SUMMARY

Arcadis has been engaged by the Department of Environment and Science (DES) to undertake a critical assessment, review and evaluation of composting operations in Queensland with a focus on odour management, feedstock suitability, contamination risks and the regulation of these aspects by DES.

Composting in Queensland is a significant industry which in 2017-18 converted 1.4 million tonnes of organic residues and waste into beneficial products which generally improve soil health and quality. There are around 25 companies of varying scales whose primary business is composting plus a number of other companies and councils that engage in organics processing in various forms and amongst other waste management activities.

Without a successful composting industry, significantly more organic waste would be landfilled or otherwise disposed to land without processing, resulting in a range of environmental and social benefits including significant greenhouse gas emission reductions and pasteurisation of land-applied compost products. However, the long-term success of the industry is highly dependent on consumer confidence in the quality of compost products to retain and expand offtake markets, and community support for the industry.

Anecdotally, it has been observed that in the past, composting operators were focused on the products - using organic waste streams such as green waste and food processing residues together with some clean inorganic materials as feedstocks to manufacture compost and soil products with a focus on product quality and soil health. However, in recent years, the activities of some parts of the industry have shifted to see a proliferation in the types and nature of waste streams incorporated into compost, both organic and inorganic. Concerns have been raised about the suitability of some of these materials in compost and whether parts of the industry have shifted from the previous primary focus on compost production, to being primarily waste treatment businesses. Open windrow composting offers a low-cost alternative for the processing or disposal of a range of different waste streams, which are not necessarily beneficial to the end products.

The role of composting in the broader waste management system is set to grow over the coming years as councils and businesses look for ways to divert more organic waste from landfill, particularly food waste. The draft Queensland Waste Strategy focuses on building a circular economy in Queensland and the recovery of organic waste is already a major contributor to that. The draft Waste Strategy sets ambitious targets for recycling waste and reducing landfill which will only be achieved if more organics are recovered, processed appropriately and directed to beneficial uses.

However, composting and the use of compost also has a high potential to negatively impact on local communities and the environment. The Department has received a considerable and growing number of complaints over recent years about odour nuisance from composting operations, particularly in the Swanbank area near Ipswich, but also near other composting operations. There have also been some high profile compost contamination issues over the past two years involving PFAS contamination of compost products, which have damaged the industry's reputation and concerned the community. The Queensland Government has committed to reducing those impacts with a particular focus on addressing odour management issues and contamination of compost products, arising from the use of inappropriate feedstocks.

This study aims to improve the Department's understanding of composting processes and odour emissions from composting; best practice management of composting; the suitability of different materials as feedstocks in composting and requirements for improving regulation of the industry. This report presents the findings of Phase 2 which focused on contamination of compost products, but also incorporates key findings from Phase 1 which focused on issues of odour control at composting facilities in Queensland.

Overview of Phase 2 findings

Composting regulation and standards

- Compost products and associated products such as soil conditioners, soil mixes and potting mixes are used in a wide range of applications, each with differing degrees of exposure and risk to human health and the environment.
- Waste acceptance conditions in existing composting Environmental Authorities (EAs) vary widely with some licenses having no or very few specific waste acceptance conditions stated, which limits the level of regulatory control over feedstock contaminants. While different EAs take different approaches, the current regulatory preference seems to place the responsibility on the operator to determine which feedstocks are suitable for processing.
- There is a general need for tighter regulation of feedstocks as the current inconsistency in regulation between otherwise similar sites. The current situation creates an un-level playing field commercially (real or perceived) which may be a barrier for new market entrants and to investment in upgrades and improvements.
- Given the general lack of requirements on most operators to characterise and analyse their feedstocks, there is very little data available on chemical and physical composition of feedstocks currently being used in Queensland composting operations, which is a significant and acknowledged data gap.
- The Australian Standard for composts, soil conditioners and mulches (AS 4454 – 2012) provides minimum requirements for the physical, chemical and biological properties of composts, soil conditioners and mulches in order to facilitate the beneficial recycling and use of compostable materials with minimal adverse impact on environmental and public health, by avoiding biosecurity and phytotoxicity risks associated with inappropriate product manufacture or selection. AS 4454 does not prevent any composter from producing superior compost free of contaminants and impurities that smells as it should (earthy odour) and delivers crop yields significantly higher than without use of compost. The standard is not the problem, the lack of clear regulations and the current business model of many composters (making most of the profit on processing liquid and regulated wastes) are the issue.
- Contaminant limits in the Australian Standard for composts (AS 4454 – 2012) and international (European) standards for composts and digestates do not vary markedly. Yet the legal / regulatory status of compost quality criteria specified in overseas standards is often very different to the situation in Australia, as is the organisational structure. AS 4454-2012 is the leading reference for composting industry but it is a voluntary standard and very little or no bulk compost / soil conditioning / mulch product is independently audited and accredited against AS 4454 – 2012 quality requirements in Queensland or Australia more broadly. Bagged compost and soil mix products are typically the only product lines subjected to certification and they represent a small proportion of the market by volume. In that respect, the self-assessment option for composters has detrimental effects, as it undermines production of good quality compost, and trust in the market place.
- AS 4454 does not prevent any composter from producing very high quality compost products that are free of contaminants and impurities, far exceeds any AS 4454-2012 requirements and delivers all benefits promised by the producer. At present, the vast majority of bulk compost producers in Queensland and indeed Australia, only offer the weakest form of guarantee under AS 4454 - ‘Self Declaration’, or none at all, and certainly not third party auditing and certification. The acceptability to customers of this approach depends on the reputation and past performance of the manufacturer and requires the customer to be informed of the risks, which they often are not or they do not have visibility of the supply chain. However, as compost suppliers increasingly target high value 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.

- The existing End of Waste (EoW) framework in Queensland and associated EoW codes, although currently limited in number, provide good guidance and control over contaminants within defined waste streams that may be used in composting. This suggests that EoW codes could be an effective (existing) tool to better regulate or exclude high risk feedstocks.

Compost feedstocks

This study has identified a long and varied list of over 100 different feedstock materials that are thought to be, or are permitted to be, used as composting feedstocks in Queensland. The feedstocks have been broadly categorised by type, into groupings that have similar risk profiles and management requirements. These categories are described below.

