

Article ID: 1001-0742(2002)02-0264-05

CLC number: X701

Document code: A

Composting MSW and sewage sludge with effective complex microorganisms

XI Bei-dou¹, LIU Hong-liang², ZENG Guang-ming³, HUANG Guo-he³, BAI Qing-zhong¹

(1. Environment Department, Tsinghua University, Beijing 100084, China. E-mail: xibeiou@263.net; 2. Chinese Research Academy of Environmental Science, Beijing 100012, China; 3. Department of Environmental Engineering, Hunan University, Changsha 410082, China)

Abstract: The effects of complex microorganisms in composting process of the municipal solid waste (MSW) and sludge were examined through inspecting biomass, temperature, oxygen consumption, organic matter, and C/N (the ratio of carbon and nitrogen). The experimental results shows: complex microorganisms are effective to compose organic matter and speedup composting change into humus.

Keywords: effective complex microorganisms (ECM); temperature; oxygen consumption; organic matter; C/N ratio

Introduction

Composting is used as a treatment method of the municipal solid waste (MSW) and sewage sludge, and the process yields a stable, profitable product which is suitable for use as a soil conditioner and which also has a certain nutrient value (Biey, 2000). Generally, composting is an accelerated version of the process of the natural treatment organic matters achieved through the provision of favorable conditions for microorganisms (bacteria, actinomycetes, and fungi), but it is hard to control initial microorganisms, traditional composting would render the composting process ineffective.

Effective complex microorganisms (ECM) include microzyme, actinomycetes, lactobacillus, azotobacter, and so on. The alternant effects of these microorganisms accelerate decomposition of heterogenous organic matter in a warm moist artificial environment (Tuomela, 2000).

The objective of this study was to examine the effect of ECM by mixed cultures of white-rot fungi and EM on the efficiency of a combination of MSW and sewage sludge composting, to develop composting procedures, to formulate reproducible compost recipes, to enhance their quality as soil amendments and fertilizer; and to operate full-scale commercial composting operation (Golueke, 1980).

1 Methods

1.1 Composting reactors

A schematic diagram of the reactor is shown in Fig. 1.

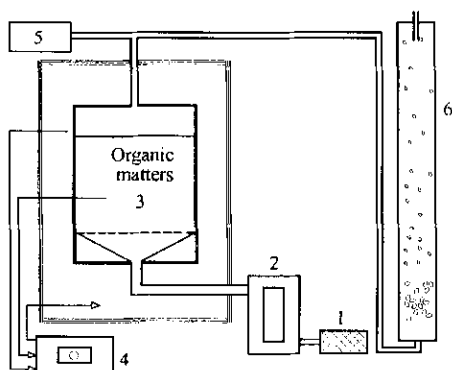


Fig.1 Schematic diagram of experimental reactor

1. gas pump; 2. gas flow meter; 3. composting tank; 4. temperature maintenance box; 5. gas analyzer; 6. filter

The reactor could receive forced aeration through perforated PVC tubing placed below a fine mesh screen near the bottom of the reactor. Air flow range from 0 L/min to 10 L/min. The volume of reactor is 30L. Precision solid wastes temperature sensors were used for temperature measurements. The ambient temperature was also monitored. A datalogger was used to register temperature data. Outlet vent content with a O_2-H_2S type: MD-520E equipment, and CO_2 analyzer: LX-710. The flow of aeration was controlled by air flow meter. Temperature profiles were controlled under $70^\circ C$. Moisture was controlled from 50% to 70%. 150g samples from the composting were evaluated for various

chemical and biological properties.

1.2 Materials and performance

Standardized MSW taken from Chinese Research Academy of Environmental Science, Beijing was composted with sewage sludge, sawdust and mature composting. Sewage sludges were taken from Beixiaohu Municipal Wastewater Treatment Plant. The contents of solid wastes are shown in Table 1. The loading to composting reactor corresponds to a 45:25:15:15 (w/w) ratio of MSW: sewage sludges: sawdust: mature composting.

