



Project Summary

Microbial Activity in Composting Municipal Sewage Sludge

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Research was conducted to identify the most important operational parameters that limit the growth and decomposition activity of composting sludge microbiota. Sensitive and nonselective biochemical methods of monitoring microbial biomass and activity were tested and used to study the interactions between the microbial communities and temperature, the primary factor affecting their activity during composting. Optimum temperatures for microbial activity and biomass were generally within the 35° to 55°C range. Biokinetic analyses revealed that compost samples from low-temperature (25° to 45°C) areas of the pile had much greater microbial activity (measured as the rate of incorporation or mineralization of ¹⁴C substrates) than did samples from high-temperature (60° to 75°C) areas. The microbial communities became better adapted to increasing temperatures as composting progressed, but their temperature optimum was never greater than 55°C. Biomass was monitored by measuring the lipid phosphate content (an important cell membrane component) of the compost. Other parameters that were measured included the moisture content, total organic content, total protein content, and pH.

This Project Summary was developed by EPA's Water Engineering Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Large aggregations of organic-rich matter have long been known to heat up and

become increasingly humified over extended periods. These effects are brought about by the activity of the indigenous microbial community, which decomposes the usable matter for energy and growth substrates, producing metabolic heat as a byproduct. In organic piles of sufficient size and insulation, this metabolic heat is trapped and can elevate the temperatures within the pile to in excess of 80 °C within a few days. The production of composted material through this process has been a means of recycling organic waste products throughout much of history. Recently the process has become an important means of disposing of municipal solid waste and sewage sludge. The primary goals of composting in solid waste management are to rapidly reduce the pathogens, odors, putrescible organic matter, moisture, and bulk, and to produce a biologically stabilized material.

No general agreement has yet been reached on the best conditions and procedures for optimizing the efficiency of decomposition (stabilization) during the composting process, so a wide variety of methods are currently practiced. However, temperature is generally agreed to be the most critical parameter influencing the rate of composting and the quality of the product, given reasonable initial environmental conditions of moisture, free air space, pH and nutrients, and provided that oxygen does not become generally limiting.

Many of the findings on optimum temperatures for maximum decomposition rate during composting have been in conflict. These discrepancies may be partly due to the indirect and incomplete nature of many of the studies concerning microbial activity and biomass in composting

material. Direct comparisons of decomposition rate between different temperature regimes require experimental arrangements unrelated to the practice of composting and produce unrealistic results. Estimates of microbial decomposition in composting material have typically been made using such indirect indices as the overall temperature of the composting pile, odors, moisture content, carbon dioxide evolution from the composting pile, or oxygen uptake by the composting pile. In most cases, concurrent assessments of microbial biomass were not made, or they were aimed only at quantifying the numbers of surviving pathogens or other specific groups using selective isolation techniques.

The purpose of this study was to provide a better understanding of the factors influencing the microbial activities in composting sewage sludge. The activity and biomass of the microbial community as a whole were accurately and consistently measured to permit conclusions to be made about an optimal temperature range for rapid decomposition during composting. Basic information leading to a better understanding of rapid thermogenic microbial successions was also obtained.

Results and Discussion

Composting was done in a full-sized commercial composting bin using forced aeration to regulate the overall temperatures of the piles. Each batch composting run lasted approximately 2.5 weeks, during which the material was removed and turned once or twice.

The microbiota of composting municipal sewage sludge from Columbus or Akron, Ohio, was analyzed during 10 different composting runs. A temperature gradient existed within the composting piles, with the central areas near the surface of the piles being the hottest. On each sampling day, samples were taken from several different areas, each with a different sampling temperature. In every case, a decrease in microbial activity occurred as temperature increased, with overall optimum temperatures falling between 35° and 55°C. Microbial activity was measured as the hourly rate of (^{14}C) acetate incorporation into microbial lipids per μmol of lipid phosphate biomass. The changes in this microbial activity rate in response to compost sampling temperatures during run No. 6 (see Figure 1) are typical. Microbial biomass also decreased with increasing temperature in most of the composting runs. The biomass data from run No. 6 (Figure 2) are typical. The same