Table 1: Summary of feedstock categories and general risks

Category	Description
Animal matter	Animal / livestock processing wastes including all residues from abattoirs and subsequent processing of tallow and hides; egg and milk waste, manures from intensive farming. High odour risk but assumed to be low contamination risk (no chemical residues), although question on chemicals used in hide curing effluent.
Plant matter	Predominantly clean plant material with minimal contamination. Includes green waste, gross pollutant trap (GPT) waste and clean (untreated) timber which may contain physical impurities, but otherwise includes mostly crop and forestry residues. Potential for trace pesticides and herbicides, but generally low contamination risk. Low odour risk and many of these materials can be used as bulking agents to balance / mitigate the odour risk of other materials.
Food and food processing waste	Wastes predominantly containing food and residues from food processing (predominantly crop / vegetable sources). Household and commercial food organics may contain physical impurities. Food processing wastes are assumed to contain minimal chemical contaminants. All materials present a high odour risk and low chemical contamination risk with the exception of organics extracted from MSW, which is predominantly food but can be highly contaminated.
Sewage and sewage treatment plant (STP) residues	Sludges and solids arising from the collection and treatment of human waste (sewage) including biosolids and septic tank sludges. Potential for varying degrees of chemical contamination (including metals and PFAS) and pathogens, depending on the degree of prior processing. High potential for odour issues.
Chemical fertiliser residues	Chemical residues and effluents from the manufacture of chemical fertilisers including wash waters and non-conforming product. Highly concentrated nutrients and risk of ammonia odours.
Industrial residues	A broad catch-all category for a range of solid, liquid and slurry wastes from industrial manufacturing processes or otherwise highly processed / treated materials. Contamination risk varies widely but is generally high, particularly for those materials that are poorly described. Odour risk is generally low although they may contain sulphur and nitrogen compounds that increase the odour risk.
Wastewater and washwaters	Another broad catch-all category for liquid effluent streams, contaminated stormwaters and washdown waters, mostly from commercial activities. Contamination risk varies but is generally high, particularly for the many materials in this category that are poorly described. Odour risk is generally low although they may contain sulphur and nitrogen compounds that increase the odour risk.

Category	Description
Earthworks & mining waste	Includes inert soils and slurries from earthworks and mining activities, as well as drilling mud from coal seam gas activities and mineral additives that can be beneficial soil conditioner additives (limes, gypsum). Contamination risk is generally low with the exception of chemical additives in drilling mud and residual contamination in treated soils. Other streams may contain naturally occurring contaminants (e.g. sulphate in acid sulphate sludge; heavy metals in earthen material; natural salts in drilling muds). Potential for extreme pH levels (lime, acid sulphate sludge).

- The current nomenclature for feedstocks used by operators or quoted in various reference documents, is often vague and / or potentially inaccurate, with the majority of current feedstock descriptors insufficient to enable an assessment of potential contamination risk.
- In considering potential restrictions on some feedstocks, it is necessary to understand the alternative disposal and processing options available in the market and assess the potential for perverse outcomes. While other management pathways are available for many composting feedstocks, they may not necessarily be preferable from an environmental perspective. In particular, landfilling of organic materials and regulated wastes presents a range of potential risks and adverse outcomes, and government policy is to reduce and avoid landfilling of waste where possible.
- In some cases, the alternative options may be considerably more expensive than composting which leads to an increased risk of the materials being illegally dumped or otherwise inappropriately disposed, which could have significant environmental consequences. This in itself is not a reason not to take stronger regulatory action to protect the environment, but such risks need to be acknowledged and planned for.
- Other preferred processing solutions may exist but the infrastructure is not yet available in Queensland (e.g. anaerobic digestion plants for industrial / commercial organics, both solid and liquid), which suggests a transition period is needed to allow for new infrastructure development, if there is to be a shift away from open composting of some feedstocks.

Potential contaminants

- This report discusses a range of potential contaminants which may be found in composting feedstocks and products, based on an extensive literature review. Where possible, the behaviour and fate of different contaminants is discussed although the scientific knowledge on this aspect is limited for some of the emerging contaminants.
- Physical impurities in compost such as plastic, glass and metal fragments are undesirable from an aesthetic perspective which may limit the potential use and market value of these products. They can also have an impact on soil quality and the environment.
- Microplastics (< 5mm) are likely to be an emerging problem for recycled organics, particularly for the future use of compost derived from domestic sources (such as household food and garden organics, or FOGO collections) in agriculture and horticulture applications. Research from Europe highlights the scale of the issue but it is starting to be recognised in Australia also. Work has shown that over 90% of microplastics contained in sewerage are retained in the sludge or biosolids.
- Microplastics in the marine environment have gained much attention, but they can also adversely impact soils by introducing toxic and endocrine-disrupting substances that are added during plastics manufacturing such as chlorinated paraffins, plasticisers, and flame retardants. Plastic polymers can also be very efficient at accumulating other harmful pollutants during their useful life, which can then impact soils as they deteriorate.
- The Australian Standard for composting (AS 4454-2012) includes limits on physical impurities based on the percentage by weight. Area-based assessment of impurities should be considered to

better account for highly visible light weight impurities, rather than criteria based on weight proportion or number counts of items.

