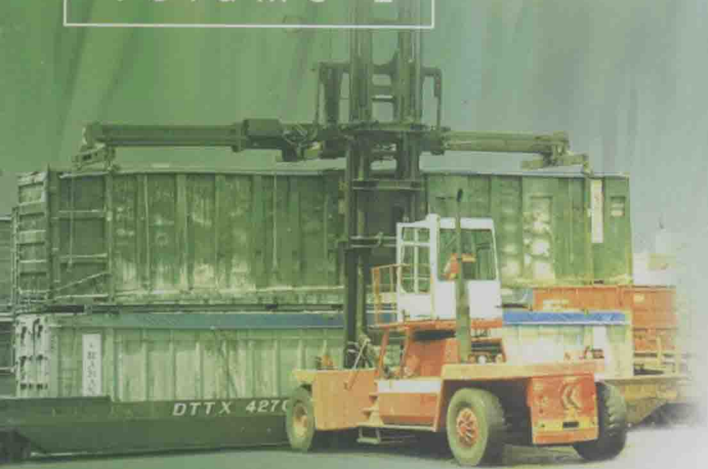
Editor
Thomas H. Christensen

Solid Waste Technology & Management

Volume 2



iwwg
international waste working group

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International Solid Waste Association

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Solid Waste Technology & Management

VOLUME 2

Edited by

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Solid Waste Technology & Management

Preface

Solid Waste Technology & Management is an international reference book on solid waste. The book holds 11 chapters written by 78 experts from around the world.

The need for a new book on solid waste with a broad coverage of all aspects has long been recognized by many professors and professionals. However, it is impossible for a single person to be an expert in all field of solid waste and if such a person existed, he would probably not have the time to write a comprehensive book of 1000 pages. Out of this schism, the idea emerged to involve many authors with a range of expertise and making a thorough edit of the contributions that emphasize the features of the book. This book has been developed over a 4-year period by the joint effort of 78 international solid waste experts. Members of IWWG, International Waste Working Group (www.iwwg.nu) and ISWA, International Solid Waste Association (www.iswa.org) as well as many other experts have contributed their expertise with the aim of supporting education and exchanging information on solid waste technology and management.

Great effort has been made by the authors in providing the draft chapters and into homogenizing the chapters in terms of terminology, approach and style. The remaining diversity in style and unavoidable repetitions still found in the book are hopefully many times compensated by the level of expert knowledge presented in the chapters.

This book would not have been possible without the dedicated contributions by the many authors (see List of Contributors), the continued secretarial work by Dr. Thomas Astrup, Thilde Fruergaard, Grete Hansen and Marianne Bigum as well as the graphical support by Ms. Birthe Brejl. These contributions are gratefully acknowledged.

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Copenhagen, January 2010
Thomas H. Christensen
Technical University of Denmark

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If you refer to more specifi information presented in a specifi chapter, full credit should be given to the authors of the specifi chapter by referring to, for example:

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Contents

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Biological Treatment

9.1

Composting: Process

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Composting is the aerobic degradation of solid organic matter. In nature the process evolves spontaneously in plant litter decomposition and in animal residues and manure transformation. This chapter presents the basic aspects of the composting process with a view to utilization in technologies for composting of solid organic waste. This chapter addresses microbial activities in aerobically degrading waste, the temperature profile of composting waste, the factors affecting composting rates and the fate of pathogens during composting. The various composting technologies available are presented in Chapter 9.2 and mass balances and compost quality are presented in Chapter 9.3.

9.1.1 Definition of Composting and Compost

Compost is the useful product of the composting process.

