Oxygen solubility in compost

Odour Technical Guide 3

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What is this document about?

Sufficient oxygen must be available to support aerobic microbes growing in compost water (the biofilm). High temperatures limit the solubility of oxygen in the biofilm and therefore limit its availability. This paper explains the effect that temperature has on the availability of oxygen for composting.

Who does it apply to?

This guidance applies to anyone taking oxygen measurements from composting systems and using that information to assess the risk of anaerobic conditions.

What is the conclusion?

Oxygen measurements from composting systems operated at high temperatures cannot be used directly to assess whether conditions are aerobic or anaerobic. Temperature is one important risk factor in this assessment. Not considering the effect of high temperatures may result in errors when assessing whether odorous anaerobic conditions have been prevented.

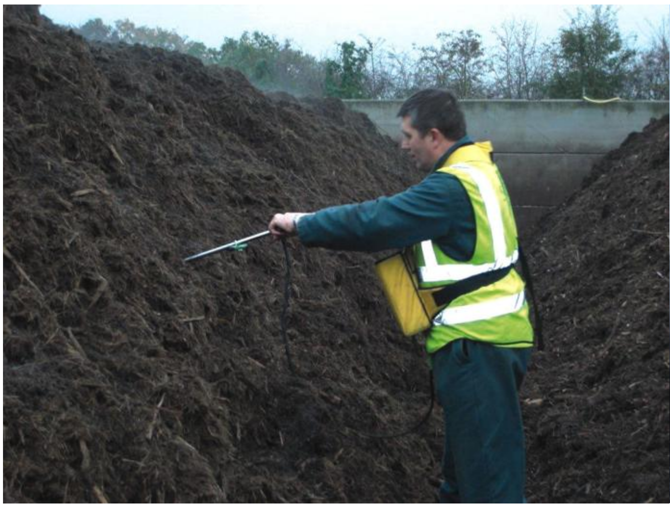

Figure 1 (Compost Manager, with permission)

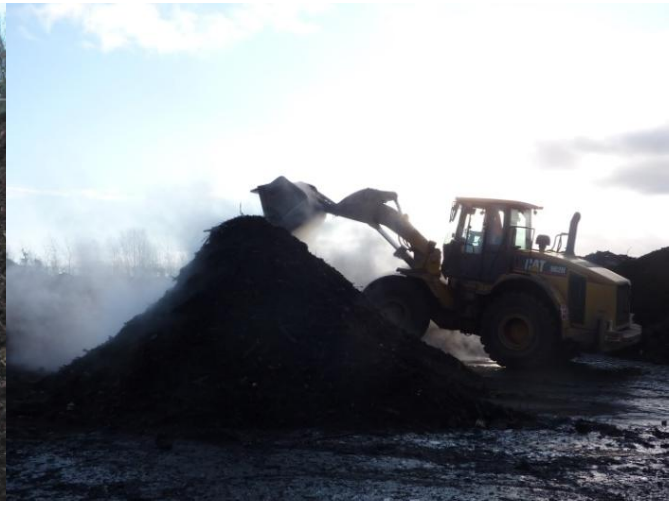

Figure 2 Hot Compost

The Problem

About half of the weight of material being composted will typically be made up of water. Aerobic bacteria living in this water/biofilm depend upon sufficient oxygen reaching them to survive. The oxygen must cross several barriers before it can be available for aerobic respiration. It must:

- penetrate into the air spaces within the core of the system (mostly by warm air currents);
- dissolve into the water layer, also known as the biofilm;
- diffuse through the liquid water layer (a very slow process);
- not be completely consumed before it can reach where it is needed.

Probes can be used to measure oxygen levels within the air spaces of a composting system. It is often presumed that as long as sufficient oxygen is present in these air spaces (5 to 10% is often quoted), then compost will be aerobic, but this is only part of the story. We must also consider how high temperatures limit the amount of oxygen which will dissolve in the biofilm.

The Solution

The solubility of a gas (oxygen) in a liquid (water) is governed by Henry's Law. This mathematical formula allows us to take into account the amount of oxygen remaining in the air. Other equations allow us to determine the effect of temperature. (The table in Odour Technical Guide 2 must be used first to correct oxygen measurements)

It is beyond the scope of this guide to describe these equations or the details of Henry's Law. However, the table below has been calculated using commonly applied Henry's Law constants for the range of temperatures and oxygen concentrations which are commonly found in composting systems. A spreadsheet which can be used to recalculate the table for other Henry's Law constants is available upon request.