- Heavy metals and other naturally occurring trace elements are a common focus of soil and compost quality guidelines. There are around 40 heavy metals (density >5 g/cm^3), some of which can accumulate in specific body organs and cause health impacts to humans and other organisms.
- The presence and variation of metals and trace elements in the environment (i.e. soil, water, plants, animal and humans) is the result of the natural occurrence of elements, mainly depending on geological processes underlying soil formation, as well as human activities. Metals such as copper and zinc are essential to the healthy growth of plants and animals. There has been no evidence of adverse impacts on plants from application of composts and biosolids with typical levels of copper. Ruminant animals are sensitive to copper deficiency. Bioavailability of copper in compost tends to be low and copper toxicity to animals is unlikely to be caused arise from compost use. Zinc phytotoxicity has been observed in sensitive crops when biosolids with high zinc concentrations were applied to acidic soils (pH < 5.5.).
- Metals and trace elements in composted organic residues form various compounds or associations when applied to soil which can affect their uptake by plants and their mobility through soils. They can be complexed by organic compounds, co-precipitated in metal oxides, be in a water-soluble state, or bound on soil or organic matter colloids in an exchangeable form. Hence, measuring total trace element content in soil or organic amendments does not necessarily predict soil-plant interactions, i.e. bioavailability and plant uptake.
- As soil acidity increases, the solubility of metals and trace elements increases, and so does the potential for uptake by plants. However, this paradigm is not universally applicable as factors such as compost feedstock, soil type and plant species may affect uptake.
- Organic matter within compost has a high cation exchange capacity compared to mineral soil, and therefore tends to bind or chelate metal ions such as Cu, Ni, Zn and Cd. Organic matter binds metals more strongly at a soil pH below 7.5, which is why metal availability in acidic soil is lower when organic matter content is high compared to the same soil with low organic matter content.
- Metal-organic matter complexes play an important role in micronutrient cycles in the soil, and are relevant here as (i) soluble organic compounds that otherwise would precipitate, (ii) metal ion concentrations may be reduced to non-toxic levels through complexion, and (iii) trace element availability to plants may be enhanced by various organic-metal-organic complexes. Plant availability and plant uptake of metals (e.g. Cd and Zn) is lower from composted materials than from uncomposted organic soil amendments.
- There are a wide range of organic chemicals / contaminants that could potentially be present in composts from a range of different feedstocks, and new compounds of concern emerging constantly.
- Elevated total petroleum (TPH) and total recoverable hydrocarbons (TRH) have been detected in finished compost samples analysed by DES, at levels which are higher than in key feedstocks such as green waste and grease-trap waste, based on a limited number of sample results provided to Arcadis. Given many hydrocarbons are biogradable in a composting process, particularly those captured in the TPH and TRH analyses, it is not known where the hydrocarbons in the finished product might have come from and there is very little research or data in the literature on this topic. Further investigation and speciation of the hydrocarbons is needed to identify the source.
- The fate of organic contaminants in composting can involve a number of different pathways including mineralisation, partial biological degradation to secondary compounds, assimilation by microorganisms, abiotic transformation to secondary compounds, complexation with humic materials in the compost substrate (i.e. humification), or loss by volatilisation, leaching, runoff, and wind. Complete mineralisation to carbon dioxide is the ideal, since secondary compounds that can accumulate during partial degradation can still be toxic.
- In view of the difficulty of establishing limits for so many potential chemicals of concern, many countries instead focus on tight feedstock control together with source separation. In many cases,

only specific feedstocks that are unlikely to contain high concentrations of or unknown contaminants can be composted (positive list). Potentially problematic organic residues are excluded from composting. This contrasts somewhat with the current Queensland approach which puts the onus on the operator to determine which feedstocks are suitable for composting.

- Hazardous compounds that are ubiquitous in many man-made products, and therefore also in the environment, such as per- and poly-fluoroalkyl substances (PFAS), that are considered a major concern for human health and the environment need to be regulated at source (e.g. banned from production / use) to reduce long-term potential for contamination of composting feedstocks. In the shorter term, composters need to be vigilant and aware of the risks of these contaminants entering with certain feedstocks and have appropriate procedures in place. But only requesting organics processors to comply with stringent product and end-use requirements, without banning the use of these compounds is likely to be inequitable and counter-productive.
- On average, compost products from a variety of feedstocks tend to show comparable concentration levels for PAH, PCB, PCDD/F and PFC, with the sole exception of biosolids compost that tends to have higher PFC levels. Although few international limits exist, the exceedance of guidance values appear to occur most frequently for the PAH compound class. Other organic pollutants tend to show very low concentration levels in all finished products and are generally not considered as compounds of concern in most countries (though this might be changing).
- There are a range of emerging contaminants constantly being investigated and discovered. As new chemicals are manufactured and used, or as the understanding of the toxicity or persistence of chemicals currently or formerly in use progresses, new groups of emerging contaminants are likely to be identified over time. Ongoing analysis as new contaminants are documented and publicised is the only way to confirm their presence or absence in feedstocks.
- The use of source separated kerbside food organics and garden organics (FOGO) and green waste materials tends to lead to better results for heavy metals and organic contaminant concentrations than when mixed municipal waste or sewage sludge / biosolids are used as input material. This confirms the notion that source separation of domestic and commercial organic feedstocks is an important part of controlling contamination.

Risk assessment of feedstocks

- Due to the lack of specific and comprehensive data on feedstock composition, Arcadis has developed qualitative approaches to assess the risks associated with composting feedstocks, for both potential odour contribution and contamination of the products.
- The assessments help to prioritise feedstocks for further investigation and potential tighter management or regulatory controls, but the lack of data is a constraint on more accurate risk assessment at this stage.
- Feedstocks have been assessed to determine their potential odour contribution in a composting process (odour risk) and potential contamination impact on final products (contamination risk).
- The odour risk assessment considered factors such as the likely proportion of putrescible content (readily biodegradable solids or dissolved organics); and likely content of nitrogen and sulphur compounds, and likely content of proteins, fats and oils. A scoring system was developed to rate feedstocks on each of these factors to arrive at an overall risk rating.
- The odour risk assessment identified 14 feedstocks classified as high risk and 13 as very high risk of contributing to odour issues in a composting process. These materials should still be acceptable for use in composting but should be subject to tighter management controls including characterisation assessments to confirm their suitability; and appropriate blending with bulking agents to balance moisture and C:N ratios. It is likely that storage and mixing facilities may need to be enclosed to manage the risk of odour release from materials that are likely to be anaerobic or putrid upon receipt, and operators who manage high risk materials should assess the need for the initial composting phase to be enclosed.
- The initial contaminant risk assessment has identified 32 feedstocks considered to pose a high risk and a further 16 materials ranked as very high risk of leading to contamination in compost

products. In many cases, the high ranking is partly due to uncertainty in composition so could potentially be re-assessed and reduced with better data. If those with a very high risk rating are confirmed by further analysis, the materials should generally not be used in composting.

