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.

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 impacts including significant greenhouse gas emissions.

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 sets ambitious targets for recycling waste and reducing landfill which will only be achieved if more organics are recovered and directed to beneficial uses. The Waste Strategy focuses on building a circular economy in Queensland and the recovery of organic waste is already a major contributor to that.

However, composting also has a high potential to impact on local communities and the environment. DES has received a considerable number of complaints about odour nuisance from composting operations, particularly in the Swanbank area near Ipswich, but also near other composting operations. 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 1 which is particularly focused on issues of odour control at composting facilities in Queensland.

Overview of findings

The report starts with a description of composting processes and different system options, as well as discussion about key process control parameters to minimise odour formation and release. It is noted that:

- Odours will form during composting even under optimal conditions. Nevertheless, failure to maintain optimal conditions is highly likely to make matters worse and the nature and noxiousness of the odours will be worse under sub-optimal conditions.
- Understanding the relationships between food source (feedstock), environmental conditions (e.g. temperature, air and water) and metabolic activity (microbial species, diversity and activity) is critical to successful operation of a composting process, including how odours are generated and managed.
- Getting the physicochemical composition of the feedstock mix right (i.e. optimal physical characteristics such as particle size and porosity plus optimal ratios of carbon, nitrogen and other nutrients) is the key to maintaining the consistent aerobic conditions necessary for low odour emissions, regardless of the composting system employed.

Composting Methods

The vast majority of organic wastes recovered in Queensland and processed through open window composting facilities. Turning of the windows is an essential part of the process in these systems and there are different approaches, noting:

- Turning frequency has less impact on the composting process than other key process variables such as feedstock physicochemical characteristics, moisture content and window size; but it can influence such things as the rate of decomposition, compost bulk density and porosity, and the time required to reach maturation.
- Turning a window in itself, has limited direct effect on maintaining aerobic conditions. Studies have shown that any oxygen which is introduced into a window during turning is generally consumed within hours.
- As such, the porosity of the composting materials is far more important, because it determines how freely fresh air can move through the pile. A degree of turning can help to improve porosity by loosening the materials and redistributing moisture. The use of bulking agents such as green waste or wood chips at appropriate particle sizes and ratios, is critical to maintaining porosity and air flow in passively aerated windows.
- On the other hand, care must be taken not to overwork or excessively turn a window. An aggressive turning schedule or method can reduce the porosity of a window by breaking down compost particles, which can reduce air flow and lead to anaerobic conditions.
- Turning also potentially assists the release of odorous gases that may have accumulated within the window voids and which would have otherwise oxidised as they moved through window. Research has shown that increased turning may increase the loss of ammonia gas in particular, which is odorous and its loss also reduces the nutrient value of the compost product.
- Specialised turners are more effective at turning and mechanical agitation and generally more efficient in terms of labour and time, compared to generic plant such as front-end loaders or excavators. However, over-use of window turners may have an adverse effect and the more gentle action of a front-end loader may be beneficial for some feedstock mixes.

Industry is increasingly considering a shift towards enclosed and/or forced aeration composting systems and some operators are already progressing towards this. This report notes that:

- Enclosed and forced aeration composting systems come in many forms but offer the potential of: more precise control over composting conditions; ensured continuous aerobic conditions; rapid pasteurisation and decomposition; and improved odour containment and control.
- Aerated static piles (ASPs) are the simplest form of forced aeration system and can be a cost-effective alternative to turned window systems. While there will be a moderate additional capital investment in the aeration floor / pipework and fan systems, there is usually reduced need for turning equipment and less land required for a given throughput as the process is more intense.
- Aeration rates need to be carefully controlled and balanced. Too much air will drive out heat and undermine pasteurisation, while it is also generally considered that increased rates of aeration result in a decrease in concentration of odorous compounds emitted, but an increase in total mass emissions. Operators need to determine the optimal aeration strategy for their particular compost mix through site trials and sampling in the commissioning phase.

Operations and Process Control

The following general findings were noted in terms of optimising site operations to minimise odour emissions:

