incoming liquid wastes are: regularly sampled and tested on receipt at the premises for all substances (including contaminants) known or reasonably expected to be present in the waste. Laboratory certificates of analysis must be retained in accordance with	Not specified

		planning and community consultation stage that the location, design, operating methodology and resources of the facility would prevent odorous emissions and degradation of the local amenity. The processing of Category 3 organics by vermiculture is an exception to the above, because there is no need to turn the biomass and, therefore, the degradation of organics can take place in containers covered with layers of material such as curing compost, generally without significant odour-emission problems.	be stored for more than 48 hours.	recordkeeping requirements specified in the licence assessed for conformance against their characterisation. Premises which accept more than one type of liquid waste feedstock are required to implement appropriate procedures to segregate non-compatible wastes and avoid adverse chemical reactions. This will require technical oversight from a suitably qualified person (see Glossary). "	
	Prohibited Waste: Incoming feedstock to be managed to identify, record and appropriately exclude any prohibited wastes. Prohibited wastes must be transported to a facility licensed to receive and/or dispose of that waste.		**Category 4:** Highest potential risk of harm to human health and the environment: enclosed with secondary odour control Liquid organic wastes are prescribed industrial wastes (PIW) and are required to be transported in line with the EP Act and IWR Regulations. PIW can only be processed at a facility authorised by EPA to accept the wastes. Liquid organic waste would fall		

			under one of the following waste codes: • K100 – animal effluent and residues • K120 – grease interceptor trap effluent • K200 – food and beverage processing wastes, including animal and vegetable oils and derivatives. The categories 2, 3 and 4 feedstocks should be processed as soon as practicable and the most odourous wastes should not be stored for more than 48 hours.		
Process requirements	Whole mass of windrow is subject to a minimum of three turns and the core temperature is maintained in excess of 550C for three consecutive days following each turn- consistent AS4454 Where compost windrows contain manure, animal waste, food or grease trap waste and biosolids and/or their sludges, the whole mass of the windrow should be subject to a minimum of five turns and the core temperature maintained in	C:N ratio for effective biodegradation are in the range of 25:1 to 30:1 Overall C:N ratios of 40 or higher have been found to be advisable The optimum range for composting between 5.5 and 8.5 Moisture content of wet organics into the range of 50% to 65% (by weight). Adequate oxygen levels are maintained, either by a	Processing Parameters for Pasteurisation and ideal ranges or ratios Nutrient balance (carbon to nitrogen ratio): 25:1 and 35:1 Total moisture: optimum level 45–60 % Oxygen content: >10 % pH: between 6.5 and 8.0 Porosity and bulk density:400 – 600 kg/m3	Compost facilities must be designed and operated to ensure that the whole mass of the compost product is subject to pasteurisation. Moisture content maintained between 40-65% during pasteurisation and 25%> in feedstock stockpiles and finished product. Temperature to not exceed 70 degrees. Maintain an aerobic state: Stockpiles or windrows are	The Australian Standard AS4454 for composts, mulches and soil conditioners provides relevant information on requirements for pasteurization, internal composting temperatures, temperature profile monitoring and methodologies for sampling compost piles (amongst other things).

	excess of 550C for fifteen consecutive days- consistent with AS4454 Refer to the draft Biosolids guideline for the safe handling and reuse of biosolids for further information. Manual and/or mechanical sorting is necessary for the removal of physical contaminants/inclusions such as litter, plastic, glass and stones. Feedstock, oversized materials, screened contaminants and finished compost products should be stored in a separate designated area at the facility to avoid cross-contamination. Residual waste and/or incoming feedstocks that are unsuitable for use in the composting process should be categorised prior to being removed offsite and transported to a suitably licensed facility to receive and/or dispose of that waste.	program of forced ventilation, or by turning or mixing the composting organics at regular intervals. Turning or mixing also has the benefit of helping to cool the composting mix; cooling may be needed if the temperature starts to climb above 60°C to 65°C	Temperature: 55C–75C Time/temperature ratio for pasteurisation- Process type Vs Type of waste **Open windrow composting- Low risk wastes:** Appropriate turning of the windrow so that the whole mass is subjected to a minimum of three turns with the internal temperature reaching a minimum of 55C for three consecutive days before each turn.- consistent AS4454 **Open windrow composting- High risk wastes:** The core of the compost mass shall be maintained at 550C or higher for 15 days or longer, during which the windrow shall be turned a minimum of five times.- consistent AS4454 **Enclosed composting: All wastes** The whole mass should be maintained at 55C or higher for a minimum of three consecutive days. (To meet this, the material will need	regularly turned or otherwise aerated (such as forced aeration). Optimal aerobic composting conditions occur at an oxygen content of 10 per cent or higher. Nutrient-input balance (carbon to nitrogen ratio) of 25:1 to 35:1. **Windrow composting: Low Risk** Appropriate turning of outer material to the inside of the windrow so the whole mass is subjected to a minimum of three turns with the internal temperature reaching a minimum of 55^{0}C for three consecutive days before each turn.- consistent AS4454 **Windrow composting: Moderate to high risk** The core of the compost mass shall be maintained at 55^{0}C or higher for 15 days or longer, during which the windrow shall be turned a minimum of five times.- consistent AS4454 as moderate category has manures