- Feedstocks have been assessed to determine their potential odour contribution in a composting process (odour risk). Following from these assessments, feedstocks have been classified into one of two categories as follows:
  - 27 feedstocks were considered to present a high or very high potential odour contribution risk and were therefore categorised as odour category 1 – suitable for composting but with additional controls.
  - The remaining 82 feedstocks were categorized as odour category 2 – suitable for composting, subject to standard composting practice, meaning that any odour risk is manageable through current / acceptable composting practices.
- Feedstocks have also been assessed to determine their potential contamination impact on final products (contamination risk). The assessment has classified feedstocks into one of four categories:
  - 16 feedstocks were categorised as *contamination category 1 – generally unsuitable for composting.* Many of these have vague and ambiguous names which imply a manufacturing or process industries origin but further clarification of the source and nature of the wastes may allow a reclassification.
  - 6 feedstocks were considered potentially suitable for composting but likely to require enhanced control measures (contamination category 2) such as maximum blending ratios within a compost mix, or potential restrictions on end use to minimise direct human contact (e.g. highway verges, mine rehabilitation, forestry).
  - 36 feedstocks were considered suitable for composting and unlikely to pose a significant risk (contamination category 3).
  - 51 feedstocks were classified as potentially suitable for composting but requiring more data (contamination category 4); reflecting the lack of useful data available to properly classify and assess feedstocks. Further analysis is required by operators who process these materials to demonstrate their suitability.

Of the 109 feedstocks identified and assessed, Table 2 below summarises the number of feedstocks in each classification and indicative high level control measures that may apply to each category, noting that more specific control measures will be appropriate for some feedstocks.

Table 3 following, presents the risk assessment and classification outcomes for each feedstock.

Table 2: Summary of feedstock classifications

Classification	Description	No. feedstocks	Suggested controls
Contamination risk categories			
1	Unsuitable for composting	16	Avoid composting, unless further analysis / definition demonstrates lower risk
2	Suitable subject to additional controls	6	Compositional analysis, blending as a minor proportion
3	Suitable for composting	36	Standard composting best practice, analysis to confirm risk
4	Potentially suitable but more data needed	51	Compositional analysis to refine rating

Classification	Description	No. feedstocks	Suggested controls
Odour risk categories			
1	Suitable subject to additional controls	27	Containment of reception / storage / blending, appropriate blending rates
2	Suitable for composting	82	Composition analysis, appropriate blending rates
TOTAL		**109**	

The feedstocks which were classified as unsuitable for composting (category 1) included a number of feedstocks with very vague and ambiguous names which imply some form of industrial origin. The unsuitable feedstocks were:

> hide curing effluent; filter/ion exchange resin backwash waters; dye Waste (water based); filter cake and presses; paint wash; process fluid; treated timber waste; water based inks; water based paints; bilge waters; effluent waste; forecourt water; leachate waste; sullage waste (greywater); treatment tank sludges and residues and waste water.

Table 3: Summmary of qualitative risk assessment results

Type	Feedstock material	Odour Contribution Potential	Odour Category	Potential Contamination Risk	Contamination Category
Animal matter	Abattoir waste	Very high	1	Low	3
	Animal manures, including livestock manure	High	1	Low	3
	Animal processing waste	Very high	1	Low	3
	Animal waste, including egg waste and milk waste	Very high	1	Low	3
	Hide curing effluent	Very high	1	Very High	1
	Paunch material	High	1	Low	3
	Tallow waste	Very high	1	Low	3
Chemical residues	Ammonium nitrate	High	1	Low	3
	Dewatered fertiliser sludge	High	1	Medium	4
	Fertiliser water and fertiliser washings	Low	2	Medium	4
	Filter/ion exchange resin backwash waters	Low	2	Very High	1

	Pot ash	None	2	Low	3
Food & food processing waste	Food organics	High	1	Low	3
	Organics extracted from mixed household waste / MSW	Very high	1	High	4
	Quarantine waste treated by an AQIS approved facility	High	1	High	4
	Beer	Medium	2	Low	3
	Brewery effluent	Medium	2	Low	3
	Food processing effluent and solids	High	1	Low	3
	Food processing treatment tank or treatment pit liquids, solids or sludges	High	1	Medium	4
	Grain waste	Low	2	Low	3
	Grease trap - treated grease trap waters and dewatered grease trap sludge	Very High	1	Low	3
	Grease trap waste (untreated)	Very High	1	Low	3
	Molasses waste	Medium	2	Low	3
	Soft drink waste	Low	2	Low	3
	Starch water waste	Low	2	Low	3
	Sugar and sugar solutions	Low	2	Low	3
	Vegetable oil wastes and starches	Medium	2	Low	3
	Vegetable waste	Medium	2	Low	3
	Yeast waste	High	1	Low	3
Industrial residues	Abrasive blasting sand (excluding heavy metal contaminated sands)	None	2	High	4
	Amorphous silica sludge	None	2	High	4
	Ash	None	2	Medium	2

Bauxite sludge	None	2	High	4
Carbon Pellets	Low	2	High	4
Cement slurry	None	2	Low	3
Coal ash	None	2	Medium	2
Compostable PLA plastics	Low	2	Medium	4
Coolant waste	Low	2	Medium	4
Dye waste (water based)	None	2	Very High	1
Filter cake and presses	Medium	2	Very High	1
Fly ash	None	2	Medium	2
Foundry sands	None	2	High	4
Paint wash	Low	2	Very High	1
Paper mulch	Low	2	High	4
Paper pulp effluent	Medium	2	High	4
Paper sludge dewatered	Medium	2	High	4
Plaster board	Medium	2	High	4
Polymer water	Low	2	Medium	4
Process fluid	Low	2	Very High	1
Total Petroleum Hydrocarbon (TPH) water	Low	2	Medium	4
Treated timber waste	Low	2	High	1
Water based inks	None	2	Very High	1
Water based paints	None	2	Very High	1
Water blasting wash waters	Low	2	High	4
Water-based glue	None	2	Medium	4
Water-based Lacquer Waste	None	2	High	4

	Wood molasses	High	1	Medium	4
Plant matter	Cane residues	Low	2	Low	3
	Cypress chip	Low	2	Low	3
	Forest mulch	Low	2	Low	3
	Gross pollutant trap (GPT) waste	Medium	2	High	4
	Green waste	Medium	2	Low	3
	Mill mud	Medium	2	High	4
	Mushroom compost (substrate)	Medium	2	Low	3
	Natural textiles	None	2	Medium	4
	Pine bark	Low	2	Low	3
	Sawmill residues (inc. sawdust, bark, wood chip, shavings etc.)	Low	2	Medium	4
	Tub ground mulch	Medium	2	Medium	2
	Wood chip	Low	2	Low	3
	Wood waste (excluding chemically treated timber) including pallets, offcuts, boards, stumps and logs	Low	2	Medium	2
	Worm castings suitable for unrestricted use	Low	2	Low	3
Sewage & STP residues	Activated sludge and lime sludge from wastewater treatment plants	High	1	High	4
	Biosolids	High	1	High	4
	Nightsoil	Very high	1	High	4
	Septic wastes	Very high	1	High	4
	Sewage sludge	Very high	1	High	4
	Sewage treatment tank or treatment pit liquids, solids or sludges	Very high	1	High	4
	Acid Sulphate Sludge	High	1	Medium	4