- Highly putrescible feedstocks, which can be characterised by a high proportion of biodegradable volatile solids, often arrive at a composting facility in an anaerobic condition due to the time and way they have been stored by the waste generator. They also decompose rapidly in a composting environment and can quickly consume available oxygen. The solution to this issue is to blend and dilute highly putrescible or potentially odorous feedstocks with slowly degradable materials and bulking agents such as green waste in appropriate ratios to control the decomposition rate. Potentially odorous material must be combined in a mix as quickly as possible upon arrival at a composting facility.
- Preparing the right mix of feedstocks for composting is critical, with particular attention to C:N ratio, moisture content and porosity. The ideal C:N ratio for composting is in the range 25 to 40 and operators should understand and monitor the C and N content of their feedstocks, including lab analysis of samples as appropriate.
- Compost mixes outside the ideal range may still heat up and appear to be composting well. However, high C:N ratio mixes (low on nitrogen) will take longer to mature and increase the risk of odour formation in the curing piles. Low C:N ratio mixes (excessive nitrogen) can lead to loss of nitrogen as odorous ammonia gas.
- The optimum moisture content for composting is considered to be around 50% but some forced aeration systems perform better at slightly higher moisture contents of 55%. Above 60%, the pore spaces in the compost are filled with water, impeding air flow and leading to anaerobic conditions.
- It is generally better to focus on achieving an optimal C:N ratio whilst erring on the side of a drier mix. It is easy to add water to a mix, but difficult to remove moisture.
- The porosity of the mix (the proportion of free air space in the voids) should be above 40% and ideally in the range 55-65%. Bulk density is often used as a surrogate for porosity (there is a linear relationship) and is easy to measure on site. Bulk density of the mix should be below 650 kg/m3.
- The optimum pH level for most composting organisms is considered to be pH 5.5 to pH 8.0. Acidic conditions (low pH) are common in the initial phase of composting due to formation of organic acids but prolonged low pH conditions can lead to increased release of VOCs. High pH conditions can facilitate release of ammonia gas. The solution to managing pH levels is adjusting the C:N ratio of the initial mix, rather than direct adjustments, e.g. by adding lime.
- Temperature is an important (and relatively easy) parameter to monitor during the composting phase. The ideal range for thermophilic decomposition is around 45°C to 60°C, while 55°C is considered the minimum to achieve pasteurisation. Higher temperatures can increase the volatility of odorous compounds and there is a direct relationship between temperature and odour emissions up to around 65°C.
- Oxygen levels of 5% within the windrow voids is generally considered to be the minimum threshold for 'aerobic' composting, though above 10% is preferable.

The curing phase of composting, which follows the main active composting phase, can be a surprisingly significant source of odours, particularly when material is moved to this phase too soon:

- The thermophilic phase of composting in a well-managed system is not completed until temperatures start to consistently decline below 45°C, at which point, the curing or maturation phase can begin.

- The curing phase is important and can take anywhere from 1 to 6 months. The smell of mature compost should not be unpleasant, while immature compost may have an unpleasant odour and become anaerobic when stockpiled.
- Compost should not be screened until the latter stages of curing, to maintain the compost porosity. Stockpiling of screened compost that is not fully cured can contribute to odour issues.
- There are a number of ways to test the maturity of compost including the Solvita™ test which can be performed on site and is considered an acceptable method in the Australian Standard AS4454 and several European guidelines.

Composting Regulation

Upon reviewing the Environmental Authorities of Queensland composting facilities and regulatory approaches in other jurisdictions, it was noted that:

- Waste acceptance conditions in existing EAs vary widely with some licences having no or very few specific waste acceptance conditions stated. Similarly, there is inconsistency in the conditions that are intended to control odour impacts. Inconsistency in regulation between otherwise similar sites creates an un-level playing field commercially (real or perceived) which may be a barrier to investment in upgrades and improvements.
- Most EAs require an outcome of no odour nuisance at any sensitive place. Such outcome-based conditions place the onus on the operator to determine the best way to achieve that outcome. The challenge with this approach is that the outcome can be difficult to measure and if there are multiple potential sources of odour around a ‘sensitive place’, it can be difficult to link a nuisance issue to a specific activity or operator and enforce these types of conditions.
- Most other jurisdictions provide clear guidance in varying forms about acceptable locations for new composting facilities and particularly, separation distances to minimise amenity impacts on residents and sensitive receptors. Such guidance is helpful to operators and developers of new projects but is not a substitute for site specific assessment of the risks, through an odour impact assessment. The separation distance needs to factor in the local topography and climate, types of materials being processed, the technology and other engineering and operational controls in place.

Composting 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 assessed at a high level for their odour contribution potential in a composting context, which is difficult to do quantitatively with the limited feedstock data available. The assessment consider factors which indicate high potential for odour formation such as putrescible content / biodegradability, likely state upon arrival at site (e.g. anaerobic), likely concentrations of nitrogen and sulfur compounds, and content of proteins, fats and oils.

The assessment identifies those feedstocks which pose a higher risk of causing or contributing to odour issues in a composting process, which will allow appropriate mitigation strategies to be targeted. A number of feedstocks have been identified as having a high or very high potential odour contribution in a composting process and should potentially be considered for increased operational and/or regulatory control as composting feedstocks.

It is noted that Phase 2 of this project will add to this assessment, by assessing the risk of contamination posed by composting feedstocks.

