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An Analysis of Composting As an Environmental Remediation Technology

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Chapter 1

Introduction

The composting process is currently viewed primarily as a waste management method to stabilize organic waste, such as manure, yard trimmings, municipal biosolids, and organic urban wastes. The stabilized end-product (compost) is widely used as a soil amendment to improve soil structure, provide plant nutrients, and facilitate the revegetation of disturbed or eroded soil (Cole, 1994; Cole, 1995; Harmsen, 1994; McNabb, 1994). The information and data presented in this document were compiled and analyzed by Michael A. Cole, Ph.D.

Within the past few years, laboratory-, greenhouse-, and pilot-scale research has indicated that the composting process and the use of mature compost also provide an inexpensive and technologically straightforward solution for managing hazardous industrial waste streams (solid, air, or liquid) and for remediating soil contaminated with toxic organic compounds (such as solvents and pesticides) and inorganic compounds (such as toxic metals). For example, a large number of hydrocarbons, which are common industrial contaminants found in soil and exhaust gas, degrade rapidly during the composting process or in other compost-based processes. Furthermore, the addition of mature compost to contaminated soil accelerates plant and microbial degradation of organic contaminants and improves plant growth and establishment in toxic soils. When mature compost is added to contaminated soils, remediation costs are quite modest in comparison to conventionally used methods. Mature compost also controls several plant diseases without the use of synthetic fungicides or fumigants.

This report summarizes the available information on the use of compost for managing hazardous waste streams (as well as other applications) and indicates possible areas for future investigations. Attention to cross-media transfer of contaminants during implementation of various bioremediation technologies presented in this report is recommended. A recent publication by the U.S. Environmental Protection Agency (EPA), entitled *Best Management Practices (BMPs) for Soil Treatment Technologies* (EPA530-R-97-007, May 1997), could be consulted to address the cross-media transfer concerns.

The Composting Process

Composting is a managed system that uses microbial activity to degrade raw organic materials, such as yard trimmings, so that the end-product is relatively stable, reduced in quantity (when compared to the initial amount of waste), and free from offensive odors. Composting can be done on a large or small scale, with the management requirements and intensity increasing dramatically as system size increases. In its simplest form, compostable material is arranged in long rows (windrows) and turned periodically to ensure good mixing (Figure 1). This process can handle large quantities of input, such as yard trimmings of up to 100,000 cubic yards per year, on only a few acres of land.

Raw materials that tend to be very odorous during composting, such as municipal waste sludge (biosolids), can be processed in more elaborate systems and in a confined facility where odorous air can be treated. These systems use rotating drums, trenches, or enclosed tunnels for initial processing, followed by a covered curing period (Figures 2, 3, and 4). In addition, the Beltsville Agricultural Research Center in Beltsville, Maryland, developed a composting system of intermediate complexity, between open-air windrows and the sophisticated systems shown in Figures 2 to 4 (Parr, 1978; Willson, 1980; U.S. EPA, 1985). The Beltsville system has several desirable features, and its generic design is adaptable to suit specific purposes. As shown in Figure 5, air is drawn through the compostable material and scrubbed of odorous compounds in a soil filter. Mature compost can be substituted for the soil filter. A compost filter has several advantages over a soil filter, including a higher adsorptive capacity for volatile organic compounds (VOCs) and better air permeability properties. Compost filters are currently used in Europe at composting plants to eliminate nearly all volatile emissions.

All composting methods share similar characteristic features and processes. Initially high microbial activity and heat production cause temperatures within the compostable material to rise rapidly into the thermophilic range (50 ^{o}C and higher). This temperature range is maintained by periodic turning or the use of controlled air flow (Viel, 1987). After the rapidly degradable components are consumed, temperatures gradually fall during the "curing" stage (Figure 6). At the end of this stage, the material is no longer self-heating, and the finished compost is ready for use. Substantial changes occur in microbial populations and species abundance during the various temperature stages (Gupta, 1987). Mesophilic bacteria and fungi are dominant in the initial warming period, thermophilic bacteria (especially actinomycetes) during the high temperature phase, and mesophilic bacteria and fungi during the curing phase

(Finstein, 1975). The resulting compost has a high microbial diversity (Beffa, 1996 and Persson, 1995), with microbial populations much higher than fertile, productive soils (Table 1) and many times higher than in highly disturbed or contaminated soils. Therefore, compost bioremediation takes far less time than natural attenuation of toxic materials (land farming). Microbial populations in soil (both fertile and contaminated) substantially vary from season to season. In most cases, the addition of compost greatly increases microbial populations and activity (Table 2). Since the microbes are the primary agents for degradation of organic contaminants in soil (Alexander, 1994), increasing microbial density can accelerate degradation of the contaminants (Cole, 1994). In soil systems, microbial composition is greatly modified by organic input composition (Martin, 1992 and Struwe, 1986); the same degree of variation can be expected in composting systems. The impact of initial feedstock composition on microorganism development in compost needs to be further studied.