Earthworks waste and additives	Bentonite	None	2	Medium	4
	Crusher dust	None	2	Low	3
	Drilling mud / slurry (from Coal Seam Gas industry)	Low	2	Medium	2
	Gypsum	Medium	2	Low	3
	Lime	None	2	Low	3
	Lime slurry	None	2	Low	3
	Mud and dirt waste	None	2	High	4
	Sand	None	2	Low	3
	Soil	None	2	High	4
	Soil treated by indirect thermal desorption	None	2	High	4
Wastewater & wash-waters	Bilge waters	Low	2	Very High	1
	Boiler blow down water	None	2	High	4
	Brine water	None	2	Medium	4
	Calcium water	None	2	Medium	4
	Car wash mud & sludge	Low	2	High	4
	Carpet cleaning wash waters	Low	2	High	4
	Effluent waste	Medium	2	Very High	1
	Forecourt water	Low	2	Very High	1
	Ground wWater	None	2	Medium	4
	Latex washing	Low	2	High	4
	Leachate waste	Very high	1	Very High	1
	Low level organically contaminated stormwaters or groundwaters	Low	2	Medium	4
	Muddy water	None	2	Medium	4

Oily water	Low	2	High	4
Soapy water	Low	2	Medium	4
Stormwater waste	Low	2	High	4
Sullage waste (greywater)	Low	2	Very High	1
Treatment tank sludges and residues	High	1	Very High	1
Vehicle wash down waters	Low	2	High	4
Wash bay water	Low	2	High	4
Waste water	Medium	2	Very High	1

Recommendations

Odour Control Recommendations

A number of recommendations were proposed in Phase 1 to improve the management and regulation of odour from composting facilities. Those recommendations are presented below for completeness.

Best Practice Management Guidelines – Odour Control

A number of the recommendations made in Phase 1 related to operational measures to control or minimise odour and while it is up to DES to determine the most effective way to implement these measures or encourage their implementation by industry, one option is to develop a Queensland specific Best Practice Environmental Management Guideline for organics processing, which may include and build upon these recommendations. The following recommendations can be considered best practice measures that could be incorporated into any future guidance, noting that any such guidance would need to cover a broader range of operational and management aspects beyond those on which this study has focused, such as siting, water management, dust, noise, fire / safety and monitoring.

1. Turned windrow management – there is no best practice standard for the frequency and method of turning. Turning methods and schedules need to be optimised for the feedstock mix, available machinery and site requirements. This requires a balancing of several factors such as maintaining aerobic conditions versus releasing accumulated odours; loosening of the compost and breaking up clumps versus reducing the porosity of the compost mix; and redistribution of moisture. The optimal turning strategy should be determined by an experienced operator through site trials and measurements.
2. That said, there are some common considerations in optimising the turning strategy for an open windrow operation:
    - Focus on adequate porosity - mix odorous materials with a generous and appropriate ratio of bulking material (e.g. shredded green waste) that has both readily available carbon sources and large, structurally stable particles that are able to maintain adequate porosity (ideally 35-45%) to facilitate passive aeration of windrows, which is driven by the temperature gradient between internal and external windrow temperatures.

- Minimise turning events for windrows containing odorous feedstocks, especially during the first 7-10 days of composting, with only the minimum turning required to support pasteurisation and moisture redistribution. This enables the odorous by-products generated during this initial phase to be oxidised to less odorous compounds before they are released to the atmosphere. The compounds will continue to decompose as they move through the windrow mass.
- When turning with a front-end loader, ensure that the operators do not drive up on the compost when windrows are being formed, which can cause compaction and reduce airflow.

3. Composters processing odorous materials in open windrows should be encouraged to experiment with caps (or blankets) of mature compost as a measure to reduce odour emissions during the initial stage of composting and to ultimately implement this is as a regular operational control.
4. Composting operations that process highly odorous materials and/or are located close to sensitive receptors should consider enclosing the waste reception / storage / blending functions and assess the implementation of some form of forced aeration and/or enclosed composting process, for at least the initial phase of composting.
5. Forced aeration, if adopted, needs to be optimised for a particular compost mix, so as not to have an adverse impact on odour emissions.
6. Engineered biofilters are a very efficient and cost-effective method of treating odours if they can be captured within an enclosed or forced aeration composting system. They could similarly be applied to treat air from an enclosed feedstock receival and mixing building. Other measures including physical and chemical treatments are unlikely to be as effective.
7. For best practice feedstock receival, operators should:
    - Keep an ample stockpile of bulking agent or high carbon material at the receiving area to immediately mix with all deliveries of odorous materials
    - Immediately mix potentially odorous materials upon receipt and ensure that materials are mixed uniformly throughout
    - Consider enclosing the receival facilities for highly odorous materials and the initial mixing operation, with appropriate ventilation and biofilter systems
    - Consider blanketing odorous solid materials with a thick layer of bulking agent
    - Work with generators and transporters of commercial organic residues to increase collection frequency
    - Have a system in place to assess and reject unacceptably odorous materials and eliminate troublesome feedstock sources
    - Undertake small scale trials of new feedstocks prior to accepting regular full loads, to assess the practical aspects of handling the new material and to monitor its performance in a composting pile.
8. Operators should have a clear procedure in place to ensure the initial compost mix is optimal in terms of C:N ratio, moisture and porosity and to understand the odour potential of each feedstock. This should include testing and analysis of feedstocks to understand their physicochemical characteristics. Such testing need not be of every load for consistent feedstocks, but sufficient to understand the key parameters and variability.
9. Parameters such as temperature and pH should be regularly monitored throughout the composting process. Other parameters such as moisture content and oxygen levels may also be measured, at least during critical phases (e.g. the first few days) and particularly when processing wet or odorous feedstocks.
10. Compost piles should not be moved to the maturation or curing stage until the thermophilic stage of composting has been completed, indicated by consistent temperatures below 45°C (assuming all other aspects managed correctly).
11. Maturity tests such as Solvita™ are widely accepted and can be done on site, to ensure compost is mature enough to be safely stored.