Understanding and Quantifying Odour

This report contains extensive information to assist readers to understand how odours from composting can be described and measured. It is noted that:

- Odour concentration is the most commonly used odour dimension to characterise an odour for regulatory purposes and is measurable by well-established olfactometry methods in a lab setting. However, other dimensions such as intensity, character, offensiveness and persistency are also important in assessing or describing a nuisance odour (together the CICOP dimensions of odour).
- The assessment of odour impact is complex. The FIDOL factors describe the key factors that influence the extent to which odours adversely affect communities – they include frequency, intensity, duration, offensiveness and location. There is some overlap with the CICOP dimensions which describe a particular odour, but the FIDOL factors are more specific to a site and community and can be used to assess odour impact of an operation.
- Composting facilities are typically characterised by multiple point and fugitive sources of odour (receival areas, open windrows, turning activities, maturation pads, leachate dams, biofilters), and are often sited in areas of relatively complex terrain. Odour dispersion modelling can be an effective tool to assess odour impact on receptors, taking into account these complex factors, provided the right type of model is used. Models can also help operators and regulators to understand the effects of different variables such as weather conditions.
- Odour emissions measurements taken on site are a critical part of odour dispersion modelling and impact assessment to maximise their accuracy
- Field odour surveys can be a useful tool to quantify and delineate an odour plume but they require careful planning and analysis of the data to provide a comprehensive assessment of nuisance potential and extent.
- Composting releases a complex mix of many different odorous compounds at different stages of the process and depending on the composition of the feedstock and process conditions. The compounds all behave and change differently as they travel through the atmosphere. Therefore, there is often little benefit in trying to trace odours by measuring specific isolated compounds in air.
- Most composting odours are associated with a range of different volatile organic compounds that are released and it is noted that:
  - Feedstocks which are high in nitrogen are prone to producing ammonia gas during composting which has a recognisable pungent odour. Although ammonia has been noted to have a high odour threshold (i.e. it takes relatively high concentrations to be detected) and to dissipate rapidly.
  - Sulfur containing materials such as food, paper, gypsum, manure and biosolids can lead to release of mercaptans and other volatile organic sulfur compounds, while anaerobic conditions in a compost pile can lead to release of hydrogen sulfide gas with its characteristic rotten egg smell which is offensive even at low concentrations.
  - Feedstocks high in proteins such as food waste, manures and animal processing wastes are particularly vulnerable to production of odorous compounds as they can release both volatile nitrogen and sulfur based compounds.
  - Anaerobic conditions within a composting pile lead to formation and accumulation of particularly odorous compounds.
- Odour balance studies of composting facilities overseas, which measure the odour emission factors from different parts of the process have found that for high odour potential, rapidly biodegradable feedstocks (such as MSW organics) the main composting phase accounts for most of the odour emissions. For slower degrading

materials such as green waste, the odour emissions are more evenly spread across the entire process from receival to final product storage. In both cases, the curing phase was also a significant odour source and this is consistent with other studies which have shown curing can be responsible for more odour release than the main composting stage.

- Weather has an impact on odour emissions and in Queensland's warm climate the tipping or receival area can be a major source of odours due to waste significantly decomposing in the heat before it arrives on site, which is less of an issue in colder climates.
- Typically, poor dispersion of odour emissions from composting facilities occurs during light stable wind conditions, particularly during the evening and early morning when odour emissions can become entrained within slowly flowing air flows, travelling with little dilution along the path from source to receptor.
- On the other hand, moderate wind speeds may strip or draw out odorous compounds from a windrow resulting in a significant, well-defined and concentrated odour plume, which may be transported considerable distances downwind.
- Meteorological data collected onsite at a composting facility can be extremely useful when responding to complaints, planning site operations to minimise odour impact or for use within an atmospheric dispersion model. Meteorological observations can be carefully analysed to help an operator understand the dispersion mechanisms governing their odour plume, which can provide useful odour mitigation insights. Weather stations have to be carefully sited, typically 10 metres above the ground, following the appropriate Australian Standard.

Odour Treatment

In composting operations, it is far more effective to avoid or minimise the formation of odours at source, than to try to capture and treat them. That said there are treatment options and it is noted that:

- It is difficult to apply odour treatment techniques to open windrow composting but one option which has been found to be effective is to apply a 'cap' of matured compost (up to 150-200mm thick if unscreened) on top of a newly formed windrow. The layer acts as a biofilter and can be very effective at reducing VOC emissions. After the first turning, the mature compost gets mixed into the compost where it acts as an inoculum and continues to have a beneficial impact.
- Where process emissions can be captured, such as in an enclosed or covered system or an aerated static pile operating in suction mode, the odours can be effectively treated through an engineered biofilter. Biofilters provide a high rate of odour removal efficiency for a moderate capital cost and low operating costs.
- Wet scrubbing systems can be used to treat particularly strong odorous air streams, often as a pre-treatment to a biofilter.
- Other physical and chemical treatments are available but have experienced limited application or success on composting facilities.
- Chemical masking agents, often applied as a fog or mist over a site, have been used at composting facilities but their efficacy is debatable and they can actually contribute to the odour nuisance.