Table 1 Some characteristics of samples of compost at the beginning

Samples	Analyses									
	Organic C, %	Water content, %	Dry matter, %	Ashes, %	Organic matter, %	Total N, %	Total P, %	Total K, %	Total C/N	pH
MSW	30	58	42	30	60	1.3				6.8
Sludges	35	68	25	20	70	3.4				7.2
Sawdust	43	5	80	10	85					
Composting	16	20	75	50	33					
Mixture	40	58.5	55	40	60	1.4	0.69	1.25	30	6.8

The rates of adding ECM are shown in Table 2.

1.3 Chemical and biological analyses

Samples were taken from approximately six sites of the reactor, then assembled, mixed and sieved through a 4 mm mesh screen. Dry matter content was analyzed in paralalled on replicate samples at 105℃ for 12h. Total N, total C and pH were determined in water extracted (1:5 by volume) from fresh samples after shaking for 2h. Total N in the mixtures was measured by the Kjeldahl method and samples were pretreated with sulfuric acid. Total C was measured by standard method (Sequi, 1986).

Mesophilic and thermophilic bacterial strains were obtained by plating samples taken during composting progress in cultivating plates at 30℃ and 60℃ respectively. Mesophiles and thermophiles were isolated and maintained on trytone soy agar (TSA) and peptone agar (PA) respectively. Isolates were obtained by streaking out all the colonies of a spread plate within a sector containing 40 colonies. All isolates were tested for a number of properties on identical media, at 30℃ and 60℃ respectively.

A basal agar (BA) containing 0.1% peptone (Difco), 0.1% yeast extract (Difco) and 1.5% agar. Test substrates were added to BA as follows: starch (0.5%), gelatine (1%), carboxymethyl cellulose (CMC, 1%), Chitin (swollen precipitated substrate, 30 ml/litre), and Tween 80 (1%) with CaCl₂ · 2HO₂(0.01).

2 Results

2.1 Temperature

During the composting period, the ambient temperature only fluctuated in a narrow range (around 29—33℃). Since the experiment was carried out in summer (Fig.2), after the moisture content was adjusted and CM was added at day 0, the temperatures rose up quickly. The C0 treatment rose to a peak of about 55—60℃ by day 5, and these readings were maintained until day 10 (thermophilic stage). The temperatures declined slightly thereafter and were maintained at a lower lever from day 10 to 25 (cooling stage), before further dropping slowly to 30℃ (ambient temperature) from day 25 to day 50 (maturing stage).

Table 2 Quantity of inoculation in materials

Name	Microorganisms	Quantity, w/w
C0	Control	
C1	ECM	2%
C2	ECM	3%
C3	ECM	5%

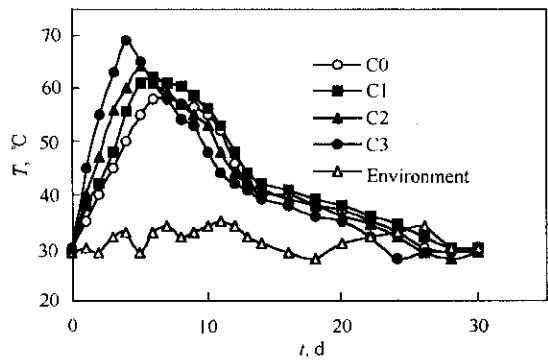


Fig.2 Temperature profile in composting
moisture: 58% w.b.; aeration flow: 0.8 L/(min·kgDM)

3. The population of total aerobic heterotrophs of all piles (added ECM) were at a high level, the \log_{10} CFU (colony forming units) g^{-1} were from 8.0 to 11.0 at the onset beginning of the composting period (Fig. 3). The bacterial counts in treatment C3 reached a peak time with \log_{10} CFU equal to 10 at hour 32, C2 equal to 9.5 at hour 40, C3 equal to 9 at hour 60, and C0 equal to 8.5 at hour 100, respectively. These met with temperature profile.

Treatment C1, C2 and C3 have the same stage changes, but the maximum temperature achieved during the thermophilic stage were different. Treatment C1 rose to maximum temperature 55—62°C and the maintain time during the thermophilic stage were from 4 day to 11 day; treatment C2 during the same stage was 55—64°C, from 3 day to 10 day; treatment C3 during the same stage was 55—69°C, from 2 day to 8 day, respectively.