Regulation of odour

Regulation of composting facilities is primarily controlled by conditions set out in the Environmental Authorities of each composting facility as well as general obligations which apply to all businesses in Queensland under the *Environmental Protection Act 1994*.

A review of those EAs has identified vast differences in the degree of control and regulation applied to each operator. In some cases, this is due to operators undertaking other environmentally relevant activities which increases the risk associated with the operation, such as processing of regulated wastes under ERA 55. In most cases though, it is a function of the age of each approval and the difficulty of changing an existing approval unless the operator voluntarily agrees to those changes.

The discrepancy means that there are some composters, including some very large-scale operations, which are operating with minimal controls over key environmental risk aspects such as waste acceptance, product quality, and management of odour, leachate and stormwater.

12. DES should investigate options to harmonise and reduce the inconsistency in EA conditions for composting operations with a similar risk profile and implement consistent minimum standards on key aspects such as waste acceptance (including testing requirements), product quality and odour control. There are good examples amongst some of the more recent existing EAs which may serve as a template, but the main focus should be on achieving consistency. The initial (and so far, limited) feedback from industry suggests they are open to changes provided it applies consistently to all and helps to 'level the playing field'.
13. DES should consider whether there is a need for more stringent regulation or conditioning on sites that receive feedstocks considered to have a high or very high contribution to odour risk (as assessed in the Phase 1 report). This is not to suggest that these feedstocks are not suitable for composting, but that additional control measures may be warranted such as maximum blending ratios with green waste in the compost mix, additional requirements for their storage and mixing, more sophisticated processing (aerated / enclosed), and/or additional analysis and documentation requirements.
14. With respect to odour, DES should consider whether the current outcomes-based approach is appropriate for regulating odours from composting facilities. Outcome based conditions are generally preferred by industry but challenging to enforce when the outcome itself is difficult to measure and quantify, or to trace back to a specific activity. These challenges are heightened even more so when there are multiple operators potentially having a similar impact in one area, as is the case at Swanbank and elsewhere. The existing outcome based conditions should be retained but could be supplemented with specific additional conditions which address the root causes of odour as discussed in detail in the Phase 1 report (e.g. feedstock storage and blending; characterising feedstocks, and monitoring of key process parameters). There is a fine balance to be struck between being overly-prescriptive and maintaining flexibility for lower risk applications, which other states have not necessarily achieved in full. Therefore, a Queensland specific approach is recommended, considering some of the operational methods noted in the Phase 1 report but refined in consultation with industry.
15. It is apparent that waste collectors and transporters exert a high degree of power within the organic waste management supply chain (commercially and in terms of controlling feedstocks), yet it is the composters at the end of that chain that bear the brunt of regulation. In considering how to better regulate the composting industry, DES should be cognisant of this and consider options to better regulate the whole supply chain, making sure that waste generators and transporters are taking responsibility for providing adequate and accurate information about their waste streams, and ensuring they are managed appropriately. The new amendments under the Regulated Waste Framework will go some way to addressing this (for regulated wastes), provided they are properly applied by all parties in the supply chain and enforced by DES.
16. It is also apparent that the current waste tracking system is ineffective at tracking and flagging anomalous waste movements which may indicate waste has been taken to an inappropriate facility. DES should consider options to upgrade or overhaul the Waste Tracking System to an electronic platform that ensures that critical information is accessible to transporters, operators and the regulator in real time. This could potentially stop, for example, transporters 'shopping around' for an alternative disposal option after being rejected from one facility.

17. For new facilities, industry, local governments and residents could benefit from clear guidance produced by DES on the regulation of composting facilities including aspects such as locating composting facilities, separation distances, process and operational controls to minimise odour issues. Guidance documents from other states provide examples which may be considered, but the guidance should be tailored to Queensland context, be risk-based and allow a degree of flexibility for low risk applications.

18. To improve standards at existing facilities, industry seems open to measures to lift operational standards and knowledge levels. However, commercial competition means that measures such as voluntary codes of practice are unlikely to be developed by industry in isolation and may not be universally adopted. Government may have a role to play in leading and facilitating the collaborative development of minimum standards and training requirements. Consideration would need to be given as to how to incentivise existing operators to comply with the standards, if not regulatory.

Assessing odour from composting facilities

The Phase 1 report presented extensive information about different odour assessment and measurement techniques. It is apparent that some composters have rather limited technical understanding of how odours are caused and dispersed in the atmosphere, and it seems that the use of odour modelling and other tools to inform that understanding for their specific site, is limited. As such, the project team recommends more robust assessment and analysis of odour sources and dispersion mechanics, including the use of modelling and sampling where appropriate, but also training and development of industry knowledge on these aspects.

19. For any new proposed composting facilities, an odour impact assessment should be undertaken as part of the site's environmental and development approval processes. The assessment may vary depending on the risk posed by the scale, feedstocks and location but would generally include the following components:

    - An assessment of background odour in the existing environment. The assessment should include all sources of odour emissions from other existing activities in the local area with specific attention given to activities that may generate odours of a similar character or degree of offensiveness. This is to understand the current odour situation in the area, the frequency of potential odour episodes and the likelihood that the community is sensitised to odour or not. It is not for inclusion as background odour concentrations for use in an odour dispersion model unless the odour is deemed to be similar in character or from a sources at a similar activity, e.g., a proposed composting facility is located near an existing composting facility, landfill, waste transfer station, wastewater treatment plant or other activity where similar volatile sulphur and organic compounds may be released.
    - A representative odour dispersion model should be developed to assess the odour footprint of facility operations under all site-specific operating and meteorological conditions. The model should adequately represent the important features of the region's topography, land surface characteristics, and sensitive receptor locations and density.

20. For higher risk facilities, once it is approved and commences operation, an odour emissions audit should be conducted to develop a representative odour emissions inventory of the site's operations. A representative number of samples from each emission source should be collected and analysed by the methods prescribed in the Australian standards e.g., AS4323.3 and AS4323.4, to suitably assess the site's odour footprint. Further details of odour sampling, testing and assessment techniques are provided in the EPAQ (1997) and EPA (2006). Notwithstanding the guidance provided in these standards, consideration should be given in sampling device selection to the conditions, chemical mass transfer properties and diffusion mechanisms taking place at the surface of each odour source being sampled to ensure worst case emissions are captured for analysis.