Recommendations

A number of preliminary recommendations are proposed in this report, which will be further developed and added to in Phase 2 of the project.

Operational and Process Controls

The following recommendations are made to assist in improving odour management at composting facilities, based on knowledge of current processes and discussion of best practice methods in this report.

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 and site requirements. This requires a balancing of several factors and 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 turning the strategy:
    - Focus on adequate porosity - mix odorous materials with a generous and appropriate ratio of bulking material (e.g. shredded green waste) with particles that are not too small.
    - 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 of mature compost as a measure to reduce odour emissions during the initial stage of composting.
4. Composting operations that process highly odorous materials and/or are located close to sensitive receptors should consider 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 used, 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 from an enclosed or forced aeration composting system. They could similarly be applied to treat air from an enclosed feedstock receival and mixing building.
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 collectors 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 (e.g. including nitrogen and sulfur content). 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 useful, particularly when processing wet or odorous feedstocks or optimising the process.
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

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 of effective conditions 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 'levels 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 this 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 in green waste, additional requirements for their storage and mixing, more sophisticated processing, 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 challenging to enforce when the outcome is difficult to measure and quantify or to trace back to a specific activity. Even more so when there are multiple operators potentially having a similar impact in one area, as is the case at Swanbank and elsewhere. Those existing conditions could be supplemented with additional conditions which address the root causes of odour as discussed in this report (e.g. feedstock storage and blending; windrow mixing and turning; maintaining aerobic conditions; 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. Therefore a Queensland specific approach is recommended, considering some of the operational methods noted in this report.
15. It is apparent that waste collectors and transporters exert a high degree of power within the organic waste management supply chain, yet it is the composters at the end of that chain that feel they 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, 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 a disposal option after being rejected from one facility.

17. For new facilities, industry 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 development of minimum standards or a code of practice and generally lifting operational standards and knowledge levels. However, commercial competition means that such measures are unlikely to be developed by industry in isolation. 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.

Assessing odour from composting facilities

This report contains extensive information about different odour assessment and measurement techniques. It is apparent that some major composters in Queensland have rather limited technical understanding of how odours are caused and dispersed in the atmosphere, and it seems that the use of odour measurement and modelling as 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 through modelling and sampling as follows.

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 of the facility.

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. 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.

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.

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. This will vary for each site but it is worth noting the receival area and curing piles can be major odour sources, in addition to the mixing and composting stages.

23. Ongoing environmental management of existing and future composting facilities should 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.
    - Site-specific meteorological data should be collected and recorded on site in accordance with appropriate standards.
    - 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.

Swanbank Composting Improvements

As part of the Phase 1 investigations for this study, the project team reviewed two major composting facilities currently operating in South East Queensland and developed detailed case studies of their operations. Detailed findings are contained in a separate commercial-in-confidence report appended to this report. Based on the review of the two Swanbank composting facilities, a number of common actions or areas for improvement were identified which are in line with industry best practice and could potentially be applied more broadly:

24. Operators receiving odorous liquid and other materials in sensitive areas should consider enclosing the reception and storage facilities for those feedstocks as well as the feedstock mixing areas, within an airtight structure along with air extraction to a biofilter.

25. Operators should implement operational procedures to avoid or minimise the formation of leachate through appropriate solid and liquid blending ratios and efficient methods of mixing the materials.

26. Where leachate is generated and storage is unavoidable, it should be able to drain freely from all operational areas and stored in an aerated pond to maintain aerobic conditions, or in enclosed tanks with adequate ventilation systems. Leachate storages should have adequate capacity to avoid uncontrolled overflows in heavy rainfall and be regularly desilted to prevent excessive accumulation of organic solids, which leads to anaerobic and odorous conditions.

27. Operators using open windrows should consider simple methods of mitigating odour from windrows in the early stages of composting, such as application of a thick layer or blanket of mature compost (unscreened or oversize fraction) and/or pure green waste mulch over the windrows once they are initially formed.

28. Large scale and higher risk composting facilities should be encouraged to develop an odour dispersion model, together with on-ground sampling to calibrate the modelling, to better understand the impact of different point and fugitive odour sources and activities, and the effects of different weather conditions.

29. Operators should provide training of staff to understand odour causes, dispersion and best practice control methods. DES can potentially support by developing technical guidance materials and manuals.