Information Sheet No. 5-4

Composting Science for Industry

Oxygen

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Importance of oxygen

The microorganisms responsible for *aerobic* composting, by definition, cannot grow in the absence of oxygen.

Many microorganisms are capable of growth at low oxygen concentrations, while some are killed in the presence of oxygen (termed *anaerobic* microorganisms).

> 'Anaerobic microorganisms ferment organic materials in anaerobic digestion systems. They are responsible for much of the unpleasant odours in compost systems, and are a result of inadequate oxygen.'

When microorganisms feed on the carbon component of organic materials for their energy, oxygen (O_2) is used up and carbon dioxide (CO_2) is produced. See Figure 1 for a scanning electronic micrograph of a common microorganism present in composting systems.

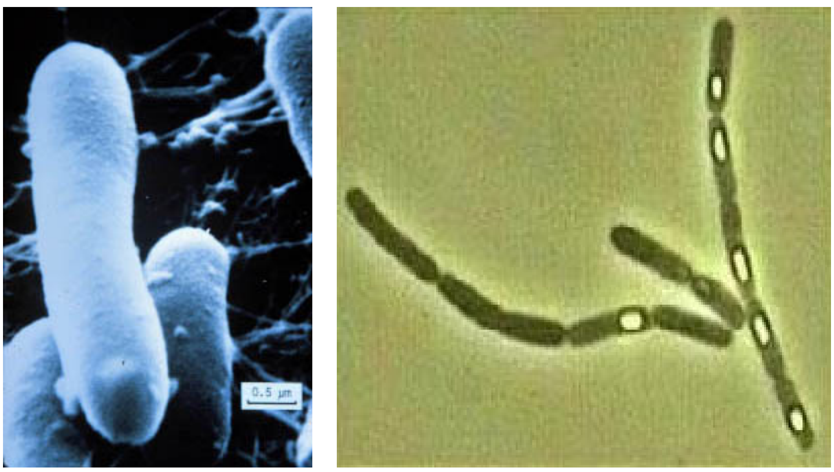
The oxygen concentration in air is about 21%, but aerobic microorganisms cannot function effectively at concentrations below about 5% in compost.

Oxygen concentrations of about 10-14% in a compost mass are ideal and results in optimum composting conditions (provided other parameters are correct).

In *windrow* systems, aeration is assisted by physical turning with either a front-end loader or a specialised windrow turner.

The main reasons for turning windrows are to move the outside portions of a windrow into the middle, and to loosen and fluff the material so that air can move more

Figure 1. Scanning electron micrograph of thermophilic *Bacillus* sp. bacteria commonly found in composting systems (left). Note their characteristic 'rod' shape. A phase-contrast light microscope picture of *Bacillus* sp. bacteria in chain form (right). These bacteria are in a spore generating phase. Heat resistant spores are produced when temperatures exceed that tolerable by the cells (e.g. temperatures above 65°C).



freely into the windrow.

The agitation of composting particles that occurs during turning stimulates higher rates of decomposition by exposing new surfaces to microbial attack.

> ‘Turning ensures that decomposition proceeds at a rapid rate, but also ensures that all clumps are broken up in a composting mass and are exposed to conditions necessary to eliminate pathogens and weeds.’

Windrow turners are usually more effective at breaking up clumps and aerating the mass than front-end loaders.

Windrow turners are also more effective at mixing the materials as they pass over a windrow.

Note that oxygen supply to a composting system does not have to involve turning.

Mechanical blowing or sucking air into and/or through materials by an aeration fan can remove excess heat and also increase the concentration of oxygen in the material.

Mechanism of aeration

Oxygen gets into the pile or system by convection and diffusion. Natural convection is the movement of outside air into a compost pile or system as a result of the “chimney effect” — warm air rises through the pile or system and cool air enters the lower sections, as long as the mix is “loose enough” to permit air flow (Figure 2).

Diffusion then transports oxygen into the smaller pores of compost and into the water layer surrounding compost particles.

In windrows or piles, convection is assisted by physical turning.