			to be in the enclosed vessel for longer to ensure it gets to and maintains temperature.) Scheduled composting operators may use demonstrated methods of pasteurisation or, alternatively, seek EPA approval to use practices that are not listed above. All composters are encouraged to follow these parameters or approved alternative processes.	**In-vessel composting: All feedstocks** The whole mass should be maintained at 55⁰C or higher for a minimum of three consecutive days. (To meet this, the material will need to be in the enclosed vessel for longer to ensure it gets to and maintains temperature.)	
Contaminant and testing parameters	Finished compost product should be tested to demonstrate compliance with the criteria specified in Table 2.-Contaminant testing for contaminants Out of the 19 unrestricted use upper limits for chemical contaminants in table 3.1(C) of AS4454 the SA compost guidelines specify that 9 must be met for unrestricted use. Of the Physical contaminants % dry matter w/w) table 3.1 (A) – A2 As4454 out of the 6 requirements the SA guidelines address 2.	Does not specify specifically- refers to AS 4454 The processing conditions should be able to ensure a satisfactory reduction in the levels of human, animal and plant pathogens and the inactivation of noxious weeds, weed seeds and propagable shoots. The product should not contain harmful biodegradable contaminants. Products should meet the requirements of Australian Standard AS 4454–2003: Composts, Soil Conditioners and Mulches (Standards Australia 2003).	The chemical and physical contaminant limits appropriate for compost designated for unrestricted use are listed in tables 9 and 10. It states "the limits for chemical and physical contamination are consistent with AS 4454: 2012 - Composts, Soil Conditioners, and Mulches" Out of the 19 unrestricted use upper limits for chemical contaminants in table 3.1(C) of AS4454 the compost guidelines specify that all 19 must be met for unrestricted use.	Pasteurisation is achieved when the feedstocks have been exposed to the appropriate time/temperature ratio and the product meets the standards in Table 8. Quality sampling and testing are required to provide ongoing assurance that compost products meet the product specification and are fit-for-purpose. The department requires the minimum standards for sampling and testing based on tables 10-12 or compost products partially or wholly derived from biosolids, maximum pathogen levels for Grade	Does not specify specifically- refers to AS4454 The Australian Standard AS4454 for composts, mulches and soil conditioners provides relevant information on requirements for pasteurization, internal composting temperatures, temperature profile monitoring and methodologies for sampling compost piles (amongst other things).

	Where composting facilities incorporate Category B feedstocks into their compost process, quality control processes should comply with sections 5.3 and 6 of the Standard for the production and use of waste derived soil enhancer. Where biosolids are incorporated into the compost process, quality control processes should comply with the requirements of the Biosolids guideline for the safe handling and reuse of biosolids. The EPA recommends that the following Australian Standards be adopted in setting environmental goals and quality parameters for compost products: • AS 4454–2012 Compost, soil conditioners and mulches • AS4419–2003 Soils for landscaping and garden use • AS 3743–2003 Potting mixes • AS/NZS 5024 (INT)–2005 Potting mixes, composts and other matrices:	For organic products that are derived from biosolids or organic mixtures with biosolids, the requirements laid down in Environmental Guidelines: Use and Disposal of Biosolids Products (EPA 1997) including the amendment (EPA 2000a) apply.	Varies from SA which requires only 9 requirements. Of the Physical contaminants % dry matter w/w) table 3.1 (A) – A2 As4454 out of the 6 requirements the Vic guidelines address 2. These are the same 2 requirements as SA. Pasteurisation is achieved when the feedstocks have been exposed to the appropriate time/temperature ratio and the product meets the standards in Table 8. Appropriate pathogen limits are presented in Table 8. AS 4454: 2012 outlines a variety of methods to demonstrate the level of maturity of the product. These include reporting the details of the processing conditions and a variety of laboratory tests that can be undertaken by NATA-accredited laboratories.	P1 in the Biosolids Guidelines Or for compost products with a fit-for-purpose product specification (see Section 18.3.2), the maximum contaminant concentrations in that document (fit for purpose assessment report). Out of the 19 unrestricted use upper limits for chemical contaminants in table 3.1(C) of AS4454 the compost guidelines specify that all 19 must be met for unrestricted use. Of the Physical contaminants % dry matter w/w) table 3.1 (A) – A2 As4454 out of the 6 requirements the WA guidelines address 2. Also states requirements for Salmonella spp and Faecal coliforms which aren't mentioned in the other guidelines except as a alternative testing method for Victoria. Also provides minimum analtyes for oil interceptor waste and Oil sludge