Table 1

Microbial Populations in Soil and Mature Yard Trimmings Compost

Material	**Bacteria** (millions per gram dry weight)	**Fungi** (thousands per gram dry weight)
Fertile soil[a]	6 to 46	9 to 46
Recently reclaimed soil after surface mining[b]	19 to 170	8 to 97
Pesticide-contaminated mix of silt and clay[c]	19	6
Mature compost[d]	417	155

[a] Cole, 1976 (for reclaimed soil)
[b] Cole, unpublished data
[c] Cole, 1994
[d] Cole, 1994

Dramatic changes in chemical composition occur during the composting process. Most starting materials for composting are plant-derived residues and contain carbon in the form of polysaccharides (cellulose and hemicellulose), lignin, and tannin. The end-product has a low polysaccharide content, most of which is microbial cell wall and extracellular gums (Macauley, 1993), with about 25 percent of the initial carbon content present in the form of highly stabilized humic substances (Chen, 1993). Organic matter content ranges from 30 to 50 percent of dry weight, with the remainder being minerals. The combination of high organic content and a variety of minerals makes compost an excellent adsorbent for both organic and inorganic chemicals.

The practical aspects of using the composting process or mature compost to manage hazardous industrial waste streams are described in the sources cited above. Additional information can be found in the documents cited in the Bibliography on page 105.

Table 2[a, b]

Dehydrogenase Activity in Uncontaminated Soil or Pesticide-Contaminated Soil With or Without Mature Yard Trimmings Compost

Percentage of Contaminated Soil	Matrix	Not Planted	Planted
100	Contaminated soil	16[c]	18[c]
50 25	Contaminated soil and Uncontaminated soil	25 25	32 59
0	Uncontaminated soil	40	68
50 25	Contaminated soil and Compost	336 613	370 575
0	Compost	1,464	1,299

[a] This table shows the high dehydrogenase enzyme activity as a measure of microbial activity in contaminated soil.
[b] After preparing the mixtures and transferring them into flower pots, the pots were incubated in a greenhouse for 6 weeks. Planted treatments had four corn plants per pot, while unplanted treatments had no plants.
[c] Units are µmoles product formed per 24 hours per gram of soil, with higher values indicating greater microbial activity.

Figure 1

Windrows of Leaves at a Community Yard Trimmings Composting Site

Height and width of windrows are determined primarily by the size of the turning equipment.

Figure 2

Aerated Rotating Drum Composting System at Aufschafenburg, Germany

The drum temperature and oxygen content are monitored continuously, and air addition and mixing are done as needed to maintain conditions within designated ranges.

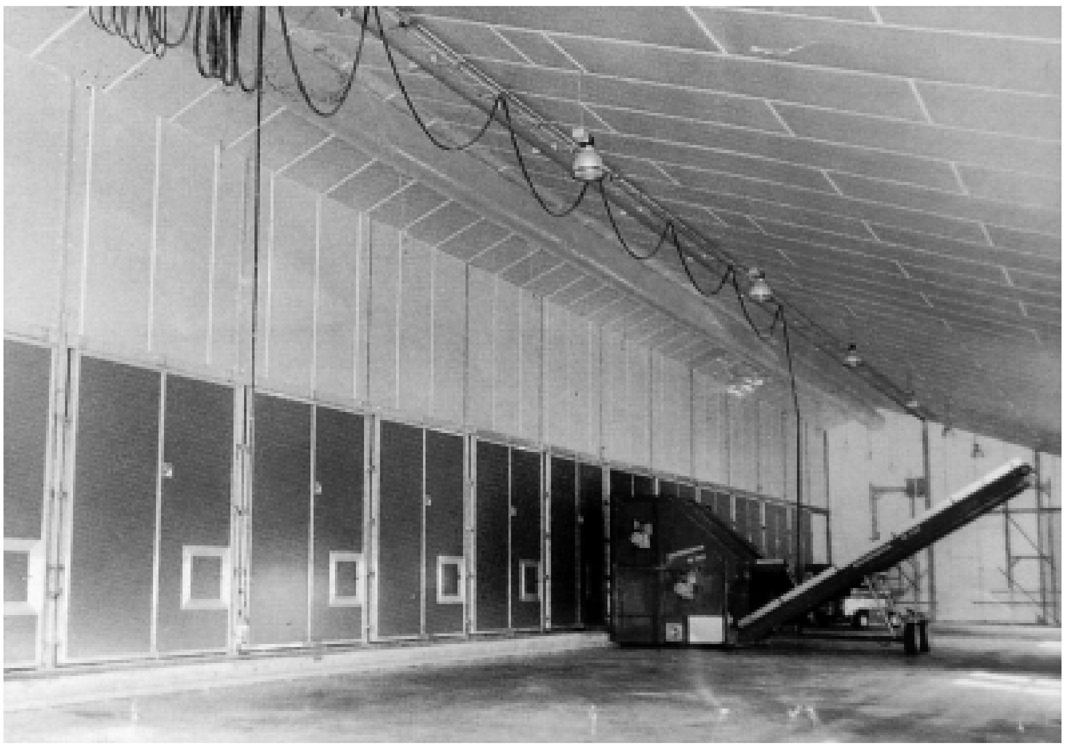
Figure 3

Trench Composting System at Saint Cloud, Minnesota

Air and temperature control is provided by subfloor vents and large blowers. Material is turned daily and water is automatically added as necessary.

Figure 4

Tunnel Composting System Used in Europe



Exit air is treated in a compost biofilter, and temperature and oxygen content of the air are monitored.