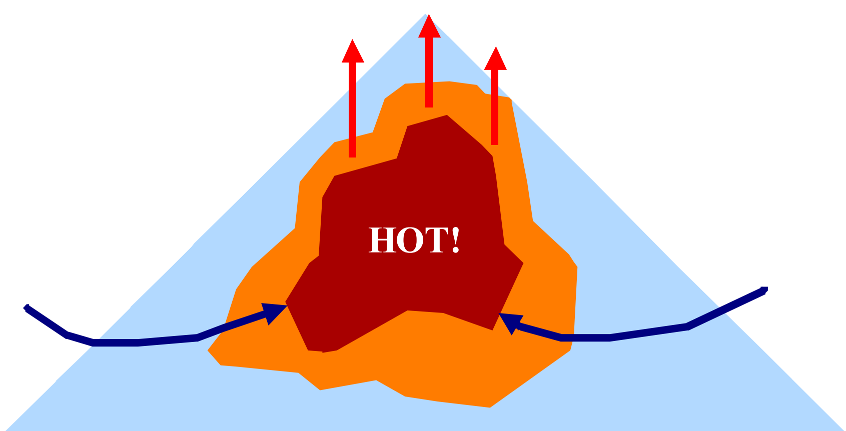
Turning only adds a small amount of oxygen directly, but it loosens and fluffs the material (reducing its density) so that air can move more freely into the windrow by convection.

> ‘Turning can provide sufficient aeration for six to seven days, provided that careful attention is paid to optimising the particle size in the compost recipe and mixing of materials in windrows.’

In *forced aeration* systems, convection also occurs mechanically with blowers — delivering air by suction or blowing or a combination of the two.

Forced aeration is a feature of *aerated static pile* or *in-vessel* systems. In the case of static piles, forced aeration by blowing also has the advantage of delivering warm air

Figure 2. Convective flow of air in a compost windrow.



Definitions*

Aerobic
In the presence of, or requiring, oxygen.

Anaerobic
In the absence of oxygen, or not requiring oxygen. Composting systems subject to anaerobic conditions often produce odorous compounds and other metabolites that are partly responsible for the temporary phytotoxic properties of compost. Anaerobic conditions are important for anaerobic digestion systems.

Turning
A composting operation which mixes and agitates material in a windrow pile or vessel. Its main aeration effect is to increase the porosity of the windrow to enhance passive aeration. It can be accomplished with front-end loaders or specially designed turning machines.

Forced Aeration
Means of supplying air to a composting pile or vessel which relies on blowers to move air through the composting materials.

Aerated Static Pile
Forced aeration method of composting in which a free standing pile is aerated by a blower moving air through perforated pipes located beneath the pile.

Windrow (with or without aeration)
System of composting involving the aeration of horizontally extended piles formed by a front-end loader or windrow turner. Extended piles are generally 1.5 to 3

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to the cooler outer layers, which assists in decomposition.

Another advantage of forced aeration systems is that the exhaust air can be recirculated and treated to remove odorous compounds.

Convection can be increased by constructing piles or windrows over channels or inserting pipes that extend from outside through to the core of the heap (*passively aerated windrow*).

Oxygen profiles

Turning or the forced delivery of air into a composting mass is necessary to ensure that the entire mass is kept in an aerobic state.

As with temperature, the concentration of oxygen is not uniform throughout the composting mass.

The centre of a turned windrow often has the lowest concentration of oxygen, whilst the exterior surface often has the highest concentration of oxygen.

This occurs because oxygen entering the outer surface of the pile is consumed by microorganisms before it has a chance to reach the centre (Figure 3).

The centre of the pile, therefore, becomes anaerobic, resulting in odour production. When these piles are turned, odours are often released into the air, potentially affecting the amenity of neighbours.

To minimise the release of odour during turning, turning should be performed when the concentration of oxygen decreases to about 12-14% (Standards Australia AS 4454, 2002). This is usually measured at the centre of the pile where oxygen limitations are most pronounced.

Figure 3. A typical oxygen profile of a turned windrow of size reduced garden organics and biosolids three days after turning during the thermophilic stage of composting.

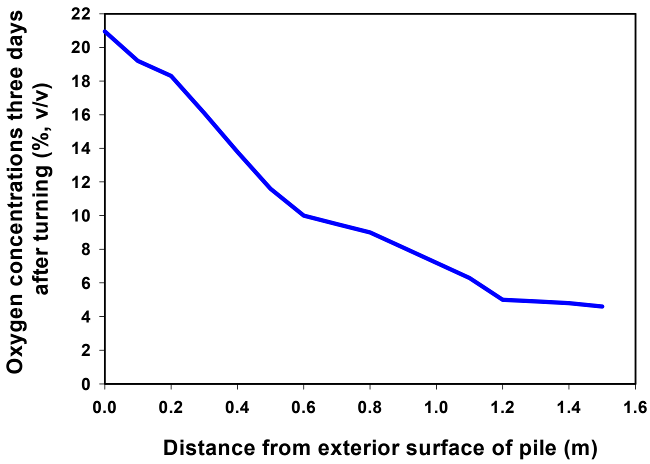
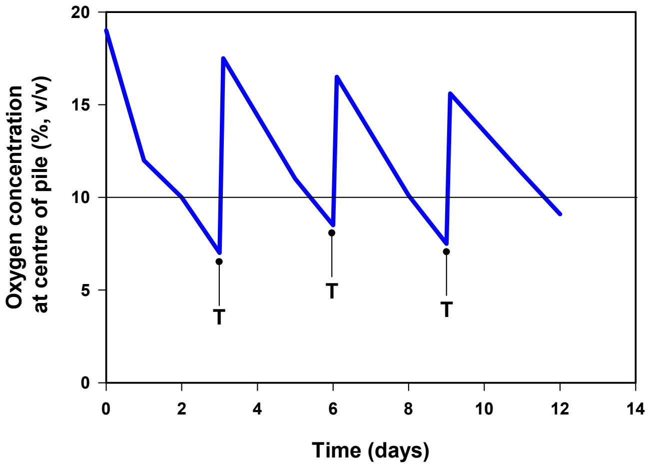