2.2 Total heterotroph counts

Total heterotroph counts are shown in Fig.

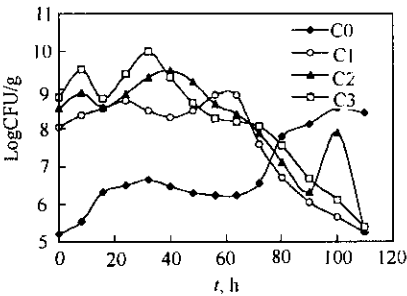


Fig.3 Total heterotroph counts in composting
moisture: 58% w.b.; aeration flow: 0.8 L/(min·kgDM)

Table 3 Emission of gas in outlet

Time, day	Emission of oxygen, % O ₂				Emission of carbon dioxide, % CO ₂				Emission of H ₂ S, ppm			
	C0	C1	C2	C3	C0	C1	C2	C3	C0	C1	C2	C3
0	20.9	20.9	20.9	20.9	0	0	0	0	0	0	0	0
2	18.2	17.5	16.3	15.7	2.55	3.10	4.18	4.72	0	0	0.5	1.0
4	16.7	12.1	11.3	10.1	3.82	5.8	8.7	9.82	0	0.3	1.0	4.0
6	13.2	14.5	13.8	12.9	7.07	6.0	6.50	7.9	30	10	5	3.2
8	14.2	15.8	15.2	17.5	6.20	4.64	5.11	3.10	28	8.2	4.8	2.8
10	15.6	18.0	17.8	20.1	5.35	2.65	2.91	0.75	20	6.5	3.3	1.9
12	17.8	20.2	20.3	20.5	2.92	0.64	0.55	0.37	15.4	4.3	2.0	0.5
14	19.6	20.3	20.4	20.6	1.20	0.54	0.45	0.27	12.1	2.2	1.0	0.2
16	20.1	20.4	20.5	20.7	0.74	0.45	0.36	0.18	7.4	1.1	0.4	0
18	20.3	20.6	20.7	20.8	0.56	0.27	0.35	0.1	2.3	0.5	0.1	0
20	20.8	20.8	20.8	20.8	0.1	0.08	0.05	0.03	0.6	0	0	0

2.3 Emission of oxygen, carbon dioxide and H₂S

The emission of gas in outlet is shown in Table 3. When aeration flow was 1.2 L/(min·kgDM), the moisture of composting matters was 58.5%, Table 2 indicates carbon dioxide (% CO₂) concentration, oxygen (% O₂) and H₂S concentration. Carbon dioxide (% CO₂) and oxygen (% O₂) have a good correlation during composting:

(% O₂) = 20.9 - 1.1 (% CO₂).

H₂S in control system were high during composting processes. The maximal emission of H₂S strongly correlated with the (HECM) content of the H₂S-emission was 30 ppm, 10 ppm, 5 ppm, 4 ppm during C0, C1, C2, respectively. Next to this the H₂S-emission during treatment C0 system was not completely finished after the 14 day period. In accordance with this, added (HECM) is useful to control H₂S-emission.

2.4 Organic matters

There are many methods to measure the organic matter of waste. The degradation rate of organic matter reflect the microorganisms activity. Organic matters degradation is shown in Fig.4. The result met with Fig.1 and Fig.2. The degradation of organic matter as follows: treatment 3> treatment 2> treatment 1> control. The degradation rates after 15 days are 33.3%, 28.5%, 25.1 and 20% respectively.

3 Discussion

3.1 Compost environment

During composting microorganisms transform organic matter into CO₂, biomass, thermo-energy and humus-like product, the ratio of organic substrates, bulking agents and amendments used in composting is important (Table 1). The capacity of microorganisms to assimilate organic matter depends on their ability to produce the enzymes needed for degradation of the substrate. The more complex the substrate, the more extensive and comprehensive is the enzyme system required. Through the synergistic action of microorganisms complex organic compounds are degraded to smaller molecules which can be utilized by the microbial cells.