9.1.1.1 Composting

Composting is a microbial aerobic transformation and stabilization of heterogeneous organic matters in aerobic conditions and in solid state. The process is esoergonic and energy is released. A part of this energy (about 50–60 %) is utilized by microorganisms to synthesize ATP, the other is lost as heat. This heat can generate a temperature increase in the mass. The first phase of the composting process is mesophilic and starts the aerobic decomposition of easily degradable organic matter; this rapid decay of material releases a great quantity of energy in form of heat, which enhances the mass temperature and the degradation rates of the organic waste. Within a few days this gives rise to the thermophilic phase. Without control, the temperature can easily reach and exceed 70 °C. The main positive effect of operating at such high temperature is the reduction of pathogenic agents present in the waste (see later). In controlled composting processes

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this phase is limited in terms of temperature and exposure time (degrees and days) to obtain a balance between high stabilization rates and good sanitization, often to satisfy local legislation regarding sanitization conditions. The third phase, maturation includes not only the mineralization of slowly degradable molecules, but also the humification of lignocellulosic compounds. This phase can last some weeks, according to the composition of the starting material. During the microbial transformation intermediate metabolites are produced which can make the composting material phytotoxic. This phytotoxicity is completely overtaken at the end of the process; thereafter the final product becomes beneficial to plant growth. The composting process ideally should be stopped when the phytotoxicity is over. If the process goes on too long, there is an excessive loss in organic matter reducing the beneficial impacts of the final product. The composting process leads to the production of carbon dioxide, water, minerals and biologically stabilized organic matter. The latter, including part of the water and minerals, is called compost.

From a microbiological point of view, composting is a discontinuous process (batch) resulting from a sequential development of different microbial communities. The microorganisms involved in the composting process are normally present in the starting material. Only when the starting material is deficient in microorganisms should an inoculum be needed.

9.1.1.2 Compost

Compost is the result of a composting process and the preferred definition is: 'Compost is the stabilized and sanitized product of composting which is beneficial to plant growth'. It has undergone an initial rapid stage of decomposition and is in the process of humification. To be rightfully called compost, the organic matter must be biologically stabilized or 'cured' and should become a humus-like product. It should be degraded into fine particles, having lost its original identity. It must be a stable product which can be stored without further treatment and can be applied to land without damage to standing crops. If stabilization has not been achieved, phytotoxins are produced in the soil until completion of the decomposition stage (Zucconi *et al.*, 1981a, b).

In a technical context it may be useful to distinguish between 'stabilized compost' and 'mature compost':

- Stabilized compost is the condition of the material after it has passed through the fist stage of rapid biooxidation.
- Mature compost refers to compost that has been stored for an extended time allowing for substantial humification to take place.

Many adjectives have been used for compost; some of them are correct such as aerobic, solid state, biologically stabilized and sanitized. Some others are in conflict with the same definition of compost such as anaerobic, fresh and liquid state.

9.1.2 Microbial Biomass and Succession

Bacteria, actinomycetes and fungi are the main microbial biomass responsible for the degradation of the organic waste. Box 9.1.1 presents their main characteristics. Higher organisms, for example compost worms (e.g. *Eisenia foetida*) may be numerous in very mature compost or in dedicated vermiculture.

Box 9.1.1 The Microbiology of Composting.

Bacteria

Bacteria are small single-cell organisms proliferating by cell division. When easily degradable material is available this results in high bacterial growth rates. Bacteria in aerobic environments consist of versatile consortia capable of degrading many waste materials. These consortia are relative robust and will thrive under a variety of environmental conditions. Bacteria of different types can degrade waste under anaerobic as well as aerobic conditions. Bacteria are often categorized according to their optimal temperature range as psycrophilic (5–15 °C), mesophilic (25–35 °C) and thermophilic (55–60 °C), but they may be active in a much wider temperature range (Finstein and Morris, 1975). A variety of bacterial genera have been identified in compost including thermophilic bacteria (e.g. *Bacillus*, *Clostridium*, *Thermus*, *Hydrogenobacter*, *Microbispora*, *Streptomyces*; Insam and de Bertoldi, 2007), nitrogen-fixing bacteria (*Azotobacter*, *Azomonas*, *Enterobacte*, *Klebsiella*, *Bacillus*, *Clostridium*; de Bertoldi *et al.*, 1983) as well as ammonia- and nitrite-oxidizing bacteria (*Nitrosomonas*, *Nitrosospira*, *Nitrosococcus*, *Nitrobacter*, *Nitrospira*, *Nitrococcus*, *Pseudomonas*; Insam and de Bertoldi, 2007).