	examination for legionellae.		Also provides Pathogen and plant propagules reduction performance standards for alternative methods of pasteurisation as specified for • Enteric viruses • Helminth ova (Ascaris sp. and Taenia sp • E. coli • Faecal coliforms • Salmonella spp • Destruction of noxious weeds (viable plant materials and propagules): EPA recommends alternative processes demonstrate they can meet the standards listed above in Table 8; these are based on AS 4454: 2012 and EPA Guidelines for Biosolids Land Application (EPA Publication 943). Where possible, NATA (or equivalent) accredited laboratories should be used.		
Other End Product requirements	Product labelling Objective Compost should be appropriately labelled to ensure that a consumer is informed about the	Marketing of stabilised processed organics A plan for the marketing and sales, or the giving away, of the different types of processed organics	A product – not a waste There are a number of pieces of legislation (EP Act, SEPP (PMCL) and IWR regulations) that prohibit or control the disposal to land	Product specification Composters must demonstrate that compost products do not present an unacceptable risk to the environment and human	End product must not cause environmental harm The department does not regulate product characteristics such as nutrient levels but GED

	potential environmental and human health risks of the compost product. Minimum expectations Compost product should be protected to prevent contamination during transportation, handling and storage. Compost products that are bagged should include an appropriate hazard warning which specifies the health risks, safety precautions, first aid and disposal requirements which are recommended for the compost product. The hazard warning should be appropriate to address the risks of compost which is made from organic materials and may contain living micro-organisms, including bacteria, fungi and protozoa. Compost product that has total copper concentrations in excess of 60 mg/kg and less than 150 mg/kg should include a warning on the label which states that the product should not be used as a complete soil replacement or growing	should be prepared annually and should be based on the anticipated quantities of organics to be received at the site. The seasonal fluctuations that may affect the availability of different types of feedstock organics will need to be considered. Quality assurance of the product and the consistency of products sold to users is important for maintaining and increasing sales of organic products (e.g. Allen 1999). Australian Standard AS4454-2003: Composts, Soil Conditioners and Mulches (Standards Australia 2003) contains guidance regarding product quality assurance. Assessment of quality and consistency could include sampling and testing of the following (Woods End Research Laboratory 2000): • heavy metal levels • physical composition and inert contamination • pathogenic bacteriology and phytopathogens	of various wastes – such as municipal waste, prescribed waste, sewage sludge and litter. Composts, soil conditioners and mulches produced from suitably composted materials that meet the general requirements of AS 4454: 2012 (outlined in t guideline under sections 7.2 Pasteurisation and 8.1 Product requirements) are regarded as a genuine product and not as a waste. Compost that does not meet these general requirements can sometimes be acceptable if made for a very specific use. EPA may grant approval for land application of a particular waste product after suitable processing where: • it does not constitute an environmental hazard in the proposed application • it is fully pasteurised • a particular need is satisfied in its use and • appropriate controls are in place to ensure these criteria are always met. 8.2.1 Product classification	health when used for their intended purpose. This can be achieved by following one of the two approaches outlined below: 1. Compliance with AS 4454-2012 and Biosolids Guidelines Licence holders producing compost products which comply with AS 4454-2012 are required to classify their products according to the physical and chemical requirements set out in the standard. The department expects that most compost products produced from low- to moderate-risk feedstocks will meet the physical, chemical and biological contaminant requirements set out in AS 4454-2012. Compost products which are partially derived from biosolids need to comply with the P1C1 unrestricted use requirements specified in the Biosolids Guidelines. 2. Development and maintenance of a fit-for-purpose assessment report This approach is required where:	requires that the end product does not contain pathogens or contaminant levels that when applied could cause harm to the environment and human health. Producers that sell or distribute a composting product should consider the level of product pathogen or contaminant levels that are appropriate for product end use. For example, certain products may be more appropriate for food production or residential use while other products are more suitable for development or rehabilitation of industrial sites. The sale or distribution of a product that could be found to have caused or contributed to environmental harm may result in enforcement action."