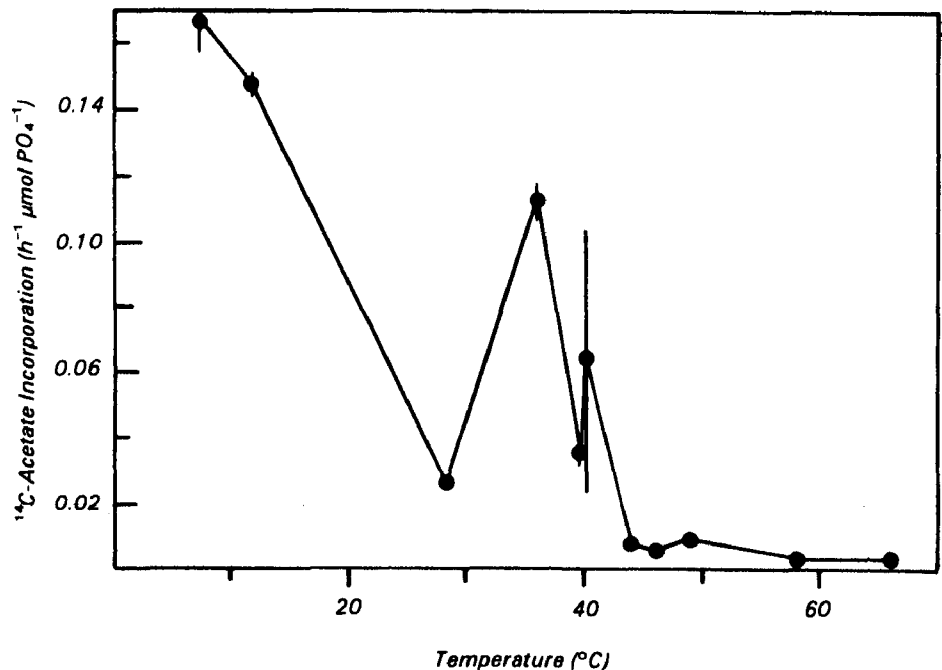


Figure 1. Microbial activity, measured as the rate of (^{14}C) acetate incorporation into lipids per hour per μmol of lipid phosphate biomass $\times 10^{-1}$, of pooled sewage sludge compost samples in response to the mean sampling temperature of the pooled samples during composting run No. 6. Sampling days are indicated by the numbers associated with the data points. Activity values are the mean \pm one standard deviation of three replicates.

trends in microbial activity were found for all of the substrates tested (^{14}C) acetate, glucose, and glutamate), and the results were similar whether the data were expressed in terms of biomass (per μmol of lipid phosphate biomass) or in terms of the amounts of compost (per gram of dry compost).

Of all the physical and chemical parameters measured during this study, temperature had the most dramatic and consistent effects on microbial biomass and activity. Microbial activity and biomass also correlated with the pH of the compost, indicating that pH may be an indirect indicator of microbial activity. The typical increases in pH during composting are primarily a result of microbial activity, and in addition, the microbiota may be more active at the neutral-to-slightly alkaline pH values found later in the runs. This hypothesis was not tested directly during this study, however.

During four of the composting runs, each composting pile was divided into a low-temperature section (mean pile temperature $\leq 55^\circ$ to 60°C) and a high-temperature section (mean pile tem-

peratures up to 70°C). Microbial activity and biomass were higher in the low-temperature section, even when samples taken from the high-temperature section came from the same sampling temperature.