Actinomycetes

Actinomycetes constitute a large group of filamentous (thread-shaped) organisms. Actinomycetes grow slower than most bacteria but are enzymatically better equipped to degrade more complex substrates. High concentrations of actinomycetes may be seen in compost piles as blue-green or light green fluffy and dusty formations (Golueke, 1977). Genera as *Thermomonospora* and *Micropolyspora* have been identified in compost (Finstein and Morris, 1975). Actinomycetes do not thrive at low oxygen concentrations and at high temperatures. They are active in degrading hemicellulose, cellulose and lignin.

Fungi

Fungi are more complex organisms than actinomycetes. Fungi are also sensitive to low oxygen concentrations and high temperatures, nonetheless several types of thermophilic fungi have been identified in compost (e.g. *Mucor pusillus*, *Penicillium duponti*, *Chaetomium thermophilum*, *Scytalidium thermophilum*, *Talaromyces thermophilus*, *Sporotrichum thermophile*, *Aspergillus fumigatu*, *Thermoascus aurantiacus*, *Humicola insolens*, *Micelia sterilia*; de Bertoldi *et al.*, 1983). Numerous mesophilic fungi have been identified in compost, for example Ascomycotina (e.g. *Chaetomium* sp., *Dasyscipha* sp., *Emericella nidulans*, *Mollisia* sp., *Thermoascus aurantiacus*), Basidiomycotina (e.g. *Armillaria mellea*, *Clitopilus insitus*, *Lentinus lepideus*, *Polyporus versicolo*) and Deuteromycotina (e.g. *Alternaria tenuis*, *Aspergillus amstelodami*, *Cephaliophora tropica*, *Cephalosporium*, *Cladosporium herbarum*, *Geotrichum candidum*, *Penicillium*, *Sporotrichum termophile*). Fungi are very important in the degradation of hemicellulose, cellulose and lignin (de Bertoldi *et al.*, 1983).

Mesophilic bacteria, actinomycetes and fungi start their activity in the first phase of composting until high temperatures inhibit their metabolism. Most of them die or drastically reduce their activity in the thermophilic phase. Only a few sporigenous bacteria and nonsporigenous thermophilic bacteria (such as *Bacillus*, *Clostridium*, *Thermus*) show metabolic activity above 70 °C (Finstein and Morris, 1975; de Bertoldi *et al.*, 1983).

During the thermophilic phase only organisms adapted to high temperatures can survive and metabolize organic matter. Previously flourishing mesophiles die off and are eventually degraded by the succeeding thermophiles. The high temperature is the direct consequence of heat produced during composting. Owing to the lower activity of the fewer thermophilic microorganisms and to the decreasing degradability of the organic waste remaining, the rate of release of heat reduces and the process slowly enters in a new mesophilic phase (second).

Mesophilic microorganisms start to recolonize the substrate, either starting from surviving spores and microorganisms or from microorganisms colonizing from the outside. This phase is characterized by an increasing number of organisms able to degrade the long polymers: Lignin, cellulose, pectins and hemicellulose. The prevalent microflora consists of fungi and actinomycetes. Bacteria also are present but in a reduced number. In the later phases of composting the number of cellulolytic bacteria decreases, while the number of cellulolytic fungi (eumycetes) increases. The fungi benefit from the decrease in temperature, pH and moisture content and from the higher oxygen concentrations caused by lower water content and lower degradability of the organic waste. The same environmental factors positively affect the presence and diffusion of actinomycetes. With the degradation of lignin, an enzymatic aerobic transformation restricted to a limited microbial group namely the higher fungi (basidiomycetes), humification of organic matter begins together with the production of aromatic compounds (e.g. geosmin). These processes gradually lead to the final biological stabilization of the product.