    Once operational data is collected, it can be fed back into the site odour dispersion model (developed for the facility's environmental approvals) to calibrate and refine the model. The odour impact assessment can then be reviewed to evaluate whether the facility is likely to comply with the conditions under which it was approved, or whether further control measures may be warranted to ensure ongoing compliance. The calibrated dispersion model will then be a valuable tool for the operator to understand how their operation can impact on sensitive receptors under different conditions.

The performance of the odour dispersion model generated for the actual operating conditions could be evaluated and verified through a series of field ambient odour assessments. A minimum of ten field odour surveys in a period of 30 days should be conducted at different times of the day and in different meteorological conditions. This assessment could be repeated at least once during a different season within the first year of operation. Selection of seasons should be informed by dispersion model results and consider the following:

- Times of the year when winds are most likely to blow emissions towards key identified sensitive receptor areas,
- Peak odour emissions (e.g. potentially summer time) when ambient and compost temperatures are likely to be at their maximum, thereby generating peak odour emissions. This may also coincide with the period when compost material volumes are at their peak.
- Worst case dispersion conditions (e.g. winter time), particularly at night and around sunrise and sunset, but not limited to these times, and elevated ground-level odour concentrations.

An odour impact assessment technical report of these studies should be prepared by a suitably qualified and experienced person. This level of odour assessment will not be required for all facilities and is not directed at facilities that are demonstrably at low risk of impacting on sensitive receptors.

21. For an existing composting facility that has been the subject of a certain number of complaints (to be determined by the regulator) from the community related to offensive odours that may cause nuisance, the proponent of the facility should be required to conduct an odour impact assessment of its operations. The assessment should include, but not be limited to:

- An odour emissions audit, with sampling and measurement by the methods prescribed in the Australian standards e.g., AS4323.3 and AS4323.4. The results of the audit should be compiled into an emissions inventory for comparison with the inventory developed after the facility’s approval.
- An odour impact assessment report should be prepared which considers the likely contribution from all sources including:
    a. all phases of processing (e.g. pre-treatment, decomposition, aeration and maturation),
    b. raw organics and organic products managed at the premises, including impacts during receipt and storage (i.e. including stockpiling of organics),
    c. movement of raw organics and organic products at and to/from the premises.
- An odour dispersion model may be a useful tool to understand the interactions and contributions of different sources / activities. Field ambient odour surveys should be conducted to evaluate odour model performance and provide an actual assessment of odour experienced in the surrounding area.
- Consideration may also be given to ongoing and routine field ambient odour assessment surveys as an odour management tool. Surveys should be conducted by suitably trained and qualified odour assessors, and preferably independent of the occupier’s organisation. Should staff from the occupier’s organisation conduct these surveys, they should not be plant operators that spend their time on the site and are desensitised to the odours released. These surveys should be recorded and documented appropriately in order for the regulator to assess compliance upon request.

22. For all facilities, operators should undertake an odour audit or odour balance study, which can be a useful exercise to identify and quantify odour emissions from each stage of the process, resulting in an odour emissions inventory for the site. The sophistication and level of detail of such a study will vary for each site in accordance with the scale or the operation and risk profile (function of waste types, process, proximity to sensitive receptors). It is worth noting the receival

area and curing piles can be major odour sources which should not be overlooked, in addition to the mixing and composting stages.

23. Ongoing environmental management of existing and future composting facilities may include, but not be limited to:

- A site-specific odour management plan, the purpose of which is to identify odour sources and proactively reduce the potential for odour generation as well as to have a reactive plan for managing odour during upset conditions. The complexity of the plan should match the risk posed by the operation but a typical odour management plan may include the following:
    a. An inventory of all sources of odour,
    b. Odour sources and controls under normal conditions,
    c. Odour monitoring and recording regime,
    d. Odour management during upset conditions, and
    e. Routine maintenance of odour control equipment (where installed).
- Site-specific meteorological data should be collected and recorded in accordance with the Australian standard AS3580.14 (2014) and EPA NSW (2016). The establishment of meteorological stations at all higher risk composting and related organics processing facilities should be encouraged to help verify odour complaints and evaluate or enhance dispersion model performance. The meteorological monitoring station should be maintained in good working order. Meteorological stations installed at composting and related organics processing facilities should, where practicable, continuously measure and electronically log the following parameters, at a minimum, in accordance with the Australian standard AS3580.14 (2014):
    a. Wind speed at 10 metres (m/s),
    a. Wind direction at 10 metres (°),
    b. Ambient temperature at two levels (2 metres and 10 metres) (°C),
    c. Parameters needed to determine the Pasquill-Gifford stability class—that is, either sigma theta (°) or solar radiation (W/m2).
- All complaints reported to the occupier regarding odour must be considered in the light of meteorological data and/or site activities such as delivery of unusual organics to identify any correlations.

Contamination Recommendations

A number of recommendations are made to reduce the risk of compost product contamination, primarily by better managing and regulating feedstocks used in composting. The recommendations are set out below.

Composition data and feedstock characterisation

24. The initial contaminant risk assessment has identified 32 feedstocks considered to pose a high risk and 16 ranked as very high risk of leading to contaminants in compost products. Where there is reasonable confidence in the composition of the feedstocks and a high or very high rating is still applied (contamination category 1 materials), these should generally be banned from composting. In many cases though, the high ranking is partly due to uncertainty in composition so could potentially be reduced with better compositional data. The onus should generally be on operators to undertake sufficient analysis to demonstrate that the risk profile of their feedstocks is acceptable.

25. The lack of detailed data on feedstock composition has been a significant barrier in this study and more broadly in understanding and quantifying the scale of the issues. DES should establish a database of feedstock compositional analyses, by collecting data through a number of means such as:

a. For common and consistently used feedstocks, DES could undertake sampling and analysis and make data available to industry

b. For less common or more variable feedstocks, require operators to undertake regular sampling and analysis

c. DES could require operators that need to analyse and characterise feedstocks to satisfy EA conditions, to regularly submit that data to supplement a non-published database.

26. Better analysis and data collection by industry is also needed to characterise and risk assess their own feedstocks, but DES could provide a framework and clear guidance on how to do this.