medium and specify the copper concentration. It should also state that copper may accumulate in soils and become harmful over time11. Compost product that has zinc concentrations in excess of 200 mg/kg and less than 300 mg/kg should include a warning on the label which states that the product should not be used as a complete soil replacement or growing medium and specify the zinc concentration. It should also state that zinc may accumulate in soils and become harmful over time12. 5 Compost product should include information about recommended rates of application. 11 See AS 4454–2012 section 5.3(h) 12 See AS 4454–2012 section 5.3(h)"	• potentially toxic elements (PTEs) • maturity and plant growth performance.	The output from a composting operation ceases to be waste if it can be classified as a product. Products are classified based on a range of factors. These include the protection of the environment, animal and human health, and the end users' needs. The definitions provided in AS 4454: 2012 for the following three products have been reproduced below as the three classifications that EPA describes products as: Pasteurised product: An organic product that has undergone pasteurisation as defined in section 7.1.1 but is relatively immature and lacking biological stability. Compost: An organic product that has undergone controlled aerobic and thermophilic biological transformation through the composting process to achieve pasteurisation and reduce phytotoxic compounds, and has achieved a specified level of maturity for compost (as	• compost products do not comply with the physical, chemical and/or biological contaminant requirements in AS 4454-2012 • compost products do not comply with the P1C1 unrestricted use requirements in the Biosolids Guidelines, or • compost products contain chemical contaminants which do not have upper limits specified in Table 3.1(C) of AS 4454-2012. This includes but is not limited to all compost products which are partially derived from liquid wastes. A fit for purpose report must include: • identification of all potential contaminants associated with the feedstocks used to produce the compost product. Lab analysis for liquid waste feedstocks (see Section 17.3.1 and Appendix B) and may also be required for other high-risk feedstocks.

stated in AS 4454: 2012 Appendix N).

Mature compost: An organic product that has undergone controlled aerobic and thermophilic biological transformation through the composting process to achieve pasteurisation and exhibits lower levels of phytotoxicity and a higher degree of biological stability (as stated in AS 4454: 2012 Appendix N). If the product is being blended with other materials to create a product for a specific end market it should still meet one of these product requirements before blending to ensure that at a minimum pasteurisation has occurred.

9.1. Waste characterisation The characterisation of the incoming feedstocks is important in understanding the wastes that are being accepted, what waste code they are covered by (when appropriate), and the processing requirements for the different waste streams. It also enables a

- a description of the intended end use of the product
- a fit-for-purpose product specification (max concentration limit)s for all identified potential contaminants which either do not meet or are not specified in AS 4454-2012 or the Biosolids Guidelines
- an assessment of the potential risks to human health and the environment which may arise from the compost product being used (with reference to the product specification).
- a quality-assurance sampling and testing plan which will be implemented to ensure ongoing compliance with the product specification. See minimum standards for sampling and testing (Section 18.3.3).

2 Investigation into the impacts of contaminants in mineral fertilisers, fertiliser ingredients and industrial residues and the derivation of guidelines for contaminants (Sorvari et

	site to reject loads that are contaminated or do not meet the facility's requirements. 9.2. Monitoring plan The elements that are important in the composting recipe remain important throughout the pasteurisation and maturation phases. These need to be monitored as part of a monitoring plan for the premises. The requirements for a monitoring plan vary depending on the category of waste being accepted and the associated technology. Enclosed designs are able to have real-time monitoring for the many parameters whereas for the lower order technologies the monitoring plan will need to articulate when and what will be monitored, and how this will be done. Monitoring for the parameters listed in section 7.1 will ensure that the optimal conditions for pasteurisation are being maintained and will minimise the generation of offensive odour.	al., 2009) and the Environmental risk assessment guidance manual for agricultural and veterinary chemicals (Environment Protection and Heritage Council, 2009).	

	9.3. Product testing Products should be tested in accordance with this guideline or AS 4454: 2012 to demonstrate that the feedstocks and processes being employed are able to meet the required standard. Once this has been clearly established the product testing should be adjusted to suit the ongoing management and quality assurance requirements of the premises. If significant changes are to be made to the feedstocks being processed, an increase in product testing may be recommended.	