Microorganisms require nutrition source such as carbon, nitrogen, phosphorous and potassium, and certain trace elements for their growth. Carbon serves primarily as an energy source for the microorganisms. Nitrogen is a critical element for microorganisms because it is a component of proteins, nucleic acids, amino acids, enzymes and co-enzymes necessary for cell growth and functioning. The optimum C/N ratio has been reported to be 25—40, but the value varies depending on the substrate (Golue, 1991). In this composting the C/N ratio is about 30.

Microorganisms are able to use organic molecules which dissolve in water. If the moisture content falls below a critical level, microbial activity will decrease and the microbes become dormant. On the other hand, too high a moisture content can cause a lack of aeration and leaching of nutrients. We maintained proper composting moisture in 50%—60%.

The length of the composting phase depends on the degree of aeration. Aeration is essential for metabolic heat generation from aerobic microbials. However, an improper air supply rates which would cause heat to accumulate faster than conductive and ventilative, or cause heat losses surpass microbial heat production, and would render the composting process ineffective. In this composting, at the beginning of the composting, the proper aeration rate is 0.8 l/(min·gDM), at the thermophilic phase, the aeration rate should be adopted to 1.2 l/(min·gDM).

3.2 HECM effects

Composting is a dynamic process carried out by a rapid succession of mixed ECM populations. The main groups of ECM involved bacteria, such as: microzyme, lactobacillus, actinomycetes, diazotrophic

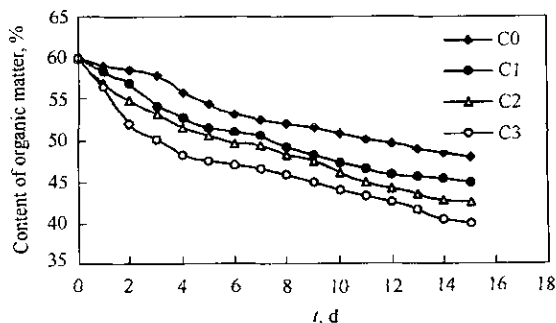


Fig.4 Content of organic matters change in composting
moisture: 58.5% w.b. aeration flow: 0.8 l/(min·kgDM)

bacteria, and white-rot fungi. They were shown to be capable of composting MSW and sewage sludge. When ECM were added 5% (w/w), the temperatures rose up quickly and reached 69°C on the third day. These values indicated that these mixture were more efficient than others. Analyzing the total number of microorganisms change during four composting systems, at the beginning of composting the microbial counts were as follows: C3 > C2 > C1 > C0, and oxygen consumption met with the same profile. Although, the precise nature of succession and the number of microorganisms at each composting systems depended on the substrate and the processing of the composting, it was obvious that inoculating ECM was useful for increasing microbial counts.

At the beginning of composting EM were predominate, and they decomposed soluble and easily biodegradable organic matter such as: monosaccharides, starch, lipids and proteins, and rise the temperature up to optimum condition, then white-rot fungi decomposed cellulose, hemicellulose and lignin by means of oxidative enzymes which are lignin peroxidases (LiPs), manganese peroxidases (MnPs) and laccase. They change cellulose, hemicellulose, lignin to glucose which EM could be used easily. So inoculating microorganisms was useful for composting proper through maintaining microorganisms high activity and the counts relatively stable during composting.

References:

- Biey E M, Mortier H, Verstraete W, 2000. Nitrogen transfer from grey municipal solid waste to high quality compost[J]. *Bioresource Technology*, 73: 47—52.
- Golueke C G, Lafrenz D, Chaser B *et al.*, 1980. Composting combined refuse and sewage sludge[J]. *Compost Sci Land Utiliz*, 21(5): 42—48.
- Golueke C G, 1991. Principles of composting[J]. *BioCycle*, 33: 55—57.
- Hatakka A, 1994. Lignin-modifying enzymes from selected white-rot fungi: production and role in lignin degradation[J]. *FEMS Microbiol Rev*, 13: 125—135.
- Sequi P, De Nobili M, Leita L *et al.*, 1986. A new index of humification[J]. *Agrochimica*, 3: 175—9.
- Tuomela M, Vikman M, Hatakka A *et al.*, 2000. Biodegradation of lignin in a compost environment: a review[J]. *Bioresource Technology*, 72: 169—183.

(Received for review March 7, 2001. Accepted April 27, 2001)