An experiment was designed to determine the optimum temperatures for the activities of the microbial communities from various temperature zones in the composting pile. Activities in samples from low-temperature areas (25° to 50°C) of the pile were almost always much higher than those in samples from high-temperature areas (60° to 75°C), regardless of the assay's incubation temperature. When incubated at different temperatures during the incorporation assay, the samples from low-temperature areas of the pile exhibited optimum thermal activity at 30° to 55°C . Not only did samples from high-temperature areas have much lower levels of activity, many did not respond at all to varied incubation temperatures, indicating that the microbial populations were probably very debilitated. As composting progressed, the optimum temperatures increased somewhat, in-

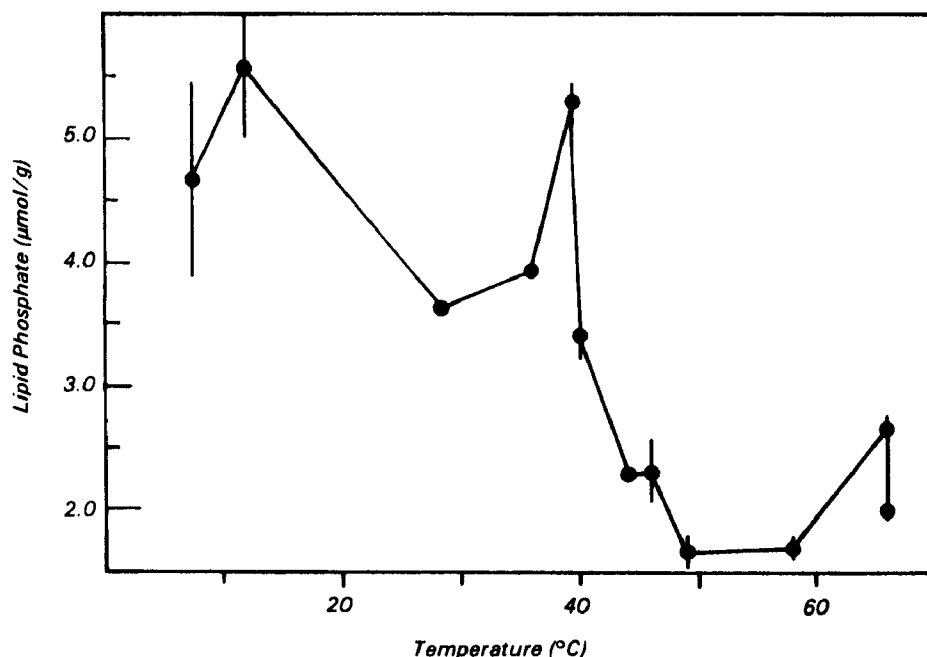


Figure 2. Microbial biomass, measured as the lipid phosphate concentration, of pooled sewage sludge compost samples in response to the mean sampling temperature of the pooled samples during composting run No. 6. Sampling days are indicated by the numbers associated with the data points. Biomass values are the mean \pm one standard deviation ($n=3$).

dicating that the microbial communities were adapting to the higher temperatures. Nonetheless, optimum temperatures of the communities never exceeded about 55°C, even in the samples from the high-temperature areas.

Conclusions and Recommendations

The major conclusions of this study include the following:

1. The optimum temperature range for composting sewage sludge in a forced-aeration batch, static-pile system appears to be 35° or 45° to 55°C. The lower limits of this range are much less distinct than the upper limits. These conclusions are based on measurements of the levels of microbial activity (rates of ^{14}C substrate incorporation or mineralization) and biomass (lipid phosphate concentration). Microbial activity and biomass dropped off very rapidly as composting temperatures exceeded 55°C. Other indirect and much less responsive indicators of microbial activity and biomass (such as the compost pH and protein concentrations)

were also maximized within this temperature range. The minimum levels of microbial activity were always found in compost samples at very high temperatures (> 60°C).

2. As composting progressed, evidence showed that the microbiota were adapting to higher temperatures, but no microbial communities acclimated to temperatures above 55°C. No evidence indicated that extremely thermophilic organisms (those with optimum temperatures above 60°C) played a measurable role in composting.
3. Compared with piles composted simultaneously at 60° to 85°C, piles aerated to maintain temperatures at or below about 55°C showed significant improvements in the rates of microbial metabolism and growth.

The recommendations that naturally follow from these conclusions include the following:

1. Composting should be done at temperatures within the stated optimum range whenever possible.

2. Nonselective, responsive, and sensitive methods for analyzing microbial activity and biomass should be used to monitor the process when necessary.

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