Figure 4. Typical changes in the concentration of oxygen at the centre of a turned windrow consisting of size reduced garden organics and biosolids during the initial stages of composting. T, physical turning.



Changes in the concentration of oxygen after physical turning of a windrow can be seen in Figure 4.

Odours produced during composting

Odour formation is strongly associated with the development of anaerobic conditions in composting systems.

These odours are produced through the anaerobic decomposition of organic matter.

Composting odours are mostly produced as vapours, though particulate (i.e. aerosol) odours can be produced.

Table 1 lists some specific compounds reported to cause odour problems during composting. Note that it is often difficult to identify individual components of an odour by olfaction (i.e. through smelling with your nose).

The main odour produced by composting operations is ammonia.

Odours can easily be treated in composting systems that permit the collection of process air. Examples

Table 1. Some compounds implicated in composting odours, and their characteristics. Modified from Miller and Macauley, (1988).

Compound	Formula	Characteristic odour	Threshold (nL/L)
Ethanal	CH_3CHO	Pungent	2
Butanoic acid	$CH_3CH_2CH_2COOH$	Rancid	0.28
Ammonia	NH_3	Pungent	37
Trimethyl amine	$(CH_3)_3N$	Pungent	4
3-methylindole (skatole)	$C_6H_5C(CH_3)CHNH$	Faecal	$7.5x10^{-5}$
Hydrogen sulfide	H_2S	Rotten egg	1.1
Carbon oxysulfide	COS	Pungent	-
Dimethyl sulfide	CH_3SCH_3	Foul	20
Dimethyl disulfide	CH_3SSCH_3	Foul	-
Diethyl sulfide	$CH_3CH_2SCH_2CH_3$	Foul	0.25
Methanethiol	CH_3SH	Decaying cabbage	1.1
Ethanethiol	CH_3CH_2SH	Decaying cabbage	0.016
1-Propanethiol	$CH_3CH_2CH_2SH$	Unpleasant	0.075
1-Butanethiol	$CH_3CH_2CH_2CH_2SH$	Skunk like	1.4

include in-vessel systems with forced aeration, or an aerated static pile with a suction-type aeration system.

Process air produced by these systems can be directed to a biofilter — a vessel containing mature compost — to remove the odourous compounds from the air.

Bacteria present in the biofilter decompose the odourous compounds and use them as a food source, thereby removing the smell from the air.

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m in height, and length is limited by the size of the composting pad. Aeration can be achieved by mechanical turning and/or the delivery of air from the base of the windrow (see aerated static pile).

Passively Aerated Windrow
A composting method in which windrows are constructed over a series of perforated plastic pipes, which serve as air ducts for passive aeration. Windrows are not turned.

In-vessel
System of composting involving the use of an enclosed chamber or vessel in which (in most cases) the composting process is controlled by regulating the rate of mechanical aeration. Aeration assists in heat removal, temperature control and oxygenation of the mass. Aeration is provided to the chamber by a blower fan which can work in a positive (blowing) and/or negative (sucking) mode. Rate of aeration can be controlled with temperature, oxygen or carbon dioxide feedback signals.

* Recycled Organics Unit, (2002).

Important references

- Standards Australia (2002). Australian Standard AS 4454 for Composts, Soil Conditioners and Mulches. Standards Australia, Homebush, NSW.
- Miller, F.C. and B.J. Macauley (1988). Odours arising from mushroom composting: a review. *Australian Journal of Experimental Agriculture,* 28: 553-560.
- Recycled Organics Unit (2002). Recycled Organics Industry Dictionary & Thesaurus: standard terminology for the recycled organics industry. Recycled Organics Unit, internet publication: http://www.rolibrary.com

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