Saturation O2 concentrations in water mg/l (ppm)
O2 partial pressures (%) vs temperature (C)

O2	20ºC	25ºC	30ºC	35ºC	40ºC	45ºC	50ºC	55ºC	60ºC	65ºC	70ºC	75ºC	80ºC
20%	9.17	8.32	7.57	6.91	6.33	5.81	5.35	4.94	4.57	4.24	3.94	3.67	3.42
19%	8.71	7.90	7.19	6.57	6.01	5.52	5.08	4.69	4.34	4.02	3.74	3.48	3.25
18%	8.25	7.49	6.82	6.22	5.70	5.23	4.82	4.44	4.11	3.81	3.54	3.30	3.08
17%	7.80	7.07	6.44	5.88	5.38	4.94	4.55	4.20	3.88	3.60	3.35	3.12	2.91
16%	7.34	6.66	6.06	5.53	5.06	4.65	4.28	3.95	3.65	3.39	3.15	2.93	2.74
15%	6.88	6.24	5.68	5.18	4.75	4.36	4.01	3.70	3.43	3.18	2.95	2.75	2.57
14%	6.42	5.82	5.30	4.84	4.43	4.07	3.75	3.46	3.20	2.96	2.76	2.57	2.39
13%	5.96	5.41	4.92	4.49	4.11	3.78	3.48	3.21	2.97	2.75	2.56	2.38	2.22
12%	5.50	4.99	4.54	4.15	3.80	3.49	3.21	2.96	2.74	2.54	2.36	2.20	2.05
11%	5.04	4.58	4.16	3.80	3.48	3.20	2.94	2.72	2.51	2.33	2.16	2.02	1.88
10%	4.59	4.16	3.79	3.46	3.16	2.91	2.68	2.47	2.28	2.12	1.97	1.83	1.71
9%	4.13	3.74	3.41	3.11	2.85	2.62	2.41	2.22	2.06	1.91	1.77	1.65	1.54
8%	3.67	3.33	3.03	2.77	2.53	2.32	2.14	1.98	1.83	1.69	1.57	1.47	1.37
7%	3.21	2.91	2.65	2.42	2.22	2.03	1.87	1.73	1.60	1.48	1.38	1.28	1.20
6%	2.75	2.50	2.27	2.07	1.90	1.74	1.61	1.48	1.37	1.27	1.18	1.10	1.03
5%	2.29	2.08	1.89	1.73	1.58	1.45	1.34	1.23	1.14	1.06	0.98	0.92	0.86
4%	1.83	1.66	1.51	1.38	1.27	1.16	1.07	0.99	0.91	0.85	0.79	0.73	0.68
3%	1.38	1.25	1.14	1.04	0.95	0.87	0.80	0.74	0.69	0.64	0.59	0.55	0.51
2%	0.92	0.83	0.76	0.69	0.63	0.58	0.54	0.49	0.46	0.42	0.39	0.37	0.34
1%	0.46	0.42	0.38	0.35	0.32	0.29	0.27	0.25	0.23	0.21	0.20	0.18	0.17
0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

kH for O2 in H2O
0.0013
(l atm / mole)

van't Hoff constant
1700
(ºK)

6 ppm and above
5 to 5.99 ppm
4 to 4.99 ppm
3 to 3.99 ppm
2 to 2.99 ppm
1 to 1.99 ppm
0 to 0.99 ppm

This chart clearly shows that the ability of oxygen to dissolve in water depends on both oxygen concentration in the air space AND temperature. While we do not recommend assigning absolute standards for these, lower numbers clearly carry a greater risk of anaerobic conditions, which need to be prevented. As a rule of thumb, saturation concentrations below 2 parts per million (ppm) in active composting systems may not prevent anaerobic conditions from developing. Highly active or wet materials, such as food waste, may require 3 ppm or more of dissolved oxygen to prevent anaerobic conditions and their associated odours.

References

Compilation of Henry's Law Constants for Inorganic and Organic Species of Potential Importance in Environmental Chemistry http://www.mpch-mainz.mpg.de/~sander/res/henry.html

Perry's Chemical Engineers' Handbook ISBN 978-0-07-142294-9

Further information

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