27. In general, composters should not be accepting wastes which are of unknown origin or composition. Where the composition of a waste is not known, it should conservatively be considered high risk until shown otherwise. If the waste generator or transporter fails to provide this information, there should be a clear mandate for the operator to reject the material and measures to restrict other operators then accepting it.

28. Likewise, it would be advantageous if compost quality data, differentiated into product types (feedstock, end-use based) was collated centrally by industry or a quality assurance organisation, and made available as collated anonymous information for public-interest interrogation.

29. The government should allow an adequate transition period for any regulatory changes which will divert materials away from composting, where there may be a need for industry to develop new infrastructure, to prevent perverse disposal outcomes and worsened environmental outcomes.

30. It would be beneficial to have a standard list of feedstock names which provide a more accurate and descriptive picture of the material, including the source industry or sector and accompanied by a short statement regarding source and composition of each feedstock. This is an important piece of information to record as it will assist in guiding management decisions on the assessment of new feedstocks, and consistency in terminology used across industry will aid in ensuring that incoming feedstocks are classified in a consistent manner upon receipt at composting facilities and that risks are better understood.

31. Further work is also needed to collate data on organic contaminants (and other characteristics) in compost products from a wide variety of sources to establish what proportion of products exceed the AS4454/ Biosolids limits, and which compounds are causing issues. Without sufficient data, it is impossible to have an informed discussion and to make informed decisions.

32. Further investigation is needed to evaluate the risks associated with new ‘emerging’ chemicals of interest, especially PFOS/PFAS. An approach similar to that used by Clarke and Smith (2011) as referenced in this report would be highly valuable, in which emerging contaminants were scored on certain criteria in order to prioritise for further research. This research could be used to reset the proposed suite of Organic Chemicals to be tested. This list may vary a little depending on the waste being composted.

33. Further investigation is needed to assess whether elevated TPH and TRH levels found in the finished compost samples collected by DES in 2017 are widespread and common, and what the specific hydrocarbons are and where they came from. TPH and TRH have been detected in common feedstocks including green waste and grease-trap waste but these do not fully account for the levels detected in finished compost products and the fact that most volatile hydrocarbons are readily biodegradable in a composting process. It is possible that compounds are being formed during the composting process, which are being detected in the TPH / TRH tests, but this needs to be confirmed.

34. There is also a need for improved management procedures for tracking, assessing, and managing contamination risks, which may include:

- Procedural improvements – develop templated forms and record keeping requirements, including forms to document feedstock sources, volumes, testing done, etc.
- Procedural improvements – require improved record keeping of composting processes, to ensure biological hazards are being managed (i.e. pasteurisation requirements)

- Improved guidance on analytical requirements – to be developed following further data collection on current feedstocks.

Regulation of contaminants

35. As with odour regulation, DES should investigate options to harmonise and reduce the inconsistency in EA conditions relating to the management of contamination in feedstocks and compost products. The main focus should be on achieving consistency and there is a case for more prescriptive conditions to regulate some aspects, such as feedstock characterisation, risk assessment and product testing.

36. There is a strong need to restore consumer confidence in the quality of compost products in the Queensland market and in the ingredients used in composting. Feedstocks which have been rated as high or very high risk of causing product contamination need to be further investigated and characterised to confirm the risk and then consideration given to whether they are appropriate feedstocks, or whether the risks can be adequately controlled with management and regulatory measures.

37. The government should consider whether feedstocks which are confirmed as high or very high risk in terms of contamination, including those processed under ERA's 55 and 58, should be processed in physically separate composting facilities, or indeed whether other treatment technologies are more appropriate. The combining of ERA 53 composting with ERA 55 activities, and in some cases ERA 58, seems to add to the risk of product contamination and certainly undermines consumer confidence in the product.

38. This review has considered whether there may be a case for differentiation in labelling and permitted end uses of compost products that are derived from low risk organic feedstocks (under ERA 53) versus those which incorporate higher risk feedstocks. The idea may be that only the low risk feedstocks would be permitted to be used in sensitive applications such as food production and horticulture, residential, commercial, institutions and public space landscaping. Higher risk and poorer quality products, whilst still complying with minimum standards, would then be confined to applications that minimise the likelihood and frequency of human contact or environmental impact, such as rehabilitation of mines, landfills and contaminated sites, highway verges and forestry. However, the project team has come to the view that such an approach will be difficult to implement and potentially counter-productive. It is better to aim for one final product standard, which allows use in any application (unrestricted) to avoid potential confusion in the market place. This will be much more practical to implement and enforce / monitor. Industry feedback supports this approach but further consultation with industry on this point is recommended.

39. The government should generally reconsider its current approach of allowing operators to be primarily responsible for determining which feedstocks are suitable for composting as set out in the Composting Guidelines, or at least provide much more specific guidance around assessing feedstock suitability. This approach and the exclusion of waste acceptance criteria from a number of EAs, has undoubtedly allowed the current proliferation of composting feedstocks and the apparent shift from production of beneficial soil products, to low cost treatment of waste streams.

40. Further work is needed to establish the suitability of the AS4454/ Biosolids organic contaminant limits to the current situation with respect to organic waste recycling. Most of these chemicals have been phased out for many years and studies overseas show that they are usually virtually absent in compost products. Conversely, there are numerous contaminants not included in these standards which could be relevant. The NEPM Soil Health Investigation Levels provide a more contemporary and comprehensive list of contaminants that should be considered, although the actual thresholds should be tailored to suit the application of compost to land (rather than the assessment of existing contamination, as the current HILs are designed for).

41. In regulating physical impurities, area-based assessment of impurities should be considered as a superior method (compared to weight or item number based measures) to better account for highly visible light weight impurities such as film plastics, which are likely to break down into microplastics over time.

42. End of Waste codes may provide a powerful tool, with minimal regulatory change, to better regulate the contaminant risks associated with specific high risk feedstocks, or to introduce regulatory limits on compost products.

43. The requirement for some composters under their EA conditions to demonstrate that new feedstocks do not have detrimental effects on the composting process or the quality / usability of finished products is good in its intention, but potentially too loosely defined. It could be tightened and industry provided with specific guidance on how to undertake such assessments, including analysis of contamination risks, which could result in utility and risk scores, that determine whether new feedstock enhance or detract from the composting process and the generated product.